PLANT COMMUNITY DISTRIBUTION AND DYNAMICS IN BRYCE CANYON NATIONAL PARK

Draft Final Report for Project PX 1200-7-0966

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SUMMARY

Bryce Canyon National Park occupies a long, narrow strip of land on the east edge of the Paunsaugunt Plateau of Utah. This long, narrow area extends along a complex temperature/moisture gradient from low elevation shrublands to upper elevation closed forests. Local areas within the Park occur on particular soils that favor the development of unique plant communities. This combination of varying temperature, moisture, and soil characteristics leads to a large variety of potential plant community types within the Park, which we call habitat types. We identified 17 habitat types within the Park, comprised of three shrub- dominated habitat types, one rush- and sedge-dominated habitat type, three woodland habitat types, and ten forest habitat types. The most common habitat types in Bryce Canyon National Park are: black sagebrush / needle-and-thread (5%), pinyon pine / Utah juniper (19%), ponderosa pine / greenleaf manzanita (14%), Douglas-fir / greenleaf manzanita (7%), and white fir / greenleaf manzanita (14%), listed generaly in order of increasing moisture. None of the remaining types contributes more than 5% of the total area. Each of the 17 habitat types is described and mapped throughout the Park.

Within each of these habitat types, a variety of disturbance-induced plant communities can occur. We developed a simple successional community classification for the types, and mapped the distribution of community types throughout the Park. Despite the large variety of community types which could occur, the vast majority of the Park is covered by one of five community types ponderosa pine / ponderosa pine (28%), pinyon pine / Utah juniper (21%), Rocky Mountain juniper / ponderosa pine (13%), ponderosa pine / white fir (11%), black sagebrush / needle-and-thread (5%). None of the remaining types covers

more than 5% of the Park. In nearly all of the forested communities the effects of fire were evident. Equally evident, in some types, are the effects of recent fire suppression on the stand composition and structure.

To better understand the successional dynamics in the Park, a simple computer-based simulation model was developed for the forested communities of the Park. Simulations indicate that the current community type distribution is compatible with fire return intervals of approximately 100 years in the mesic forest types.

Finally, the distribution and habitats of potential threatened and endangered plants were studied. Specifically, Paria breadroot and Tushar paintbrush were observed within the Park. Both species prefer relatively open, dry sites on limestone. The influence of possible stand development on the distribution of Paria breadroot is discussed.

INTRODUCTION

The resource base of a National Park is determined largely by the distribution of plant communities. These communities are the largest biotic component of the represented ecosytems, and are thus of considerable interest in themselves. Additionally, these plant communities determine in part the distribution and abundance of other resources, such as wildlife, water, or rare plants, and the risk of fire or epidemic insect attack. Accordingly, knowledge of the distribution and characteristics of plant communities is of paramount importance in effective Park management.

For management purposes, vegetation is best characterized by classification into discrete plant communities. Effective vegetation classification requires a comprehensive system which specifies (1) the geographic distribution of the various plant communities, (2) the relation of each plant community to features of the environment, and (3) the dynamics of vegetation and other resources. The vegetation classification presented here was developed from data gathered over three years, and is extensible to incorporate directly the results of future research. Where possible, the classification system employed existing classifications so that Park managers can extrapolate research results from a broad range of ecological studies to Park ecosystems, and communicate effectively with other resource managers in the region.

The basis for the system is the habitat type concept (Daubenmire 1952, Daubenmire and Daubenmire 1968), which provides a well-accepted framework for classification of site potential for vegetation development. The coniferous forests of Bryce Canyon National Park are covered by an existing forest habitat type classification (Youngblood and Mauk 1985). The non-forest plant

communities were classified into habitat types using methods similar to those for forest classification.

Within habitat types, a broad variety of successional communities occur, and a within-habitat type successional community classification was developed following the work of Steele (1984). The classification is based on vegetation structure and known or hypothesized autecological relations among component species. To portray vegetation dynamics within habitat types, a simple succession/disturbance response model was developed based on the vital attributes concepts of Noble and Slatyer (1980). The vital attributes pathway model was integrated with the successional community classification to depict community composition at different successional stages.

OBJECTIVES

The specific objectives of this study were :

1) To develop a comprehensive vegetation classification for all stages of vegetation development for all lands in Bryce Canyon National Park

2) To classify and map the land area as to current vegetation type (community type), and potential vegetation type (habitat type)

3) To construct a vital attributes succession model which relates the successional pathways and disturbance pathways from each community type to other community types and the climax type

4) To determine the habitats and plant communities in which rare or endangered plants occur, and using the community pathway models, to determine the influence of succession, disturbance, or Agency management on the possible distribution of these species

5) To map the current and potential distributions of rare and endangered species

6) To identify and map undisturbed plant communities to serve as baseline reference areas

STUDY AREA

Location

Bryce Canyon National Park occupies an area of approximately 14,250 hectares (35,240 acreas) on the east face of the Paunsaugunt Plateau in south central Utah (Fig. 1). Bryce Canyon National Park was set aside for the spectacular erosional remnants (Hoodoos) along the scarp of the Plateau, and as a result the Park is generally long and narrow running primarily NNE to SSW, consisting of a strip of land on the Plateau top itself (varying from a few to several kilometers in width), the scarp of the Plateau, and a strip of land below the scarp to the east (also varying from a few to several kilometers in width).

Geology

Bryce Canyon National Park occurs in the portion of Utah included in the Colorado Plateau province (Thornbury 1965), an area dominated by broad plateaus of gently dipping sedimentary rock, carved at their edges by exceptionally effective erosion into retreating steeply-sloping scarps. The Paunsaugunt Plateau is a block-faulted sedimentary rock mass, typical of the landforms of this region. The Plateau is delimited on the west by the Sevier fault, and to the east by the Paunsaugunt fault. The geology of Bryce Canyon National Park (and the rest of the Paunsaugunt Plateau) was surveyed by Gregory (1951), from which the following account derives.

The Plateau and area immediately below are composed of four primary geologic strata. The Plateau top and most of the scarp area are formed from a thick-bedded limestone termed the Wasatch formation by Gregory (1951), but

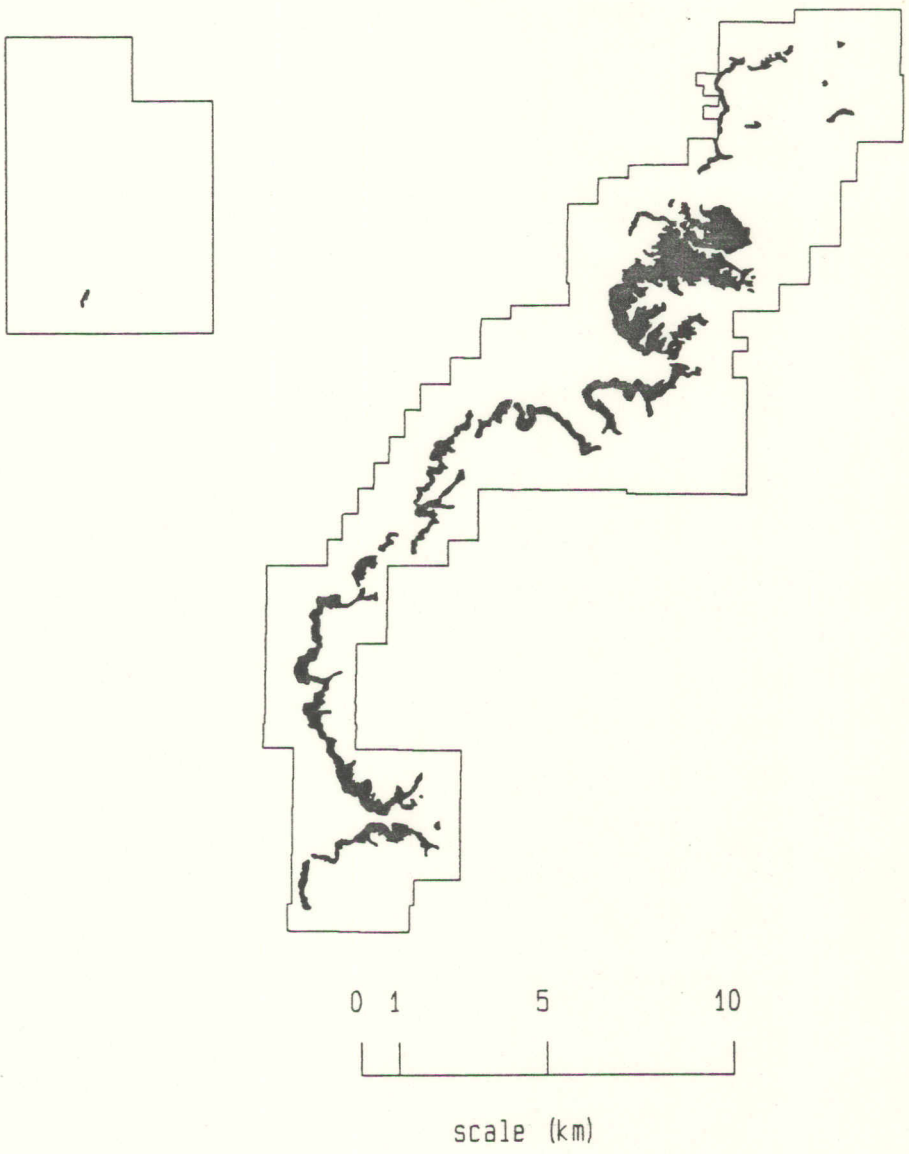


Fig. 1. Study area map. Map of Utah to the left shows the size and location of Bryce Canyon National Park in the State. Map to the right shows the size and configuration of Bryce Canyon National Park, and highlights the Breaks and Hoodoos for which the Park is famous.

more recently termed the Claron or Cedar Breaks formation. This strata is primarily massively bedded pink limestone, with inclusions of grey limestone, conglomerate, sandstone, and siltstone. Despite the image of a massive homogeneous bed which viewers observe, Gregory (1951) comments on the extreme variability within this formation. The Wasatch formation also includes a strata of white limestone above the pink beds which has been removed in most areas by erosion. Remnants of this material still occur in the Park on Whiteman's Bench, an area of relatively high elevation.

In the southern and central portion of the Park, the Wasatch formation lies on the Kaiparowits formation, a belt of primarily calcareous sandstone and shale, with inclusions of limestone and siltstone. This strata is relatively easily weathered, and often forms broad low mounds of weathered material.

Below the Kaiparowits formation, and immediately below the Wasatch formation in the north end of the Park, lies a belt of calcareous sandstone called the Wahweap and Straight Cliffs sandstone. These strata include lenses of shale, many of which have weathered extensively. The sandstone is porous, which contributes to both excessive drainage and the presence of springs in certain locations.

The three strata described above comprise the vast majority of the Park. A small area in the northeast of the Park lies across the Paunsaugunt fault on Tropic shale, a dark grey or green-grey strata which supports little vegetation.

Topography

Paunsaugunt Plateau dips gently to the north and west, and forms the divide between the internal drainage to the Great Basin and the Colorado River. Areas on the Paunsagunt Plateau itself drain into the East Fork of the Sevier River, and eventually into the Great Basin. Areas below the rim of the Plateau drain into the Paria River, and eventually into the Colorado River. Bryce Canyon National Park stradles this divide for nearly the length of the Park.

The topographic relief within the Park varies from broad areas of relatively little relief on the Plateau top to stunningly steep and complex slopes at the face of the scarp. Areas below the Plateau are generally of moderate relief with a rolling or dissected appearance. The lowest elevation in the Park (2018 m) occurs below the rim of the Plateau where Campbell Creek flows out of Fairyland Canyon into the town of Tropic. Elevations below the rim range from this low up to 2210 m, with local slopes commonly on the order of 100 to 200 meters of relief. The face of the exposed Plateau ranges from 100 to 200 meters of exposure along its length. Above the rim the Park increases steadily from a low elevation of 2315 meters at the north end to a maximum of 2775 meters at Rainbow Point in the southern end of the Park.

Soils

The soils of Bryce Canyon National Park have been surveyed and mapped by the U.S. Soil Conservation Service (SCS, no date). Soils within Bryce Canyon National Park typically fall into one of four orders, listed in order of abundance: entisols (recent soils), mollisols (grassland soils with dark surface horizons), alfisols (forest soils), and inceptisols (immature soils).

The entisols are developed primarily on alluvial deposits, and are subdivided on the basis of soil texture. In Bryce Canyon the entire range of textures from clayey to sandy is present; loamy or clayey soils predominate, however. Moisture regimes vary from dry in most years to permanently moist.

The residual soils of Bryce (soils developed from weathered in-place parent material) are primarily in the suborder boroll of the order mollisol or the suborder boralf of the order alfisol. These are soils with mean annual temperatures below 8°C. Borolls are typical of grassland sites, and boralfs are typical of the forest sites.

The U.S. Soil Conservation Service classification reflects primarily the origin and gross structure of the soils. From the perspective of vegetation, other classifications are possible. Table 1 presents a simple classification of Bryce Canyon soils by depth and texture, two of the primary determinants of soil moisture holding capacity and soil moisture availability. As can be seen from this simple classification, typical soils in Bryce Canyon are shallow and skeletal, a combination leading to very low moisture availability. A wide range of soils occur within the Park, however, with a wide range of moisture characteristics. As can also be seen from the table, a large portion of Bryce Canyon National Park is classified as badland, rock outcrop, or rubble, rather than as developed soil. This further limits the potential for vegetation development.

Climate

Precipitation

Bryce Canyon National Park lies near the transition from the zone of late-summer precipitation maximum typical of Arizona and New Mexico to the

Table 1. Ecological soil classification of soils of Bryce Canyon National Park. Table gives cross-classification by soil depth and texture, and lists each soil by SCS soil name and soil map legend number.

	DEEP		SHALLOW	
loamy/ skeletal	Behanin	1.1	Pahreah-Sheege	1.7
	Clapper	1.2,1.3	Paunsagunt	1.8
	Guben	1.4	Syrett-Vanet	1.10
	Losee	1.5,1.6	Venture	1.12
	Tridell	1.11	Whiteman	1.13
			Winetti	1.14
coarse-loamy/ fine-loamy	Andys	2.1	Pahreah-Swapps	2.6
	Hatch-Pahreah	2.2	Podo-Wiggler	2.7
	Hernandez-Clapper	2.3	Podo-rock outcrop	2.8
	Neto	2.4	Sheege-Swapps	2.9
	Pahreah-Sielo	2.5	Zyme-Lazear	2.10
fine loamy	Ahlstrom-Osote	3.1	Hatch-Swapps	3.6
	Alldown	3.2,3.3	Swapps	3.9,3.10
	Brycan	3.4,3.5		
	Mikim	3.7		
	Schausen	3.8		
	Yenlo	3.11		
fine	Baldfield	4.1	Ruko-Podo	4.5
	Bayfield	4.2		
	Blanchard	4.3		
	Kade	4.4		
	Skutum	4.6		
clayey	Waltershow	5.3	Badland-Cannonville	5.1
	Waltershow-Venture	5.4	Cannonville	5.2
			Zyme	5.5
other	badland-Paunsagunt	6.1		
	rock-outcrops	6.2		
	rubbleland	6.3		
	Ustic-torrefluvents	6.4		

zone of winter precipitation maximum typical of the Great Basin, and exhibits elements of both zones. Figure 2 presents a Walter diagram of the climate of Bryce Canyon National Park. The maximum precipitation occurs in late summer (late July and August) with a drought occuring in late-spring/early-summer (May and June), as is typical for the Colorado Plateau and southwest. Maximum monthly precipitation is 57 cm in August; minimum precipitation is 18 cm in June. Winter precipitation is also fairly high, however, with precipitation in December through March averaging over 60% of the August maximum for each of the four months.

The net result of the precipitation pattern is significant soil moisture recharge from snowmelt in most years, followed by soil drying until the late summer rains recharge the soil moisture of the upper layers.

Temperature

As is typical for arid areas of the southwest, Bryce Canyon National Park exhibits strong seasonal changes in mean monthly temperatures. January is the coldest month with a mean daily temperature of -5.9^{o}C; July is the warmest month with a mean daily temperature of 17 C. Mean monthly temperatures hide a great deal of variation, however. Daily maximum temperatures over 32^{o}C occur in each of the four months from June to September, with average daily maximums from 18^{o}C to 27^{o}C during the same period. Winter minimum temperatures range from -30^{o}C to -28^{o}C from November to February, with mean daily minimums from -9^{o}C to -14^{o}C during the same period.

Even during the warm summer months, diurnal cooling under the clear skies leads to low night temperatures. The mean minimum daily temperature is below freezing in all months except June through September, and frosts typically occur at least one day a month in all months except August.

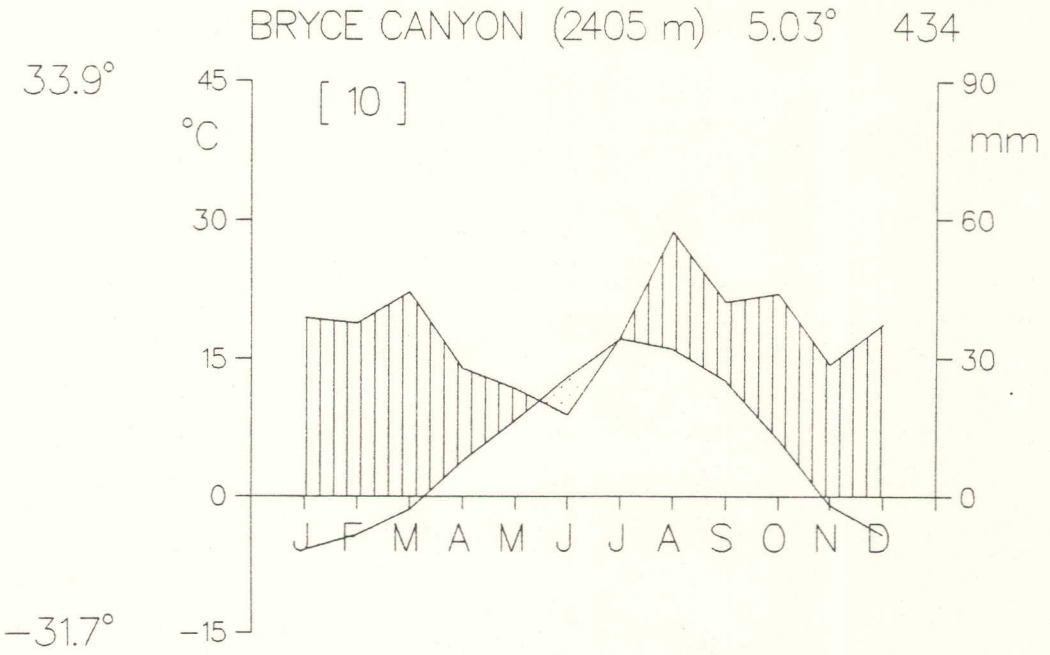


Fig. 2. Walter diagram of climate of Bryce Canyon National Park. Title line gives the elevation, mean annual temperature, and mean annual precipitation values. Diagram shows the superimposed trace of mean monthly precipitation and temperature. The line above the vertical shading is precipitation in millimeters, read on the scale to the right. The line below the vertical shading is temperature in degrees Celsius, read on the scale to the left. Vertical shading represents available moisture, where spotted stipling represents drought.

Flora

The flora of Bryce Canyon National Park is a complex mixture of elements from the Colorado Plateau, Great Basin, and Cordilleran floristic regions. The flora of Bryce Canyon National Park has been described by Buchanan and Graybosch (1981) with addenda by Hallsten and Roberts (1988). Unfortunately, because of the mixed floristic regions, these previous treatments were not consistent in classifying all taxa. During the course of the study, a flora of Utah was published (Welsh et al. 1987) which simplified many of the problem areas. Accordingly, we have updated all species names to those of Welsh et al. (1987). Appendix A presents a list of all species known in Bryce Canyon National Park, alphabetized by common name as well as scientific name. A very few remaining taxa from Buchanan and Graybosch (1981) have no synonyms in Welsh et al., and have retained the original names. A final difficulty arises in coordinating the species names with those of the established forest habitat types for this area of Utah. Specifically, Youngblood and Mauk (1985) refer to Berberis repens as a habitat type name, where Welsh et al. (1987) use Mahonia repens. For the sake of consistency, we have changed the habitat type name to Mahonia repens in this text. The map plates still refer to Berberis repens habitat types.

We have attempted to identify sample plot plants to the species level, but many taxa were difficult or impossible to identify to species in vegetative condition only. Accordingly, some specimens (especially Cryptantha and Erigeron species) were field keyed to genus only.

METHODS

Sampling

Vegetation sampling within Bryce Canyon National Park was conducted at two scales to meet the varied objectives detailed below. During the first and second years, 160 detailed vegetation samples of 375 m^2 were distributed throughout Bryce Canyon National Park following the field stratification guidelines of Pfister and Arno (1980) and Roberts and Cooper (1989). Essentially, the landscape is stratified by basic environmental factors such as elevation, aspect, slope, soil type, and parent material into relatively homogeneous areas. Within these areas, sample plots are located subjectively without bias (Mueller-Dombois 1974). As the field season progresses, sample plot distribution is assessed in an effort to avoid over-sampling common areas and under-sampling relatively less common areas. In these detailed plots, the following data were recorded:

1) elevation (nearest 12.2 m [40 ft])
2) aspect (degrees azimuth)
3) slope (percent)
4) soil type and parent material
5) basal area of each tree species present
6) age of largest (presumed oldest) tree of each species
7) percent coverage of each vascular plant species within eight cover classes (see Pfister and Arno 1980)
8) general stand description
9) estimate of spatial extent of stand
10) adjacent vegetation types
11) fire history as estimated from fire scars and presence of charcoal
12) big game use and browse evidence
13) miscellaneous observations

Data from the detailed plots were used to determine the occurrence and characteristics of forest habitat types within Bryce Canyon National Park, as well as to develop the non-forest habitat type classification, using

techniques described below.

During the second and third years a simpler plot was also employed. This plot was used simply to aid in mapping the distribution of vegetation and in determining which community types occurred within each habitat type. A total of 583 of these plots were distributed throughout the Park. The data collected in the simple plot included:

1) elevation
2) aspect
3) slope
4) basal area of each tree species
5) habitat type (as determined from dichotomous key)

The data collected from the sample plots were used in conjunction with other observations made during mapping transects to meet the specific objectives. Methods specific to each objective are presented below.

1) To develop a comprehensive vegetation classification for all stages of vegetation development for all lands in Bryce Canyon National Park

A comprehensive classification effort requires classification of all land areas into both potential natural vegetation type and current vegetation type. For potential vegetation classification, we employed a habitat type classification. This classification is a hierarchical classification based on a conceptual model developed by Daubenmire (1952) for the forests of eastern Washington and northern Idaho. This classification partitions the environment into areas where specific trees species are expected to dominate at climax. All areas where the same tree species would dominate at climax are considered part of the same "series", the highest level of the classification. Within series, the environment is further partitioned on the basis of understory indicator species. Indicator species are species with a relatively narrow and

diagnostic range of distribution. They may or may not be the dominant species of undergrowth. All areas within a series characterized by the same indicator species are part of the same "habitat type", the second level of classification. Some, but not all, habitat types are further divided on the basis of secondary indicator species into "phases", the third and final level of classification.

Basing the classification of vegetation on potential climax dominance does not presuppose an abundance of climax vegetation on the landscape. Specific guidelines for the recognition of habitat types based on existing vegetation are provided with habitat type classifications. Typically, this takes the form of dichotomous keys and diagnostic descriptions.

For the forest vegetation we employed the forest habitat type classification of Youngblood and Mauk (1985), developed for forests of southern and central Utah. Sample plots were keyed out according to the key presented in Youngblood and Mauk (1985), and then compared to the type descriptions and coverage/constancy tables as presented in that manual. Sample plots which did not fit the description of the type to which they keyed were rekeyed to the next best fit, and compared to that description until a satisfactory fit between description and sample was obtained.

Habitat types for non-forest land do not exist for southern Utah. Accordingly, several new habitat types were described from data collected in Bryce Canyon. Sample plot data were pooled into tentative habitat types based on the dominant and diagnostic species present. The tentative types were then examined statistically for within-type/between-type similarity ratios. Tentative types were redefined iteratively by transferring sample plots between types to maximize the within-type/between-type similarity ratio.

Resulting types were then analyzed for environmental characteristics

Within habitat types a broad range of community types can occur. These community types can be viewed as successional stages and organized according to a successional schema. We employed a successional community type classification based on a conceptual model from Steele (1984). In this model, community types are classified by two criteria, resulting in a binomial nomenclature. The first criterion is to identify the "most successionally susceptible" species present in the community, called the indicator species. For forest types, this is presumed to be the least shade tolerant species. The second criterion is the dominant species. These two species indicate roughly the composition and structure of the community in a simple binomial given by the indicator species first, and dominant species second. By ordering the species according to successional susceptibility, it is possible to construct a "successional pyramid" which portrays the possible successional dynamics. Figure 3 is an example of the successional community types and pyramid for the WHITE FIR / OREGON GRAPE habitat type in Bryce Canyon National Park.

The successional pyramid works well for forest communities where the successional susceptibility can be estimated from known shade tolerance relations. In non-forest communities, the successional susceptibility must be determined from observed competitive relations in various successional stages. Unfortunately, in Bryce Canyon the non-forest communities do not cover a wide range of seral stages, and sufficient data to calibrate a pyramid are not available. Accordingly, succesisonal dynamics in the non-forest communities is described in a more general manner drawing on general successional trends from the literature.

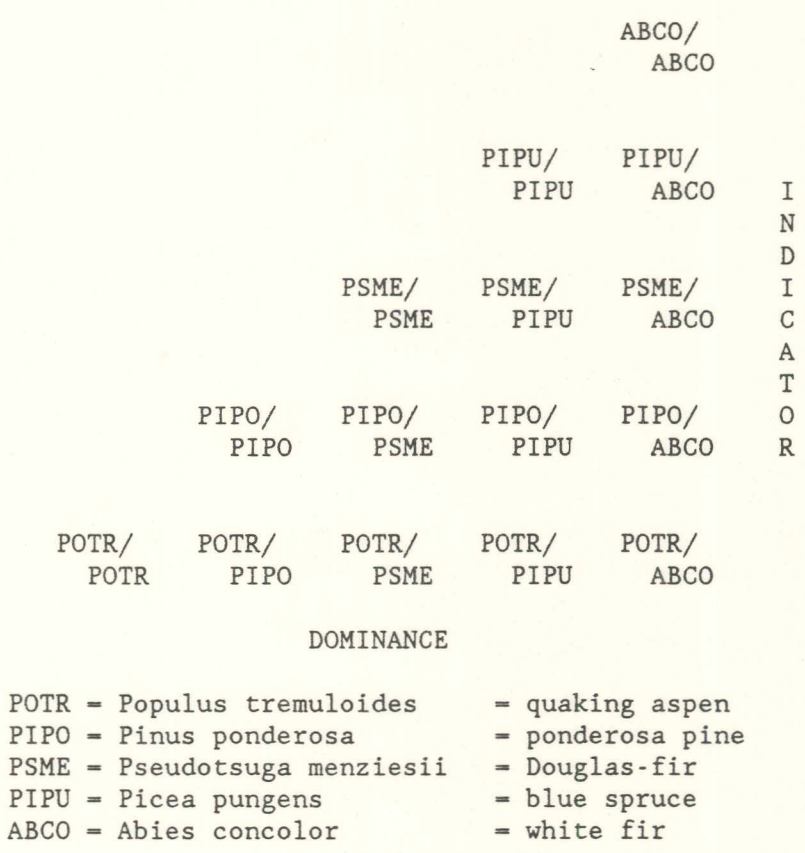


Fig. 3. Successional pyramid for community types in the WHITE FIR / OREGON GRAPE habitat type. The row of the pyramid is determined by the least shade-tolerant species present, called the indicator species. The column is determined by the dominant species (highest basal area).

Habitat types and community types were cross-classified to determine which community types commonly occurred in each habitat type. Cross-classification was performed using program WINDOW from SAGIS on the habitat type and community type maps described below.

2) To classify and map the land area as to current vegetation type (community type), and potential vegetation type (habitat type)

All sample plots were identified to habitat type and community type as described above, and located on a USGS 1:24000 scale topographic map as ground truth data locations. Using the data on adjacent types from the detailed sample plots and observations of adjacent areas on the simple plots, local areas of up to several hundred hectares were mapped in the field, thus providing in aggregate several thousand hectares of ground-truth mapped area.

Then, using criteria and procedures defined by Roberts and Cooper (1989), ground truth data were extrapolated to unmapped areas. In the case of the habitat type maps, extensive field work and color aerial photo interpretation resulted in relatively little statistical extrapolation being required. In the case of the community type maps relatively greater emphasis was placed on predictive modelling, although extensive use of aerial photography was also employed.

The statistical extrapolation techniques employed a method called "classification trees" developed by Breiman et al. (1984). The method is a statistical technique to develop optimal dichotomous keys for prediction of membership in predefined classes. The cart analysis was repeated during the course of the investigation as more data became available.

As discussed by Roberts and Cooper (1989), the factors responsible for the distribution of habitat types across the landscape are relatively fixed, and easily determined from topographic maps and soil maps. Aerial photography reflects the current vegetation, rather than the potential vegetation, and is of relatively less use, although still valuable. Accordingly, the classification tree analysis reflected these data directly. For habitat types, the following data were employed in analysis:

1) elevation
2) aspect
3) slope
4) soil depth class
5) soil texture class
6) UTM north and east coordinates
7) geographic region

The habitat types were predicted in a two step process. First, a key was produced for the major series in the Park (Fig. 4). Then, within each series a separate key was produced for the habitat types in that series (Fig. 5 and 6). Only one habitat type in the Douglas-fir (DOUGLAS-FIR / GREENLEAF MANZANITA) series was sufficiently abundant to model, so no key was produced for that series

In contrast to habitat types, the factors responsible for the distribution of community types are not fixed on the landscape. Rather, disturbance history and chance play a major role. Also in contrast to habitat types, aerial photography is extremely useful in extrapolative mapping of community types. In particular, the distribution of aspen is easily determined from photography, and relative stand densities provide valuable information on probable community type. The statistical predictive model was thus used in conjuction with aerial photo interpretation to map communty

SERIES KEY FOR BRYCE CANYON NATONAL PARK

1) UTM east coordinate <= 39200
   2) elevation > 2560 meters ..... WHITE FIR
   2) elevation <= 2560 meters
      3) soil texture loamy, fine, or clayey ..... WHITE FIR
      3) soil texture skeletal or coarse loamy .... DOUGLAS-FIR
1) UTM east coordinate > 39200
   4) elevation > 2465 meters ..... DOUGLAS-FIR
   4) elevation <= 2465 meters
      5) slope <= 24 percent ..... PONDEROSA PINE
      5) slope < 24 percent
         6) elevation <= 2198 meters ..... PONDEROSA PINE
         6) elevation > 2198 meters ..... DOUGLAS-FIR

Fig. 4. Classification tree to common forest series in Bryce Canyon National Park. This key was used as the first step in predicting habitat type for the extrapolatively mapped areas. Relatively homogeneous areas were identified on 1:2400 topographic maps, and elevation, aspect, and slope were estimated. Soil texture was detemined from soil type classification map. Each area was then run through the dichotomous key to predict the series. Ponderosa pine and white fir areas were then run through the appropriate habitat type keys (Fig. 5 and 6).

PONDEROSA PINE HABITAT TYPE KEY

1) UTM north coordinate > 41700 ..... BITTERBRUSH
1) UTM north coordinate <= 41700
   2) slope > 5 percent ..... GREENLEAF MANZANITA
   2) slope <= 5 percent
      3) Bryce Point region ..... BLACK SAGE
      3) otherwise ..... GREENLEAF MANZANITA

Fig. 5. Classification tree to ponderosa pine habitat types. Map areas identified as ponderosa pine series from the series key (Fig. 4) were run through this key to predict the habitat type for the extrapolatively mapped area. Predicted habitat types were then labelled on the maps.

WHITE FIR HABITAT TYPE KEY

```
1) below the rim or north of Swamp Canyon..... GREENLEAF MANZANITA
1) otherwise
   2) aspect >  312 ............................. OREGON GRAPE
   2) aspect <= 312
      3) UTM north coordinate >  4155 ............ SNOWBERRY
      3) UTM north coordinate <= 4155
         4) UTM north coordinate >  4150 ......... GREENLEAF MANZANITA
         4) UTM north coordinate <= 4150
            5) elevation <= 2580 meters ......... COMMON JUNIPER
            5) elevation >  2580 meters
               6) UTM east coordinate >  389 ..... GREENLEAF MANZANITA
               6) UTM east coordinate <= 389
                  7) aspect >  300 ............... COMMON JUNIPER
                  7) aspect <= 300
                     8) slope <= 29 percent
                        9) soil texture coarse or loamy
                                        ........... OREGON GRAPE
                        9) soil texture otherwise . GREENLEAF MANZANITA
                     8) slope >  29 percent
                        10) slope <= 40 percent ... GREENLEAF MANZANITA
                        10) slope >  40 percent ... OREGON GRAPE
```

Fig. 6. Classification tree to white fir habitat types. Map areas identified as white fir series from the series key (Fig. 4) were run through this key to predict habitat type for the extrapolatively mapped area. Predicted habitat types were then labelled on the maps.

types. Separate keys were constructed for each of the major indicator species (Fig. 7-9).

Final maps were prepared by tracing field-mapped units onto mylar overlays for each USGA topographic map, and then extrapolating out from the field-mapped areas using the aerial photograps and predictive keys. In addition to the habitat type and community type maps, the SCS soil classification maps were also traced onto mylar overlays. Finally, all maps were digitized by hand (using program POLYDRAW, appendix 1) into data files suitable for SAGIS.

3) **To construct a vital attributes succession model which relates the successional pathways and disturbance pathways from each community type to other community types and the climax type.**

Vital attributes theory is a simple, consistent scheme for the characterization of individual plant species autecology. Following an analysis of fire-adapted species traits by Gill (1975,1977), Noble and Slatyer (1977,1980) characterized species by three general attributes: method of propagule dispersal or persistence, conditions of seedling establishment, and age of critical life history stages (age of sexual maturity or first production of propagules by vegetative reproducers, longevity, and propagule longevity). Propagule dispersal or persistence was classified into four possible methods: dispersed seed, seed stored in the soil, seed stored in the canopy, or vegetative reproduction. Conditions for establishment were classified into three classes: able to reproduce under any conditions (tolerant), able to reproduce only in the absence of competition (intolerant), and able to reproduce only in the presence of other vegetation (requiring), corresponding to the tolerance, inhibition, and facilitation models of Connell and Slatyer (1977) respectively.

```
1) elevation >  2585 m ..................... QUAKING ASPEN / WHITE FIR
1) elevation <= 2585 m
   2) slope <= 28 % ....................... QUAKING ASPEN / QUAKING ASPEN
   2) slope >  28 % ....................... QUAKING ASPEN / WHITE FIR
```

Fig. 7. Classification tree for quaking aspen community types in Bryce Canyon National Park. This key was used as an aid in extrapolatively mapping quaking aspen community types from the habitat type and USGA topographic maps.

```
1) UTM north coordinate >  41700 ........... PONDEROSA PINE / PONDEROSA PINE
1) UTM north coordinate <= 41700
   2) UTM east coordinate >  39700 ......... ROCKY MOUNTAIN JUNIPER /
                                                          PONDEROSA PINE
   2) UTM east coordinate <= 39700
      3) soil texture fine-loamy or fine ... PONDEROSA PINE / PONDEROSA PINE
      3) soil texture otherwise
         4) slope >  22 % ................... ROCKY MOUNTAIN JUNIPER /
                                                          PONDEROSA PINE
         4) slope <= 22 %
            5) aspect <= 250 ................ PONDEROSA PINE / PONDEROSA PINE
            5) aspect >  250
               6) slope <= 3 % .............. PONDEROSA PINE / PONDEROSA PINE
               6) slope >  3 % .............. ROCKY MOUNTAIN JUNIPER /
                                                          PONDEROSA PINE
```

Fig. 8. Classification tree for ponderosa pine community types in Bryce Canyon National Park. This key was used to extrapolatively map ponderosa pine community types from habitat type, USGS topographic map, and SCS soil map data.

```
1) UTM north coordinate >  41600 ........... PONDEROSA PINE / PONDEROSA PINE
1) UTM north coordinate <= 41600
   2) aspect <= 95 degrees ................. PONDEROSA PINE / WHITE FIR
   2) aspect >  95 degrees
      3) UTM north coordinate <= 41500 ..... LIMBER PINE / WHITE FIR
      3) UTM north coordinate >  41500
         4) habitat type WHITE FIR / GREENLEAF MANZANITA
            5) slope <= 28 % ................ PONDEROSA PINE / WHITE FIR
            5) slope >  28 %
               6) aspect <= 250 degrees ..... LIMBER PINE / WHITE FIR
               6) aspect >  250 degrees ..... PONDEROSA PINE / PONDEROSA PINE
         4) habitat type otherwise ..... PONDEROSA PINE / WHITE FIR
```

Fig. 9. Classification tree for white fir community types in Bryce Canyon National Park. This key was used to extrapolatively map ponderosa pine community types from habitat type and USGS topographic map data.

Conceptual vital attributes models which produce qualitative predictions have been developed by Noble and Slatyer (1977,1980) and Cattelino et al. (1979). Kessell and Potter (1980) developed a computer model based on an extension of the same concepts which produces semi-quantitative predictions.

A stochastic simulation model which produces simple semi-quantitative predictions of plant community succession and response to disturbance was developed by slightly modifying the vital attributes concepts employed by previous workers, and integrating the successional pyramid concept from Steele (1984). The predicted composition of each stand is classified to successional community type according to the rules of the pyramid model, and the dynamics of the community types are portrayed by changes in community type abundance with time.

The structure of the model is similar to previous forest composition simulation models such as JABOWA (Botkin et al. 1972) and FORET (Shugart 1984) The model includes routines for calculating the growth, reproduction, and mortality of trees in the absence of disturbance. In contrast to these models, however, this model also includes a disturbance response routine for calculating the response of different age classes of individual species to disturbance of varying severity.

Because disturbance occurs sporadically in the forests being modelled, the model is stochastic to mimic the variability in periodicity of the disturbance regime. The response of different species to disturbance depends on factors inherent to the species, the age of individuals, characteristics of the stand, and the particular disturbance. In order to simulate such responses the model must be mechanistic, leading to the adoption of vital attribute-based methods.

The vital attributes of Noble and Slatyer (1980) were modified slightly to better represent community-level characteristics being modelled and to increase the quantitative information produced by the model. Specifically, changes were made to the reproductive methods classification, the establishment requirement classification, and a new vital attribute was specified for disturbance resistance.

The method of reproduction attribute remains largely the same as specified by Noble and Slatyer (1980). Individual species reproduce by: (1) dispersed seed, (2) stored seed, or (3) vegetatively. Because the time step of the model is ten years, dispersed seed are considered to be viable only in the time step in which they are produced; seeds which do not germinate are lost. Stored seed varies greatly in longevity, and species-specific values are required.

The viability of vegetative reproducers is extremely variable, and depends on species-specific characteristics and the history and vigor of individual organisms. In this model I assumed that the ability to sprout depends on stored carbohydrate reserve, which in turn depends on the recent carbon balance of the individual plant. Carbohydrate storage in the model is calculated as years of remaining carbohydrate, with individual species maintaining a simple carbohydrate balance as follows. For individuals with living stems, the storage is incremented every time step that sprouting does not occur, up to a species-specific maximum. For individuals existing only as root systems, the storage is decremented for every time step. Following disturbance, vegetative reproducers sprout, which removes a quantity of carbohydrate from storage. Following sprouting, successful individuals begin to replenish the stored carbohydrate. In a manner similar to the

specification of sexual maturity for seed reproducers, reproductive maturity for vegetative reproducers is considered to be the length of time required to replenish the carbohydrate expended in sprouting. If disturbance occurs when individuals have exhausted their carbohydrate storage no sprouting occurs, and the species goes locally extinct.

The establishment classification was modified significantly by employing a shade-tolerance attribute, rather than an establishment attribute. Individual species are ranked for shade-tolerance (with ties if appropriate). I assumed that species continue to add leaf area until their lower crowns reach the light compensation point, so that species cast shade proportional to their shade-tolerance. All species are assumed capable of reproducing in their own shade or the shade of less-tolerant species. Species of shade tolerance five or greater require the shade of less-tolerant species to establish (following the facilitation model of Connell and Slatyer [1977] or the R establishment attribute of Noble and Slatyer [1980]). Species are assumed not to cast shade until the sum of their age-class cohorts equals or exceeds 70. The net effect of the shade-tolerance scheme is to produce a competitive hierarchy (Horn 1975), where any species with shade-tolerance from one to four can reproduce on open sites, but where more shade-tolerant species eventually shade out their less-tolerant competitors. The shade requirement characteristic of extremely shade-tolerant species produces a time lag (typically 40 years) between the colonization of an open site by intolerant or mid-tolerant species and very shade-tolerant species.

Species-specific establishment rates are variable, even under ideal conditions. For each species, a probability of establishment under acceptable conditions is given which simulates the requirements for restricted seed beds

or reproductive sites within the simulated communities.

An additional attribute was added for disturbance resistance. The vital attributes classification of Noble and Slatyer (1980) provided for the persistence of propagules and mature individuals through disturbance, but assumed that disturbance events were of fixed intensity. Accordingly, species were either tolerant of disturbance, or were killed by the disturbance.

In the forests of the Rocky Mountains fire intensity varies greatly. Fire severity in the model depends on site-specific characteristics of fuel accumulation rate and the time since the last fire. Fuel is assumed to accumulate after fires at a rate determined by the site productivity and decomposition rate, until reaching a plateau where decomposition equals new fuel production. Severity is classified into five severity classes, which correspond to the species fire tolerance ratings described below. The fuel accumulation rate is specified as the minimum number of years required to accumulate sufficient fuel for each fire severity class. When fires occur, all the fuel is assumed to be burned.

In the Rocky Mountains, some species have adaptations such as thick bark and high self-pruning that enable mature individuals to withstand low intensity or moderate fires, while high-intensity fires may kill all individuals. Accordingly, a simple fire tolerance ranking (from zero to five) was employed to characterize the fire tolerance of individual species. If fires of an intensity class lower than the fire tolerance rating occur, individuals older than X survive the fire, where X is given by:

X = (6 - (fire tolerance - fire severity)) * 10

If fires of an intensity greater than the fire tolerance occur, all individuals of that species are killed. This fire tolerance scheme results in fire-tolerant species maintaining significant populations of mature individuals under short fire return intervals, where fire-intolerant species are periodically excluded.

The model calculates the presence or absence of ten-year age class cohorts for each species for each time step. For each species, the ten-year age class cohorts are summed to produce an pseudo-abundance. From this abundance calculation, the least shade-tolerant species present is determined as the indicator species, and the relative abundance values are used to determine membership of the stand in each of the possible successional community types. The distribution of successional community type distrinutions is stored for each time step for each replicate, and mean community type distributions for each time step are calculated at the end of the simulation. The mean community type distribution values are plotted on the successional community pyramid to portray the distribution of successional community membership values.

Vital attributes selected for Bryce Canyon species are listed in Table 2.

4) To determine the habitats and plant communities in which rare or endangered plants occur, and using the community pathway models, to determine the influence of succession, disturbance, or Agency management on the possible distribution of these species.

Potential rare and endangered plant species were determined from lists of species developed by Welsh (1979), and Welsh and Chatterley (1985). Thirty-three rare or endangered plant taxa were known to occur in Kane and Garfield

Counties. Of the 33, Buchanan and Graybosch (1981) and Graybosch and Buchanan (1983) listed seven species within Bryce Canyon National Park. We examined descriptions and vouchers for these species where possible, and determined their probable habitat from the descriptions provided. During the course of mapping the habitat types and community types, these habitats were searched for the presence of any of these species. When potential rare or endangered species were found, we surveyed the immediate area and similar habitats to determine the distribution.

Table 2. Vital attributes for species in Bryce Canyon National Park. These attributes are employed in the simulation model to determine the successional development and disturbance response in Bryce Canyon National Park forest communities.

Species	longevity	age of reproduction	shade tolerance	fire tolerance	method of reproduction
quaking aspen	140	10	2	0	vegetative
ponderosa pine	400	40	2	4	seed
Douglas-fir	300	40	3	3	seed
blue spruce	400	40	4	0	seed
white fir	300	40	5	0	seed

5) To map the current and potential distributions of rare and endangered species

When potential rare or endangered species were found, the distribution was noted by location, habitat type, community type, and general community characteristics. A map was prepared of the distribution if the population distribution could be verified.

6) To identify and map undisturbed plant communities to serve as baseline reference areas

During the course of sampling and mapping vegetation throughout the Park, plant communities were evaluated for inclusion in a system of research natural areas. Criteria for inclusion as potential research natural areas were: relatively undisturbed, extensive, and characteristic of a significant habitat or community type.

HABITAT TYPES OF BRYCE CANYON NATIONAL PARK

Classified broadly, the potential vegetation of Bryce Canyon National Park follows an elevational sequence from shrub communities through woodland to closed forest, with some communities occuring at particular sites determined by soil characteristics. At the lowest elevations of the Park in the Sheep Creek and Yellow Creek drainages, two shrub communities occur on clayey soils derived from the Tropic shale strata. These communities, CORYMB BUCKWHEAT / SALINA WILDRYE and BIG SAGEBRUSH / FOUR-WING SALTBUSH, are distributed according to both elevation and soil characteristics. Outside this area, at slightly higher elevations throughout the north end and east side of the Park is a broad zone of pinyon-juniper woodland, classified here as PINYON PINE / UTAH JUNIPER. Other low elevation areas below the rim of the Breaks typically support a mosaic of more mesic communities described below.

Above the rim of the Breaks, non-forest areas are dominated by an black sagebrush shrub community, classified here as BLACK SAGEBRUSH / NEEDLE-AND-THREAD. This community covers a large area of the north end of the Park, and extends into the central portion of the Park along drainages. Adjacent meadows with seasonally saturated soils support the WIREGRASS / ROSS'S SEDGE community, with diagnostic species wiregrass.

The forests of Bryce Canyon are represented by a series of habitat types along a complex temperature/moisture gradient, with moisture increasing generally from north to south along the increase of elevation. The dry end of the gradient is represented by three ponderosa pine habitat types: PONDEROSA PINE / BLACK SAGE, PONDEROSA PINE / BITTERBRUSH, and PONDEROSA PINE / GREENLEAF MANZANITA. These communities are dominated by ponderosa pine, but may also include Rocky Mountain juniper. With additional moisture,

Douglas-fir becomes important, and occurs as the climax dominant in two habitat types: DOUGLAS-FIR / GREENLEAF MANZANITA, and DOUGLAS-FIR / OREGON GRAPE. Associated species in these types include ponderosa pine, limber pine, Rocky Mountain juniper, and rarely, quaking aspen. With additional moisture, white fir becomes the climax dominant, represented by four habitat types, with a total of five types and phases.

Sites within the forest zone which occur on particular substrates support unique communities. In areas of cold air drainage, blue spruce communities may occur, represented by the BLUE SPRUCE / COMMON JUNIPER habitat type. In drainages below the rim, PONDEROSA PINE / GAMBEL OAK communities occur on the alluvial terraces and outwashes. Finally, on xeric, exposed sites, bristlecone pine and limber pine are dominant, represented by the LIMBER PINE / BRISTLECONE PINE habitat type.

Figure 10 is a key to the habitat types of Bryce Canyon National Park adapted from Youngblood and Mauk (1985) with the new non-forest habitat types appended as well. Details on the individual habitat types are provided below, following the topographic moisture sequence outlined above. For each type, the site characteristics, vegetation characteristics, and succession or disturbance history is given. Additionally, for the forest types, the distribution of successional conmmunity types is according to the classification scheme previously presented.

The name for each type is given in both common and scientific names. An abbreviation for each type (derived from the scientific names) is also given. This abbreviation appears on maps and tables. The typical species composition for each type is given in common names, with the scientific name for each species given the first time it appears. Nomenclature follows Welsh et al.

KEY TO HABITAT TYPES OF BRYCE CANYON NATIONAL PARK

1) sites dominated by shrubs or graminoids, not capable of supporting trees
  2) big sagebrush at least 1% cover ..... BIG SAGEBRUSH / FOURWING SALTBUSH
  2) big sagebrush less than 1% cover
    3) black sagebrush at least 5% cover ..... BLACK SAGEBRUSH / NEEDLE-AND-THREAD
    3) black sagebrush less than 5% cover
      4) corymb buckwheat or winterfat at least 1% cover ..... CORYMB BUCKWHEAT / SALINA WILDRYE
      4) otherwise
        5) wiregrass at least 1% cover ..... WIREGRASS / ROSS'S SEDGE
        5) wiregrass less than 1% cover ..... unclassified
1) sites dominated by trees
  6) white fir present and reproducing
    7) greenleaf manzanita at least 1% cover ..... WHITE FIR / GREENLEAF MANZANITA
    7) greenleaf manzanita less than 1% cover
      8) Gambel oak at least 5% cover ..... WHITE FIR / GAMBEL OAK
      8) Gambel oak less than 5% cover
        9) Oregon grape at least 1% cover
          10) common juniper at least 5% cover ..... WHITE FIR / OREGON GRAPE - COMMON JUNIPER
          10) common juniper less than 5% cover ..... WHITE FIR / OREGON GRAPE - OREGON GRAPE
        9) Oregon grape less than 1% cover
          11) common juniper at least 1% cover ..... WHITE FIR / COMMON JUNIPER
          11) common juniper less than 1% cover
            12) snowberry at least 1% cover ..... WHITE FIR / SNOWBERRY
            12) snowberry less than 1% cover ..... unclassified
  6) white fir absent
    13) blue spruce present and reproducing ..... BLUE SPRUCE / COMMON JUNIPER
    13) blue spruce absent
      14) limber pine or brustlecone pine dominant in sparse community .. LIMBER PINE / BRISTLECONE PINE
      14) otherwise
        15) Douglas-fir present and reproducing
          16) greenleaf manzanita at least 1% cover ..... DOUGLAS-FIR / GREENLEAF MANZANITA
          16) greenleaf manzanita less than 1% cover
            17) Oregon grape at least 1% cover ..... DOUGLAS-FIR / OREGON GRAPE - PONDEROSA PINE
            17) Oregon grape less than 1% cover ..... unclassified
        15) Douglas-fir absent
          18) ponderosa pine present and reproducing
            19) greenleaf manzanita at least 1% cover ..... PONDEROSA PINE / GREENLEAF MANZANITA
            19) greenleaf manzanita less than 1% cover
              20) black sage at least 5% cover .....PONDEROSA PINE / BLACK SAGE
              20) black sage less than 5% cover
                21) bitterbrush at least 1% cover ..... PONDEROSA PINE / BITTERBRUSH
                21) bitterbrush less than 1% cover
                  22) Gambel oak at least 5% cover ..... PONDEROSA PINE / GAMBEL OAK
                  22) Gambel oak less than 5% cover ..... unclassified
          18) ponderosa pine absent
            23) pinyon pine or Utah juniper dominant ..... PINYON PINE / UTAH JUNIPER
            23) otherwise ..... unclassified

Fig 11. Key to habitat types in Bryce Canyon National Park.

(1987). Where Welsh et al. (1987) have departed from commonly recognized scientific names, a synonym is also given. A table of scientific and common names appears in appendix A.

TABLE 3. Common Habitat Types of Bryce Canyon National Park

A) SHRUB-DOMINATED

1) CORYMB BUCKWHEAT / SALINA WILDRYE ..... 75 ha

2) BIG SAGEBRUSH / FOUR-WING SALTBUSH ..... 141 ha

3) BLACK SAGEBRUSH / NEEDLE-AND-THREAD ..... 758 ha

B) RUSH AND SEDGE DOMINATED

4) WIREGRASS / ROSS'S SEDGE ..... 39 ha

C) WOODLAND

5) PINYON PINE / UTAH JUNIPER ..... 2682 ha

6) LIMBER PINE / BRISTLECONE PINE ..... 31 ha

7) PONDEROSA PINE / GAMBEL OAK ..... 560 ha

D) FOREST

8) PONDEROSA PINE / BLACK SAGE ..... 185 ha

9) PONDEROSA PINE / BITTERBRUSH ..... 314 ha

10) PONDEROSA PINE / GREENLEAF MANZANITA ..... 1988 ha

11) DOUGLAS-FIR / GREENLEAF MANZANITA ..... 974 ha

12) DOUGLAS-FIR / OREGON GRAPE ..... 6 ha

13) BLUE SPRUCE / COMMON JUNIPER ..... 55 ha

14) WHITE FIR / GREENLEAF MANZANITA ..... 1993 ha

15) WHITE FIR / SNOWBERRY ..... 346 ha

16) WHITE FIR / COMMON JUNIPER ..... 225 ha

17) WHITE FIR / OREGON GRAPE ..... 462 ha

CORYMB BUCKWHEAT / SALINA WILDRYE

ERIGONOM CORYMBOSUM / ELYMUS SALINUS
ERCO / ELSA

SITE: The CORYMB BUCKWHEAT / SALINA WILDRYE habitat type is a relatively minor type occupying about 75 hectares on steep slopes above Yellow Creek adjoining the Park boundary (Fig. 11). Elevations range from 2055 m to 2120 m (6750 to 6960 feet), generally on south-westerly aspects. All plots occur on the eroded clay Badland-Cannonville soils. Adjacent sites are typically BIG SAGEBRUSH / FOUR-WING SALTBUSH or PINYON PINE / UTAH JUNIPER.

VEGETATION: These sites are extremely harsh, and support few species with low coverage. The vegetation is dominated by corymb buckwheat (Eriogonum corymbosum), fourwing saltbush (Atriplex canescens), winterfat (Ceratoides lanata), salina wildrye (Elymus salinus), Indian ricegrass (Stipa hymenoides [Oryzopsis hymenoides]), and squirreltail (Elymus elymoides [Sitanion hystrix]). Of these species, only corymb buckwheat and winterfat ever exhibit coverages greater than five percent.

SUCCESSION: There are no recently disturbed sites in the Park to serve as a data base for the successional trends in this habitat type. These sites are sufficiently harsh, however, that there are very few species adapted to the prevailing conditions, post disturbance dominants would likely be the same species as dominate at present with the addition of annual invaders.

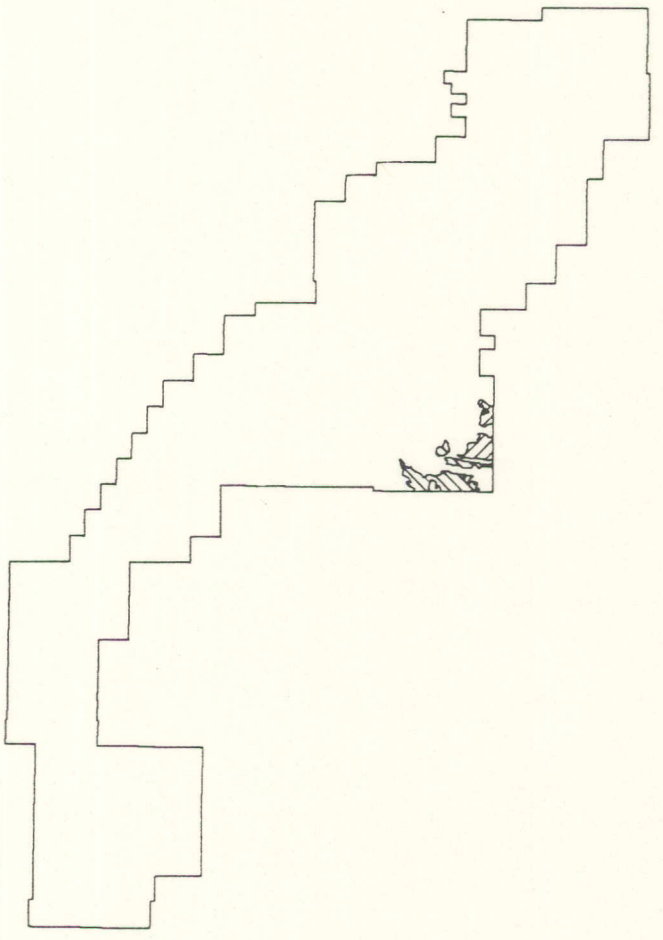


Fig. 11. Distribution of CORYMB BUCKWHEAT / SALINA WILDRYE and BIG SAGEBRUSH / FOUR-WING SALTBUSH habitat types in Bryce Canyon National Park.

CORYMB BUCKWHEAT / SALINA WILDRYE ..... /////

BIG SAGEBRUSH / FOUR-WING SALTBUSH ..... \\\\\

BIG SAGEBRUSH / FOUR-WING SALTBUSH

ARTEMISIA TRIDENTATA / ATRIPLEX CANESCENS
ARTR / ATCA

SITE: The BIG SAGEBRUSH / FOUR-WING SALTBUSH habitat type occurs on about about 140 hectares of relatively low elevation sites on shallow slopes above Sheep Creek and Yellow Creek (Fig. 11). These sites occur on well-drained fine-textured or clayey soils. Elevations range from 2025 m to 2100 m (6650 to 6900 feet), and sites occur primarily on easterly or south-easterly aspects. Sites are typically mid-slopes, but upper and lower slopes also occur. Slopes range from 5 to 45 percent, but only one plot occurs above 25 percent.

VEGETATION: Sites are dominanted by big sagebrush (Artemisia tridentata var. tridentata), four-wing saltbush, and squirreltail, with accompanying viscid rabbitbrush (Chrysothamnus viscidiflorus), Indian ricegrass, sego lilly (Calochortus nuttallii), and common globemallow (Sphaeralcea coccinea). Winterfat, western wheatgrass (Elymus smithii [Agropyron smithii]), and New Mexico thistle (Cirsium neomexicanum) occur in approximately half our sample plots.

SUCCESSION: Big sagebrush is sensitive to fire, and may be removed from sites by frequent burning. Much of the area within this type, however, has low fuel loads and may not support frequent burning. Frequent fires within this type should favor grass species at the expense of the shrub species, with a slow reinvasion by the shrubs. There is some evidence of invasion of this type by pinyon pine and Utah juniper, but indications are inconclusive at this time. BIG SAGEBRUSH / FOUR-WING SALTBUSH represents a large proportion of the

non-woodland area at low elevations in the Park. Adjacent sites are typically PINYON PINE / UTAH JUNIPER or occassionaly CORYMB BUCKWHEAT / SALINA WILDRYE.

BLACK SAGEBRUSH / NEEDLE-AND-THREAD

ARTEMISIA NOVA / STIPA COMATA
ARNO / STCO

SITE: BLACK SAGEBRUSH / NEEDLE-AND-THREAD occupies most of the non-woodland or non-forest sites at moderate elevations on the Paunsaugunt Plateau, totaling about 760 hectares (Fig. 12). BLACK SAGEBRUSH / NEEDLE-AND-THREAD occurs primarily on gentle slopes on all aspects, but also occasionally on bottoms and ridge tops. Elevations range from 2315 m to 2415 m (7600 to 7920 feet). Soils are primarily fine-textured and loamy, but also include some skeletal soils.

VEGETATION: The vegetation is dominated by black sagebrush (Artemisia nova), viscid rabbitbrush, and needle-and-thread (Stipa comata). Horesbrush (Tetradymia canescens), blue grama (Bouteloua gracilis), junegrass (Koeleria macrantha), muttongrass (Poa fendleriana), and squirreltail are all common components of the vegetation. Forbs are generally sparse, but sego lilly, redroot buckwheat (Eriogonum racemosum), granite pricklygilia (Leptodactylon pungens), and groundsel (Senecio multiradiata) commonly occur.

SUCCESSION: Post-fire succession in this type is demonstrated by experimental burns in this type conducted within Bryce Canyon National Park. Black sage is killed by fire, and does not sprout. Viscid rabbitbrush is burned back by fire, but sprouts after the fire to dominate post-burn vegetation for some time. We have few plots from which to generalize, but black sagebrush may be

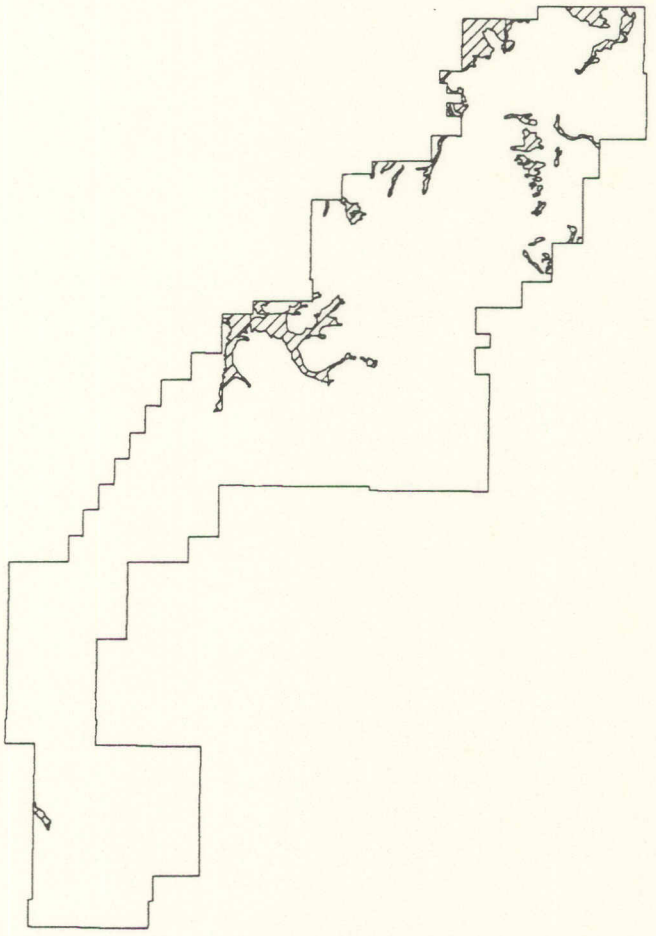


Fig. 12. Distribution of BLACK SAGEBRUSH / NEEDLE-AND-THREAD habitat type in Bryce Canyon National Park.

slow to re-invade these sites.

WIREGRASS / ROSS'S SEDGE

JUNCUS ARCTICUS / CAREX ROSSII
JUAR / CARO

SITE: WIREGRASS / ROSS'S SEDGE is a relatively minor type of about 40 hectares which occurs on small depressions with poorly-drained soils where runoff or sub-surface flow accumulates, generally within areas dominated by BLACK SAGEBRUSH / NEEDLE-AND-THREAD. These areas may be saturated during some portion of the year. WIREGRASS / ROSS'S SEDGE occupies a relatively small portion of the landscape in Bryce Canyon National Park, but may be more important to some organisms than suggested by the limited area.

VEGETATION: WIREGRASS / ROSS'S SEDGE is characterized by the diagnostic presence of wiregrass (Juncus arcticus [Juncus balticus]), but is typically dominated by other grass or shrub species. Ross's sedge (Carex rossii) and squirreltail are typically dominant, joined by fringed sagebrush (Artemisia frigida) and viscid rabbitbrush. Forbs are generally sparse.

SUCCESSION: We have no data on disturbance response in this type. In general, relatively few species are adapted to the potentially saturated soils, and the post-disturbance community may resemble those present now.

PINYON PINE / UTAH JUNIPER

PINUS EDULIS / JUNIPERUS OSTEOSPERMA
PIED / JUOS

SITE: PINYON PINE / UTAH JUNIPER occupies a very large area of the north and east end of Bryce Canyon National Park (Fig. 13). This habitat type is the most abundant habitat type in Bryce Canyon National Park, totaling over 2680 hectares. Elevations for this type range from 2060 m to 2300 m (6760 to 7560 feet), but the majority of the area lies below 2225 m (7300 ft.). PINYON PINE / UTAH JUNIPER occurs on nearly any aspect within this elevational zone, but is more typical on easterly aspects. This may reflect merely the typical aspect of this portion of the Park, however. While most sites occur on gentle slopes, PINYON PINE / UTAH JUNIPER occurs on a range of slopes up to 70 percent. Soils are typically coarse to loamy.

VEGETATION: Overstory composition in PINYON PINE / UTAH JUNIPER is typically dominated by pinyon pine (Pinus edulis) with associated Utah juniper (Juniperus osteosperma), but dominance by Utah juniper also occurs. Basal areas for the two species range up to 20^2m /ha (90 ft^2/acre) for pinyon pine and 16 m^2/ha (70 ft^2/acre) for Utah juniper, but typical basal areas are from 7 to 12 m^2/ha (30 to 50 ft^2/acre) individually, with total basal areas from 7 to 36 m^2/ha (30 to 160 ft^2/acre).

Understory composition in PINYON PINE / UTAH JUNIPER is variable. In addition to pinyon pine and Utah juniper as the overstory dominants, the understory is dominated by alderleaf mountain mahogany (Cercocarpus montanus), bitterbrush (Purshia tridentata), or Gambel oak (Quercus gambelii). Forbs and grasses are sparse, but Indian ricegrass and erinaceous pricklypear (Opuntia erinaceae) are relatively common.

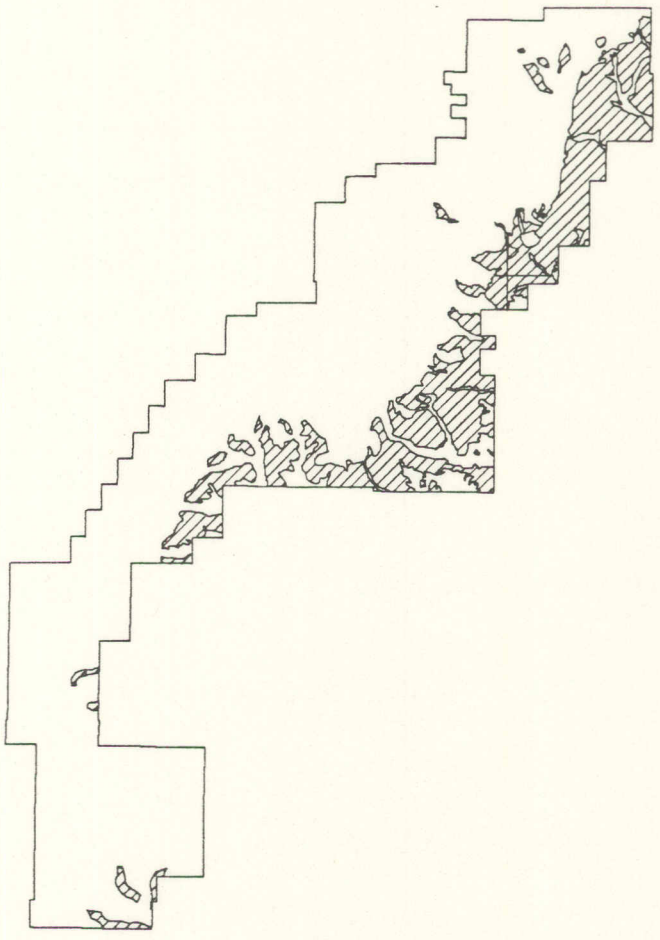


Fig 13. Distribution of PINYON PINE / UTAH JUNIPER habitat type in Bryce Canyon National Park.

SUCCESSION: Post-fire succession in pinyon-juniper woodlands has been studied by a number of ecologists, with results which vary according to the locale of the research. In some cases both pinyon pine and Utah juniper re-establish within a few years after the disturbance, but in other areas 20-30 years may be required before re-establishment, with intermediate grass and shrub dominated stages. Typically, Utah juniper is thought to establish first, followed by pinyon pine.

In Bryce Canyon, the ages of the oldest trees in a given plot ranged from about 75 years up to about 300 years, with one tree over 490 years. It is not clear whether the range of ages is indicative of patchy fire distribution, or whether pinyon pine and Utah juniper are establishing somewhat randomly on a limited number of good sites. Few of the sample plots exhibited any evidence of fire within the lifetime of the oldest trees, and many plots are much older than the initiation of fire suppression. Additionally, in over half of our sample plots individual pinyon pine tress are older than the associated Utah juniper trees, indicating that staggered re-invasion did not occur. With the open canopies of these communities successional replacement may not take place. Still, the clear trend toward dominance by pinyon pine indicates a probable lack of severe disturbance in the lifetime of these communities. Our tentative conclusion is that the PINYON PINE / UTAH JUNIPER stands in Bryce Canyon have not commonly experienced fire. Accordingly, there is little evidence to predict post-fire vegetation response for these sites.

PONDEROSA PINE / GAMBEL OAK

PINUS PONDEROSA / QUERCUS GAMBELII
PIPO/QUGA

SITE: PONDEROSA PINE / GAMBEL OAK occupies drainages below the rim primarily on alluvial terraces and outwash. Most of these communities are narrow stringers material where the drainages enter the Park, with a total area of about 560 ha (Fig. 14). PONDEROSA PINE / GAMBEL OAK sites are most common in the north end of the Park, but occur all along the eastern border. Typically these communities give way to PINYON PINE / UTAH JUNIPER sites up slope.

VEGETATION: Large ponderosa pine (Pinus ponderosa) are typically present, while the Gambel oak is restricted to large shrub or small tree size. Undergrowth is variable, but typical species include Greenleaf manzanita (Arctostaphylos patula), alderleaf mountain mahogany and Utah serviceberry (Amelanchier utahensis).

SUCCESSION: We have no samples of early successional communities of this type in the Park. However, Gambel oak is a ver strong sprouter after fire, and would probably dominate these communities strongly after fire, despite the fact that ponderosa pine and greenleaf manzanita are also fire tolerant.

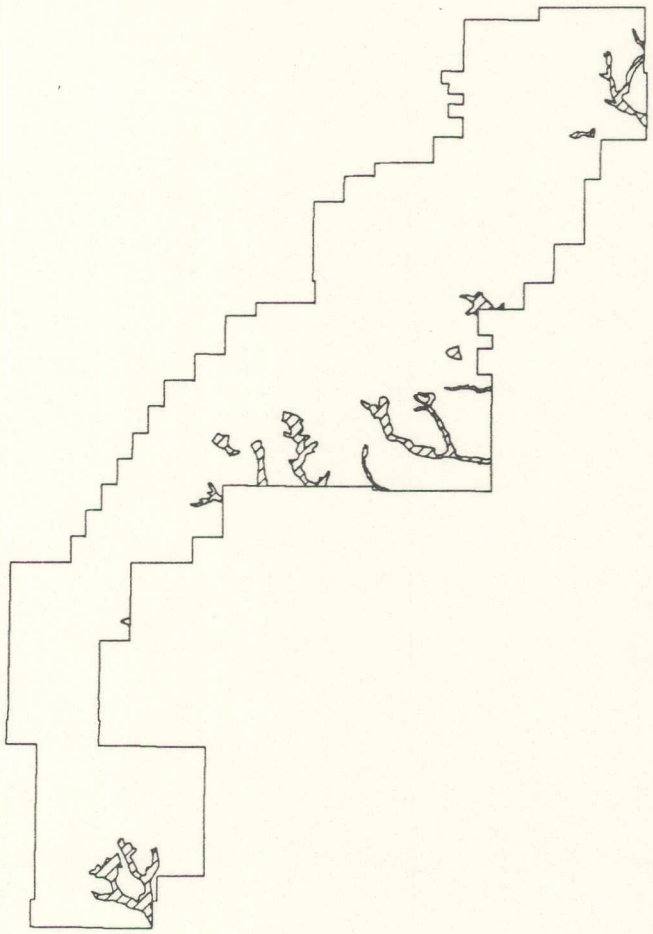


Fig. 14. Distribution of PONDEROSA PINE / GAMBEL OAK habitat type in Bryce Canyon National Park.

PONDEROSA PINE / BLACK SAGEBRUSH

PINUS PONDEROSA / ARTEMISIA NOVA
PIPO / ARNO

SITE: PONDEROSA PINE / BLACK SAGEBRUSH is a relatively minor habitat type in Bryce Canyon National Park, typically occurring in thin bands where shallow foothill slopes adjoin alluvial areas dominated by BLACK SAGEBRUSH / NEEDLE-AND-THREAD (Fig. 15). Total area is approximately 185 hectares. Sampl plots occurred at elevations of 2335 m and 2360 m (7660 and 7740 feet) on gentle north easterly aspects. These sites are transitional from the non-forest BLACK SAGEBRUSH / NEEDLE-AND-THREAD communities below to PONDEROSA PINE / GREENLEAF MANZANITA or DOUGLAS-FIR / GREENLEAF MANZANITA sites above on steeper or more exposed sites.

VEGETATION: The overstory is dominated by scattered ponderosa pine with basal areas ranging from 4 to 13 m /ha (15 to 55 ft /acre). Understory vegetation is dominated by the diagnostic black sagebrush, accompanied by bitterbrush, broom snakeweed (Gutierrezia sarothrae), and horsebrush. Common graminoids and forbs include Ross's sedge, Indian ricegrass, winged buckwheat (Eriogonom elatum), redroot buckwheat, erinaceous pricklypear, and mat penstemon (Penstemon caespitosus).

SUCCESSION: Ponderosa pine trees in both sample plots exhibited fire scars, and charcoal was observed on the ground surface in both sample plots. While we do not have an estimate of fire return interval for this type, it seems probable that low intensity periodic fires occur in this type. Understory fires would be expected to reduce the dominance of black sagebrush for a few years after fires, so that an intermediate fire return interval is indicated

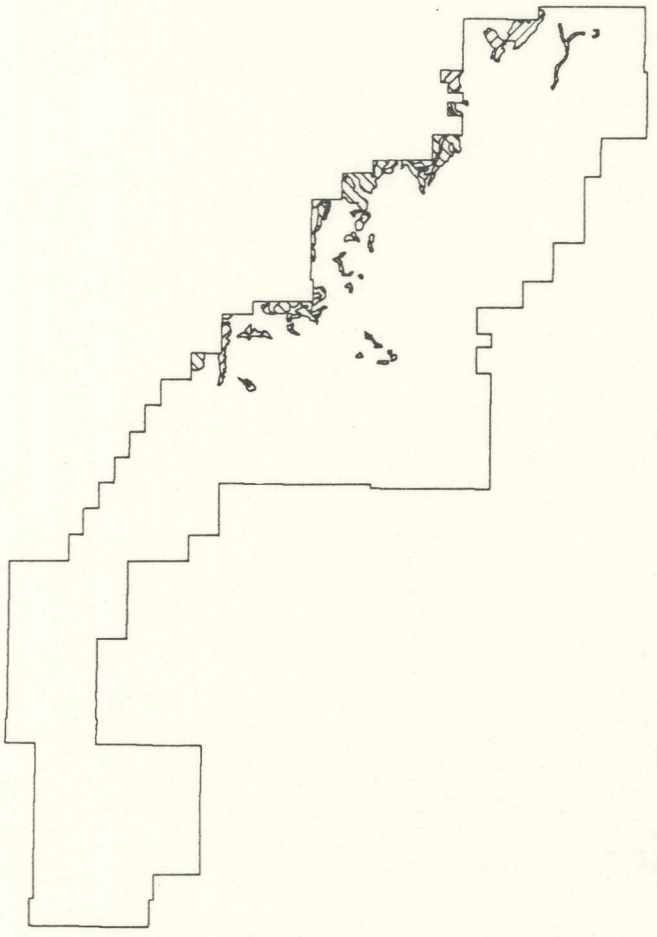


Fig. 15. Distribution of PONDEROSA PINE / BLACK SAGEBRUSH and PONDEROSA PINE BITTERBRUSH habitat types in Bryce Canyon National Park.

PONDEROSA PINE / BLACK SAGEBRUSH ..... ////

PONDEROSA PINE / BITTERBRUSH ..... \\\\

by the vegetation composition. In most cases, fires will not be severe enough to kill mature ponderosa pine trees, but may lead to episodic reproduction due to mortality of small trees.

Community type distribution within this type is:

23 ha NULL/ PONDEROSA PINE (< 6 m /ha [25 ft /acre] basal area)
150 ha PONDEROSA PINE / PONDEROSA PINE

Six m^2/ha is one third the mean basal area for this type, and represents areas with relatively low stocking. It may be, however, that these areas are merely poor sites which support few trees, and not sites undergoing successional development of a denser canopy.

PONDEROSA PINE / BITTERBRUSH

PINUS PONDEROSA / PURSHIA TRIDENTATA
PIPO / PUTR

SITE: PONDEROSA PINE / BITTERBRUSH is a fairly common habitat type (315 hectares) at elevations from 2350 m to 2555 m (7700 to 8380 feet) in the north end of Bryce Canyon National Park (Fig. 15). Sites occur on level to moderate slopes of varying aspect. Soils are typically skeletal or sandy and well-drained.

VEGETATION: The overstory is dominated by all-aged ponderosa pine, with occasional Rocky Mountain juniper (Juniperus scopulorum). Stands are fairly open, with basal areas ranging from 9 to 14 m^2/ha (40 to 60 ft^2/acre). The understory is dominated by bitterbrush, Utah mountain-lilac (Ceanothus martinii) and horsebrush, with Ross's sedge, gumweed aster (Machaeranthera grindelioides), and rock goldenrod (Petradoria pumila) commonly occuring.

SUCCESSION: PONDEROSA PINE / BITTERBRUSH stands in our samples range from 115 to 325 years, and are typically uneven-aged. Half of our sample plots show clear evidence of fire in the form of fire scars and charred material on the ground. Evidence from other parts of the Rocky Mountains suggests a fire return interval of about 50 years in this type. Accordingly, it seems that understory fires of moderate frequency are typical of this type. While ponderosa pine is fire resistant, bitterbrush is killed by fire and may be removed from these stands if fires occur too frequently. A likely consequence of this would be an increase in the abundance of grass species in the understory.

Community distribution within this type is:

137 ha ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE
160 ha PONDEROSA PINE / PONDEROSA PINE

PONDEROSA PINE / GREENLEAF MANZANITA

PINUS PONDEROSA / ARCTOSTAPHYLOS PATULA
PIPO / ARPA

SITE: PONDEROSA PINE / GREENLEAF MANZANITA is one of the three most common habitat types in Bryce Canyon National Park, and occurs across a range of sites (Fig. 16). Total area covered is approximately 1990 hectares, with another 640 hectares of area classified as transitional to PINYON PINE / UTAH JUNIPER. Elevations range from 2135 m to 2560 m (7000 to 8400 feet), and sites occur on gentle to moderate slopes with aspects from northeast to west. PIPO/ARPA also occurs accross a range of soil textures from skeletal to

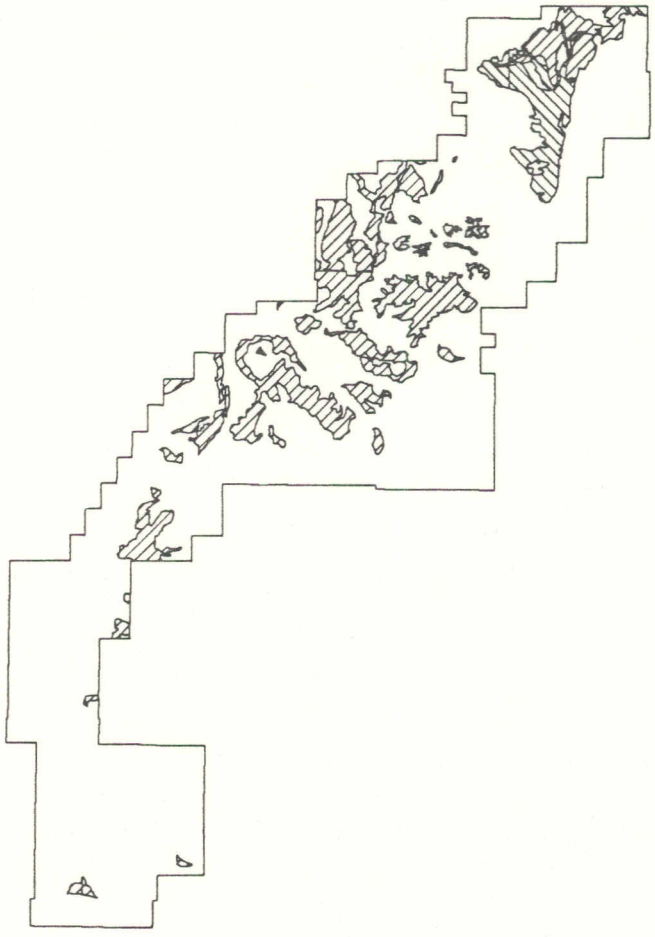


Fig. 16. Distribution of PONDEROSA PINE / GREENLEAF MANZANITA habitat type in Bryce Canyon National Park.

PONDEROSA PINE / GREENLEAF MANZANITA ..... ////

transition to PINYON PINE / UTAH JUNIPER ..... \\\\

fine-textured loamy.

VEGETATION: The overstory in PONDEROSA PINE / GREENLEAF MANZANITA is a fairly open canopy of ponderosa pine with occasional Rocky Mountain juniper. The understory is dominated by greenleaf manzanita, with Utah mountain-lilac, snowberry (Symphoricarpos oreophilus), Oregon grape (Mahonia repens [Berberis repens]), and alderleaf mountain mahogany as associated shrubs. Graminoids and forbs are less prominent, but Ross's sedge is always present, with frequent presence of gumweed aster and rock goldenrod.

SUCCESSION: Every sample plot in PONDEROSA PINE / GREENLEAF MANZANITA had evidence of fire present. Many live trees were fire scarred, many standing dead trees were charred, and charcoal was present on the ground in most plots. Certainly, recurrent understory fire is typical of PONDEROSA PINE / GREENLEAF MANZANITA. Because this type does not produce large amounts of fuel, fire intensity is probably low. Ponderosa pine is resistant to fires when past the pole stage, and probably shows little mortality as a result of these fires. Greenleaf manzanita sprouts vigorously following fire, and may increase in abundance. Snowberry will also sprout, but probably responds less vigorously than does greenleaf manzanita.

Sample plots in this type ranged in age from approximately 100 years to over 450 years. Because basal areas show no consistent trend with stand age in this type, it seems probable that after fire ponderosa pine reproduces only periodically on these sites, slowly developing an all-aged stand structure. Total stand basal area appears related more to site quality than fire history.

Community type distribution within this type is:

2 ha NULL / PONDEROSA PINE (< 6 m /ha [25 ft /acre])
7 ha PINUS FLEXILIS / PONDEROSA PINE
856 ha ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE
1005 ha PONDEROSA PINE / PONDEROSA PINE

DOUGLAS-FIR / GREENLEAF MANZANITA

PSEUDOTSUGA MENZIESII / ARCTOSTAPHYLOS PATULA
PSME / ARPA

SITE: DOUGLAS-FIR / GREENLEAF MANZANITA is also a common habitat type in, Bryce Canyon National Park occupying sites similar to PONDEROSA PINE / GREENLEAF MANZANITA, although apparently with more moisture available at lower levels in the soil horizon. DOUGLAS-FIR / GREENLEAF MANZANITA occupies about 975 hectares of area, with another 350 hectares mapped as transitional to PINYON PINE / UTAH JUNIPER (Fig. 17). Often PONDEROSA PINE / GREENLEAF MANZANITA will occur on level sites, with DOUGLAS-FIR / GREENLEAF MANZANITA occuring on adjacent hillslopes with deeper soil profiles. Elevations of sample plots range from 2245 m to 2680 m (7360 to 8800 feet), although the majority occur above 2435 m. DOUGLAS-FIR / GREENLEAF MANZANITA typically occurs on gentle to moderate slopes, with only a few sample plots on level terrain at relatively high elevations. Soils are varied, with textures from loamy skeletal to fine-textured loamy.

VEGETATION: The overstory of DOUGLAS-FIR / GREENLEAF MANZANITA is fairly open and may be dominated by either ponderosa pine or Douglas-fir (Pseudotsuga menziesii) with occasional Rocky mountain juniper. The understory is similar to that of PONDEROSA PINE / GREENLEAF MANZANITA, with dominance by greenleaf manzanita, Utah mountain-lilac, Oregon grape, and snowberry. In contrast to

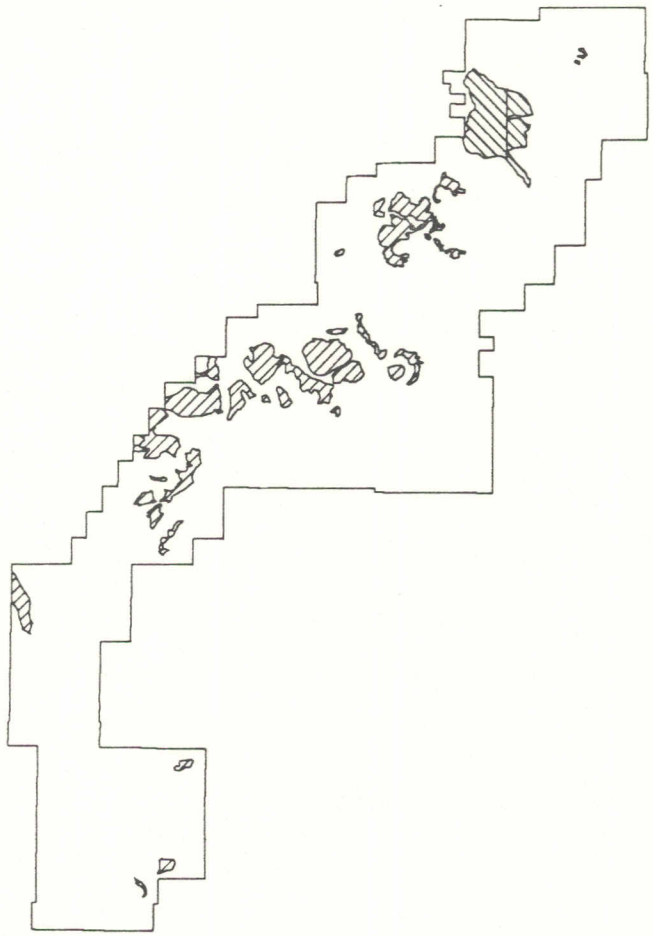


Fig. 17. Distribution of DOUGLAS-FIR / GREENLEAF MANZANITA habitat type in Bryce Canyon National Park.

DOUGLAS-FIR / GREENLEAF MANZANITA ..... ////

transition to PINYON PINE / UTAH JUNIPER ..... \\\\

PONDEROSA PINE / GREENLEAF MANZANITA, DOUGLAS-FIR / GREENLEAF MANZANITA is more likely to contain mountain lover (Pachystima myrsinites), and less likely to contain alder-leaf mountain mahogany, indicating slightly more moisture. Common graminoids and forbs include Ross's sedge, groundsel, and elkweed (Swertia radiata).

SUCCESSION: Seventeen out of eighteen sample plots exhibited evidence of fire in the form of fire-scarred standing trees, or charred down material. While Douglas-fir is not as fire tolerant as ponderosa pine, large Douglas-fir can withstand fire, and fire scarred Douglas-fir were observed. Fire probably plays a role in the type similar to that in PONDEROSA PINE / GREENLEAF MANZANITA, with periodic ground fires creeping through the understory. Given the higher moisture indicated by this type, fires may have been less frequent but more intense.

Stand ages in our sample plots range from 85 years to 400 years, typically with an all-aged stand structure. Often, ponderosa pine trees were the canopy dominants with Douglas-fir dominating the smaller size classes, and in thirteen of eighteen plots ponderosa pine was clearly older than the associated Douglas-fir. Both of these observations support a classical succession of invasion by ponderosa pine followed after time by invasion of Douglas-fir. Alternatively, moderate fire intensities would kill small Douglas-fir and leave ponderosa pine on site, followed by re-invasion of Douglas-fir. In either event, no examples of successional exclusion of ponderosa pine by Douglas-fir were observed. While Douglas-fir is more shade tolerant than ponderosa pine, most of these stands are sufficiently open that exclusion is improbable, and recurrent fires tend to favor ponderosa pine.

Community type distribution within this type is:

2 ha LIMBER PINE / PONDEROSA PINE
96 ha ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE
720 ha PONDEROSA PINE / PONDEROSA PINE
70 ha PONDEROSA PINE / DOUGLAS-FIR

DOUGLAS-FIR / OREGON GRAPE - PONDEROSA PINE

PSEUDOTSUGA MENZIESII / MAHONIA REPENS - PINUS PONDEROSA
PSME / MARE - PIPO

SITE: DOUGLAS-FIR / OREGON GRAPE - PONDEROSA PINE is a minor type (6 hectares) represented by two sample plots in Bryce Canyon National Park. Sample plots were on moderate slopes with elevations of 2540 m and 2590 m (8340 and 8500 feet), with aspects of 55 and 210 degrees respectively.

VEGETATION: Overstory vegetation in the sample plots is a mixed composition of ponderosa pine and Douglas-fir with scattered limber pine (Pinus flexilis) and quaking aspen (Populus tremuloides). White fir (Abies concolor) seedlings occur within this type, but insufficient evidence of successful fir reproduction puts these stands into the DOUGLAS-FIR series. Understory vegetation is shrubby, with dominance by Oregon grape, common juniper (Juniperus communis), mountain lover, and snowberry. Ross's sedge is the only characteristic graminoid, and forbs are sparse and variable.

SUCCESSION: Both sample plots have older ponderosa pine in the overstory which exhibit fire scars; younger Douglas-fir do not. Ages of the two stands are approximately 212 and 169 years, with the Douglas-fir aged approximately 100 years in both plots. The evidence suggests that these sites must have been subject to ground fires in the past, but that within the last 100 years

fires have been minor or absent, allowing increased reproduction of the less fire-tolerant Douglas-fir. These sites are relatively dry to support quaking aspen, so previous fires would not necessarily have favored this species. Similar to the PONDEROSA PINE / GREENLEAF MANZANITA habitat types, fires should increase the abundance of greenleaf manzanita, and may reduce coverage of other species.

Community type distributions were not estimated for this type due to limited distribution.

BLUE SPRUCE / COMMON JUNIPER

PICEA PUNGENS / JUNIPERUS COMMUNIS
PIPU / JUCO

SITE: BLUE SPRUCE / COMMON JUNIPER is a minor habitat type (55 hectares) in Bryce Canyon National Park. This type typically occupies skeletal soils at the base of slopes where cold air drainage accumulates. Elevations of sample plots are 2140 m and 2485 m (7020 and 8150 feet).

VEGETATION: Overstory vegetation is variable, with blue spruce (Picea pungens), Douglas- fir, ponderosa pine, bristlecone pine (Pinus longaeva), and quaking aspen all represented. Understory vegetation is also variable, with only snowberry, Oregon grape, Ross's sedge, and breaks draba (Draba subalpina) occuring in both sample plots. BLUE SPRUCE / COMMON JUNIPER is the only type in Bryce Canyon where kinnickinnick (Arctostaphylos uva-ursi) was observed.

SUCCESSION: Successional trends are difficult to estimate due to the relatively few areas available to sample. Both sample plots exhibit evidence of fire,including a fire scar on a standing, livivg blue spruce. These sites

typically do not produce high levels of fuel due to poor site conditions, but apparently recurrent fires do occur. Two additional observations of BLUE SPRUCE / COMMON JUNIPER were made in Bryce Canyon, both dominated by quaking aspen. From the limited evidence, it appears that following fire ponderosa pine or quaking aspen dominate early seral communities, which are then invaded by Douglas-fir or blue spruce.

WHITE FIR / GREENLEAF MANZANITA

ABIES CONCOLOR / ARCTOSTAPHYLOS PATULA
ABCO / ARPA

SITE: WHITE FIR / GREENLEAF MANZANITA is the second most common habitat type in Bryce Canyon National Park, covering over 1990 hectares in the southern end of the Park (Fig. 18). Sites are generally moderate to steep slopes with elevations from 2390 m to 2680 m (7840 to 8880 feet). Soils are variable from loamy skeletal to fine-textured loamy.

VEGETATION: The overstory is typically dominated by ponderosa pine or white fir, but may also show dominance by Douglas-fir. Limber pine and Rocky Mountain juniper may also be present in small amounts. The understory is similar to the other GREENLEAF MANZANITA types, with dominance by greenleaf manzanita, with Utah mountain-lilac, mountain-lover, snowberry, and Oregon grape as associated shrubs. Graminoids and forbs are generally sparse, with Ross's sedge and grounsel typically present in small amounts.

SUCCESSION: Eighteen of twenty-two sample plots showed clear evidence of fire, typically fire scars on standing live ponderosa pine, but also fire scars on live Douglas-fir. The evidence suggests that recurrent fires are

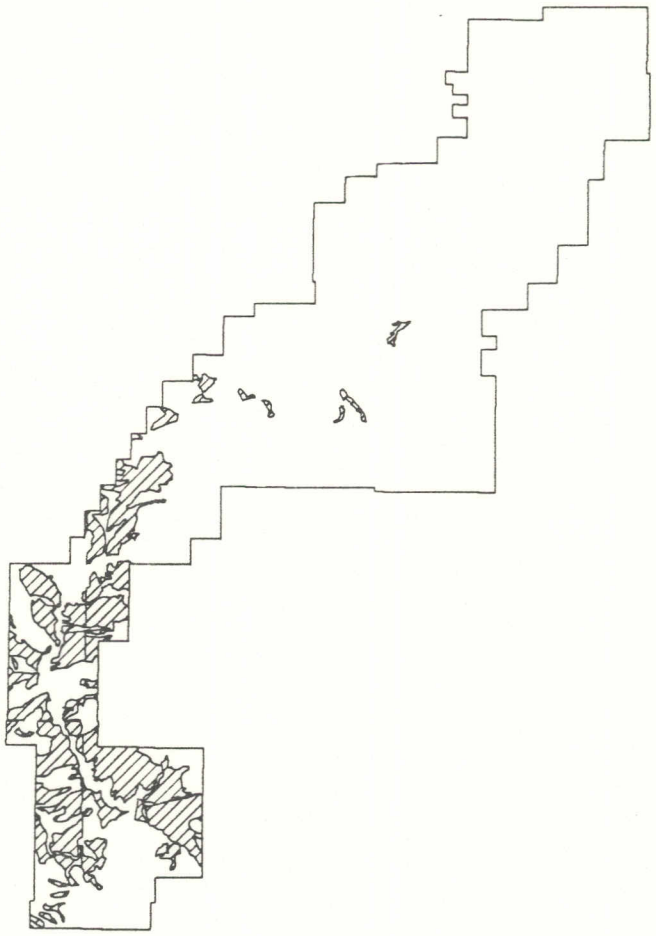


Fig. 18. Distribution of WHITE FIR / GREENLEAF MANZANITA habitat type in Bryce Canyon National Park.

typical of this vegetation type, but that fire return intervals may be somewhat longer than in the other GREENLEAF MANZANITA types. Douglas-fir is only fire tolerant as fairly large individuals, so that fire-scarred trees indicate fire after a fairly long interval in which the trees gained a large size. Stand ages of sample plots range from approximately 120 years up to approximately 350 years. Typically, ponderosa pine is the oldest tree in the stand, but surprisingly, white fir often appears to be older than Douglas-fir in the same stand, indicating that staggered invasion may have occurred, but that the species did not follow in the expected order in many cases. In almost all stands ponderosa pine is still present, if not dominant, indicating that successional replacement is rare in this type. The concequences of fire in this type would be similar to the other GREENLEAF MANZANITA types, except that small and intermediate white fir trees are likely to be removed by even moderate fire intensities. Greenleaf manzanita would undoubtedly increase in the understory following fire.

Community type distribution within this type is:

4 ha	LIMBER PINE / LIMBER PINE
19 ha	LIMBER PINE / PONDEROSA PINE
38 ha	LIMBER PINE / DOUGLAS-FIR
47 ha	LIMBER PINE / WHITE FIR
534 ha	PONDEROSA PINE / PONDEROSA PINE
258 ha	PONDEROSA PINE / DOUGLAS-FIR
813 ha	PONDEROSA PINE / WHITE FIR
14 ha	DOUGLAS-FIR / WHITE FIR

WHITE FIR / SNOWBERRY

ABIES CONCOLOR / SYMPHORICARPOS OREOPHILUS
ABCO / SYOR

SITE: WHITE FIR / SNOWBERRY is a minor type in Bryce Canyon, covering 365 hectares (Fig. 19). WHITE FIR / SNOWBERRY occupies benches and gentle slopes 2600 m (8500 feet) on Whiteman's Bench and areas nearby. Stands are typically fairly open with sparse understories.

VEGETATION: Overstories are typically mixed species, with ponderosa pine, Douglas-fir, and white fir and occasionally quaking aspen present. The understory is commonly sparse, but indicator species snowberry is usually joined by diagnostic species arrowleaf balsamroot (Balsamorhiza sagittata). Additional species include common juniper, mountain-lover, Oregon grape, and squirreltail.

SUCCESSION: We have few observations for this type, but in the sample plot both ponderosa pine and Douglas-fir exhibited fire scars.

Community type distribution within this type is:

4 ha QUAKING ASPEN / PONDEROSA PINE
18 ha QUAKING ASPEN / WHITE FIR
87 ha PONDEROSA PINE / PONDEROSA PINE
17 ha PONDEROSA PINE / DOUGLAS-FIR
198 ha PONDEROSA PINE / WHITE FIR

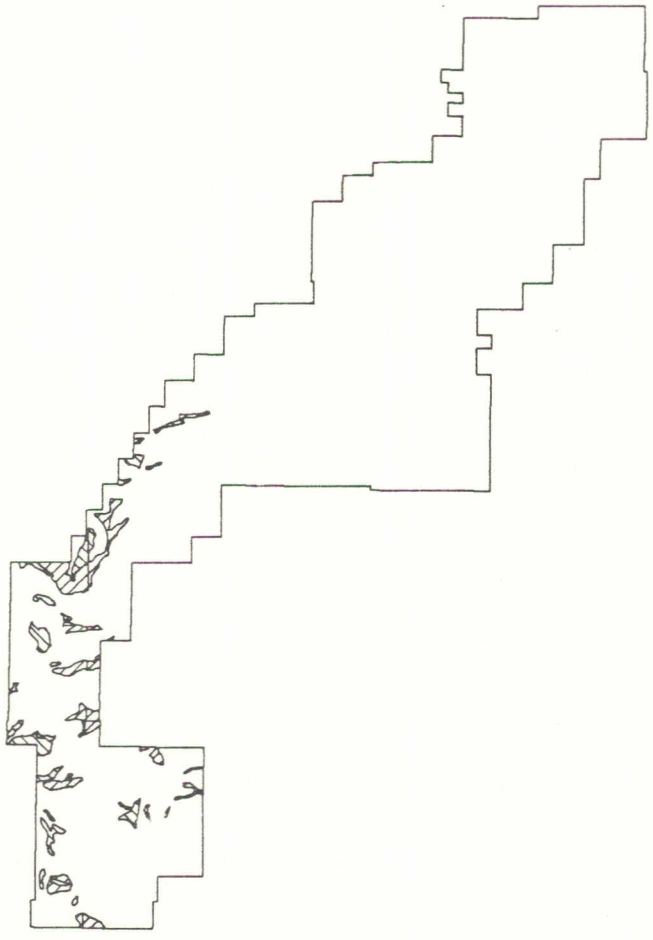


Fig. 19. Distribution of WHITE FIR / SNOWBERRY and WHITE FIR / COMMON JUNIPER habitat types in Bryce Canyon National Park.

WHITE FIR / SNOWBERRY ..... ////

WHITE FIR / COMMON JUNIPER ..... \\\\

WHITE FIR / COMMON JUNIPER

ABIES CONCOLOR / JUNIPERUS COMMUNIS
ABCO / JUCO

SITE: WHITE FIR / COMMON JUNIPER is a minor type occupying 225 hectares in the southwestern edge of the Park (Fig. 19). Plots occur on moderate slopes at elevations from 2550 m to 2645 m (8360 to 8680 feet). Soils are typically fine textured loams.

VEGETATION: Overstory composition is typically mixed ponderosa pine, Douglas-fir, and white fir, with white fir the typical dominant. The understory is typically dominated by indicator species common juniper, which is joined by mountain-lover, snowberry, and Oregon grape. Common graminoids and forbs include Ross's sedge and weedy milkvetch (Astragalus miser).

SUCCESSION: In comparison to most areas in Bryce Canyon, WHITE FIR / COMMON JUNIPER shows relatively little evidence of fire; two sample plots show limited evidence, and two show no evidence. In the sample plots white fir was usually dominant, showing a relatively low incidence of fire. Additionally, common juniper is very fire sensitive and easily removed by even moderate fires. Given the strong dominance of common juniper in the understory, fire appears much less common in this type than in most of the others. Alternatively, this type supports many of the quaking aspen community types in the Park, indicating that fires did occur in the past.

Community type distribution within this type is:

7 ha QUAKING ASPEN / QUAKING ASPEN
15 ha QUAKING ASPEN / PONDEROSA PINE
2 ha QUAKING ASPEN / DOUGLAS-FIR
31 ha QUAKING ASPEN / WHITE FIR
47 ha PONDEROSA PINE / PONDEROSA PINE
18 ha PONDEROSA PINE / DOUGLAS-FIR
98 ha PONDEROSA PINE / WHITE FIR
2 ha DOUGLAS-FIR / WHITE FIR

WHITE FIR / OREGON GRAPE

ABIES CONCOLOR / MAHONIA REPENS
ABCO / MARE

SITE: WHITE FIR / OREGON GRAPE is the moistest habitat type in Bryce Canyon, and consists of two phases: OREGON GRAPE and COMMON JUNIPER, covering 295 hectares and 168 hectares respectively (Fig. 20). WHITE FIR / OREGON GRAPE occupies relatively high elevation sites with abundant moisture. Elevations of sample plots range from 2510 m to 2735 m (8240 to 8980 feet), and occur generally on moderate slopes with west to east aspects. Soils are generally fine-textured loams.

VEGETATION: The overstory is a mixed composition of ponderosa pine, Douglas-fir, and white fir, joined occasionally by quaking aspen or limber pine. The understory composition of the two phases is similar, with increased dominance of common juniper in the COMMON JUNIPER phase. Both phases have mountain-lover, snowberry, and oregon grape as typical shrubs, with Ross's sedge and weedy milkvetch in addition.

SUCCESSION: Most of the sample plots have fire scars on standing live trees, typically ponderosa pine or Douglas-fir, but including white fir. In most cases, the white fir is well over a hundred years old, indicating infrequent

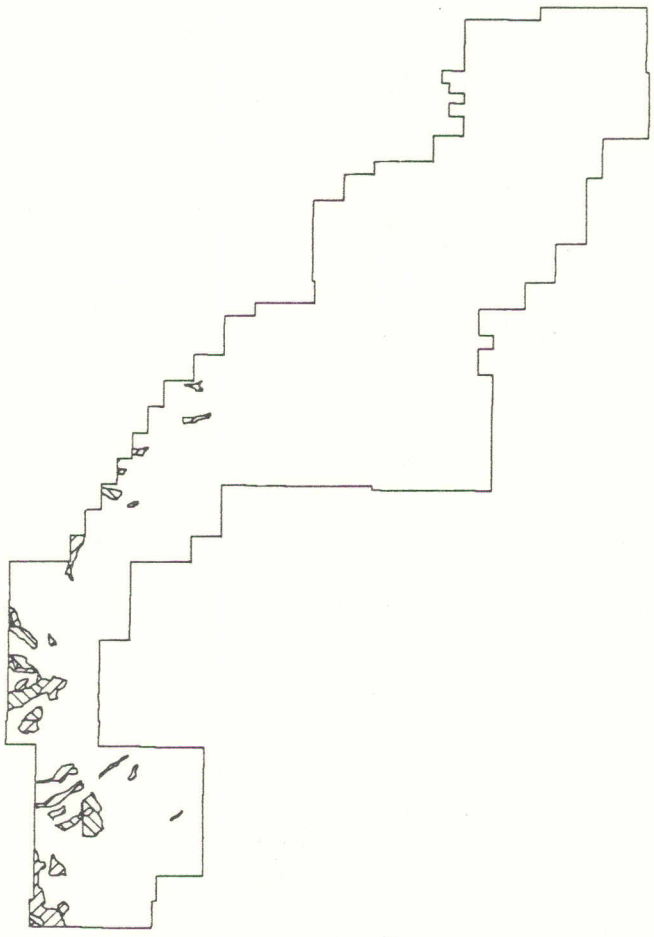


Fig. 20. Distribution of WHITE FIR / OREGON GRAPE habitat type in Bryce Canyon National Park.

WHITE FIR / OREGON GRAPE - OREGON GRAPE ..... ////

WHITE FIR / OREGON GRAPE - COMMON JUNIPER ..... \\\\

fires, which nevertheless scar some of the long-lived trees. This type is relatively moist, and should have less frequent, but more intense fires. These sites are relatively exposed to lightning, however, and many of the fire scarred trees may have been struck by lightning without starting a large ground fire.

Community type distribution within this type is:

6 ha QUAKING ASPEN / QUAKING ASPEN
21 ha QUAKING ASPEN / PONDEROSA PINE
12 ha QUAKING ASPEN / DOUGLAS-FIR
19 ha QUAKING ASPEN / WHITE FIR
3 ha LIMBER PINE / LIMBER PINE
8 ha LIMBER PINE / PONDEROSA PINE
60 ha LIMBER PINE / DOUGLAS-FIR (only COMMON JUNIPER phase)
146 ha LIMBER PINE / WHITE FIR (mostly OREGON GRAPE phase)
55 ha PONDEROSA PINE / PONDEROSA PINE
20 ha PONDEROSA PINE / DOUGLAS-FIR
186 ha PONDEROSA PINE / WHITE FIR
49 ha DOUGLAS-FIR / WHITE FIR

ADDITIONAL HABITAT TYPES

The habitat types presented above were all subject to detailed sampling. In the course of sampling for determining the distribution of each habitat type a small number of other types was encountered. The most significant of the areas not subject to detailed sampling are the Gambel oak habitat types. Examples of DOUGLAS-FIR / GAMBEL OAK, and WHITE FIR / GAMBEL OAK were both found within the boundaries of Bryce Canyon National Park.

In the extreme southern end of the Park aproximately 400 hundred hectares of WHITE FIR / GAMBEL OAK occur along the southern and easten boundaries of the Park. These communities are typically associated with alluvial deposits along stream courses. In contrast to the PONDEROSA PINE / GAMBEL OAK communities, these communities are typically associated with WHITE FIR / GREENLEAF MANZANITA communities, rather than PINYON PINE / UTAH JUNIPER communities. DOUGLAS-FIR / GAMBEL OAK occupied a relatively small area (ca. 150 hectares) in the central and southern portions of the Park, occupying sites similar to, but slightly drier than, WHITE FIR / GAMBEL OAK.

BREAKS

We did not sample within the breaks or hoodoos themselves. This area was subject to a vegetation survey by Graybosch and Buchanan (1983) who provide a detailed analysis of the communities which occur. Graybosch and Buchanan (1983) recognized six community types within the breaks: (1) Ponderosa pine - greenleaf manzanita, (2) ponderosa pine - greenleaf manzanita, alderleaf mountain mahogany, (3) ponderosa pine - Douglas-fir, (4) mixed conifer type, blue spruce phase, (5) mixed conifer type, white fir phase, and bristlecone pine type. Their ponderosa pine - greenleaf manzanita type is

similar to, but more heterogeneous than, the PONDEROSA PINE / GREENLEAF MANZANITA type described here. In addition to the typical species of PONDEROSA PINE / GREENLEAF MANZANITA, they included samples with Gambel oak, Oregon grape, Utah mountain-lilac. Their ponderosa pine - greenleaf manzanita, alderleaf mountain mahogany type occurs as stringers adjacent to the more typical ponderosa pine - greenleaf manzanita type, and is dominated by alderleaf mountain mahogany and Utah serviceberry (Amelanchier utahensis). The ponderosa pine - Douglas-fir community is co-dominated by ponderosa pine, Douglas-fir and limber pine, with greenleaf manzanita and Oregon grape in the undergrowth. Again, this type is similar to, but more heterogeneous than the DOUGLAS-FIR / GREENLEAF MANZANITA type described here, particularly in including mesic species such as mountain maple (Acer glabrum). The two phases of mixed conifer described by Graybosch and Buchanan (1983) appear variable, but somewhat similar to BLUE SPRUCE / COMMON JUNIPER and WHITE FIR / COMMON JUNIPER, with the addition of alderleaf mountain mahogany and curlleaf mountain mahogany (Cercocarpus ledifolius).

COMMUNITY TYPES OF BRYCE CANYON NATIONAL PARK

Bryce Canyon National Park covers a fairly large range of potential vegetation types, each of which may be subjected to disturbances which produce different community type (or seral stages) within the habitat type. Surprisingly, the more xeric habitat types in Bryce Canyon appear relatively homogeneous as to community type, and exist typically in later successional stages. The more mesic forested types exhibit a much broader range of community types within a habitat type, reflecting perhaps a more frequent disturbance regime or a greater length of time these types take to return to later seral stages.

Specifically, we were unable to consistently distinguish community types within the CORYMB BUCKWHEAT / SALINA WILDRYE, BIG SAGEBRUSH / FOURWING SALTBUSH, PINYON PINE / UTAH JUNIPER, AND BLACK SAGE / NEEDLE-AND-THREAD habitat types due to a lack of variety in successional communities to sample. Acccordingly, in these types the community type is the same as the habitat type.

Figure 21 presents the key to community types recognized for Bryce Canyon. The drier forested types generally have fewer possible community types because of the relatively fewer number of tree species adapted to grow on these dry sites. Table 4 presents a list of the most common community types in Bryce Canyon National Park, and Table 5 presents a cross-reference of the area for each combination of the common habitat types and community type.

KEY FOR COMMUNITY TYPES IN BRYCE CANYON

1) key stands out to habitat type first

2) estimate basal area by species

3) key out community type
   3.1) check minimum basal area
   3.2) check list of indicator species in order, stop at the first step that is true
   3.3) determine the dominant species (highest basal area)

PONDEROSA PINE / BLACK SAGEBRUSH

if BA < 25 ft/ac ..... NULL/PONDEROSA PINE
if BA > 25 ft/ac .....PONDEROSA PINE / PONDEROSA PINE

PONDEROSA PINE / BITTERBRUSH

if BA < 30 ft/ac ..... NULL/dominant
if BA > 30 ft/ac
  if Rocky Mountain juniper present
    ROCKY MOUNTAIN JUNIPER / dominant
  if only ponderosa pine present
    PONDEROSA PINE / PONDEROSA PINE

PONDEROSA PINE / GREENLEAF MANZANITA

if BA < 25 ft/ac ..... NULL/dominant
if BA > 25 ft/ac
  if limber pine present ..... LIMBER PINE / dominant
  if Rocky Mountain Juniper present
    ROCKY MOUNTAIN JUNIPER / dominant
  if only ponderosa pine present
    PONDEROSA PINE / PONDEROSA PINE

DOUGLAS-FIR / GREENLEAF MANZANITA

if BA < 25 ft/ac ..... NULL/dominant
if BA > 25 ft/ac
  if limber pine present ..... LIMBER PINE / dominant
  if ponderosa pine present .. PONDEROSA PINE / PONDEROSA PINE
  if Rocky Mountain juniper present
    ROCKY MOUNTAIN JUNIPER / dominant
  if only Douglas-fir present ..... DOUGLAS-FIR / DOUGLAS-FIR

DOUGLAS-FIR / OREGON GRAPE

if BA < 50 ft/ac ..... NULL/dominant
if BA > 50 ft/ac
  if quaking aspen present ..... QUAKING ASPEN / dominant
  if limber pine present ..... LIMBER PINE / dominant
  if ponderosa pine present ..... PONDEROSA PINE / dominant
  if only Douglas-fir present ..... DOUGLAS-FIR / DOUGLAS-FIR

Fig. 21. Key to community types for common habitat types in Bryce Canyon National Park.

```
BLUE SPRUCE / COMMON JUNIPER
          if BA < 50 ft/ac ..................................... NULL/dominant
          if BA > 50 ft/ac
               if quaking aspen present ..... QUAKING ASPEN / dominant
               if limber pine present ..... LIMBER PINE / dominant
               if ponderosa pine present ..... PONDEROSA PINE / dominant
               if Douglas-fir present ..... DOUGLAS-FIR / dominant
               if only blue spruce present ..... BLUE SPRUCE / BLUE SPRUCE

WHITE FIR / GREENLEAF MANZANITA
          if BA < 40 ft/ac ..................................... NULL/dominant
          if BA > 40 ft/ac
               if limber pine present ..... LIMBER PINE / dominant
               if ponderosa pine present ..... PONDEROSA PINE / dominant
               if Douglas-fir present ..... DOUGLAS-FIR / dominant
               if Rocky Mountain juniper present
                                        ROCKY MOUNTAIN JUNIPER / dominant
               if only white fir present ..... WHITE FIR / WHITE FIR

WHITE FIR / COMMON JUNIPER
          if BA < 50 ft/ac ..................................... NULL/dominant
          if BA > 50 ft/ac
               if quaking aspen present ..... QUAKING ASPEN / dominant
               if limber pine present ..... LIMBER PINE / dominant
               if ponderosa pine present ..... PONDEROSA PINE / dominant
               if Douglas-fir present ..... DOUGLAS-FIR / dominant
               if Rocky Mountain juniper present
                                        ROCKY MOUNTAIN JUNIPER / dominant
               if only white fir present ..... WHITE FIR / WHITE FIR

WHITE FIR / OREGON GRAPE - OREGON GRAPE
          if BA < 50 ft/ac ..................................... NULL/dominant
          if BA > 50 ft/ac
               if quaking aspen present ..... QUAKING ASPEN / dominant
               if limber pine present ..... LIMBER PINE / dominant
               if ponderosa pine present ..... PONDEROSA PINE / dominant
               if Douglas-fir present ..... DOUGLAS-FIR / dominant
               if only white fir present ..... WHITE FIR / WHITE FIR

WHITE FIR / OREGON GRAPE - COMMON JUNIPER
          if BA < 50 ft/ac ..................................... NULL/dominant
          if BA > 50 ft/ac
               if quaking aspen present ..... QUAKING ASPEN / dominant
               if limber pine present ..... LIMBER PINE / dominant
               if ponderosa pine present ..... PONDEROSA PINE / dominant
               if Douglas-fir present ..... DOUGLAS-FIR / dominant
               if blue spruce present ..... BLUE SPRUCE / dominant
               if only white fir present ..... WHITE FIR / WHITE FIR
```

Fig. 21 (cont.). Key to community types for common habitat types in Bryce Canyon National Park. See previous page for instructions.

Table 4. Common community types in Bryce Canyon National Park.

community type	hectares	
PONDEROSA PINE / PONDEROSA PINE	4011 ha	9912 ac.
PINYON PINE / UTAH JUNIPER	3040 ha	7512 ac.
ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE	1849 ha	4569 ac.
PONDEROSA PINE / WHITE FIR	1555 ha	3842 ac.
BLACK SAGEBRUSH / NEEDLE-AND-THREAD	768 ha	1898 ac.
PONDEROSA PINE / DOUGLAS-FIR	534 ha	1320 ac.
PONDEROSA PINE / GAMBEL OAK	269 ha	665 ac.
		29,718 ac.

Relatively few of the possible community types account for the vast majority of the area of the Park. The six most common community types cover approximately 80% of the area of the Park; none of the remaining types covers individually more than 2%. The common community types are presented below.

Also, several community types are discussed because they are of interest despite, or because of, their relative minimal coverage. Specifically, the quaking aspen community types are discussed, as are the late seral or climax types on mesic or moist sites.

PONDEROSA PINE / PONDEROSA PINE

PONDEROSA PINE / PONDEROSA PINE is by far the most common community type, covering an area of over 4000 hectares (Fig. 22). This community type can occur in a large number of habitat types, and was the most common community type in four habitat types. Generally, this type reflects short to moderate fire return intervals across these habitat types. On the dry end of the

Table 5. Cross reference of common community types and habitat types in Bryce Canyon National Park. Figures are given in hectares as determined by the Boolean function routine of program WINDOWS.

HABITAT TYPES	COMMUNITY TYPES			
	ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE	PONDEROSA PINE / PONDEROSA PINE	PONDEROSA PINE / DOUGLAS-FIR	PONDEROSA PINE / WHITE FIR
PONDEROSA PINE / BITTERBRUSH	137	160	0	0
PONDEROSA PINE / GREENLEAF MANZANITA	856	1005	0	0
DOUGLAS-FIR / GREENLEAF MANZANITA	96	720	70	0
WHITE FIR / GREENLEAF MANZANITA	33	584	258	813
WHITE FIR / SNOWBERRY	0	87	17	198
WHITE FIR / COMMON JUNIPER	0	2	18	98
WHITE FIR / OREGON GRAPE-OREGON GRAPE	0	47	17	131
WHITE FIR / OREGON GRAPE-COMMON JUNIPER	0	0	4	56

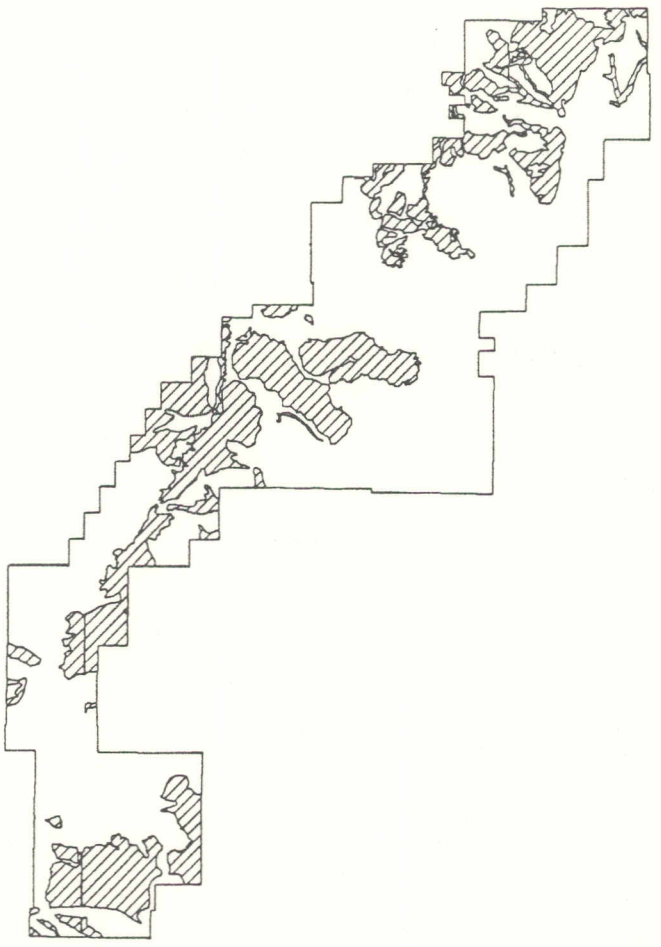


Fig. 22. Distribution of community type PONDEROSA PINE / PONDEROSA PINE in Bryce Canyon National Park

moisture gradient where this type occurs, Rocky Mountain juniper would be a component of stands which did not burn. On the more moist end of the same gradient, Douglas-fir or white fir would be the expected dominant species in the absence of fire. In particular, the area of PONDEROSA PINE / PONDEROSA PINE community type in the WHITE FIR / GREENLEAF MANZANITA and WHITE FIR / OREGON GRAPE habitat types reflects recurrent fire favoring ponderosa pine over white fir.

PINYON PINE / UTAH JUNIPER

PINYON PINE / UTAH JUNIPER community type is the second most common community type, with an area of approximately 3000 hectares (Fig. 23). In general, as the PINYON PINE / UTAH JUNIPER habitat type was not divided into community types, this simply reflects the large area of land covered by this habitat type, as well as some dry sites in the PONDEROSA PINE / GREENLEAF MANZANITA habitat type.

ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE

The ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE community type occurs in relatively warm, dry forested sites, covering an area of over 1800 hectares (Fig. 24). Our sample plots in this community type typically contained evidence of fire, despite the fact that Rocky Mountain Juniper is killed easily by fire. Apparently, in these relatively open stands fuel loads are generally low enough that fires are spotty and of low intensity, so that some individuals of Rocky Mountain juniper survive the fire.

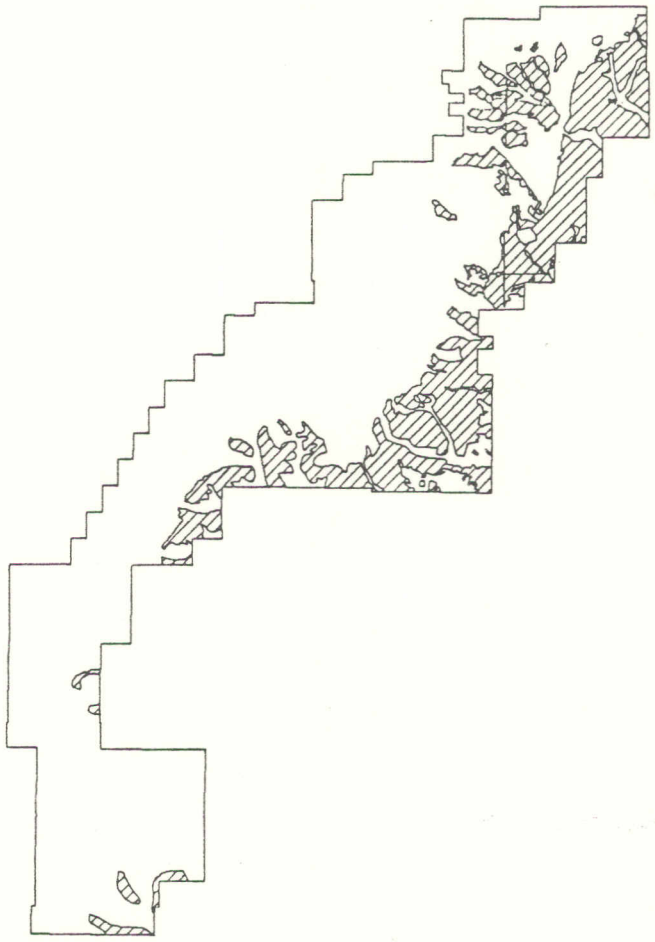


Fig. 23. Distribution of community type PINYON PINE / UTAH JUNIPER in Bryce Canyon National Park.

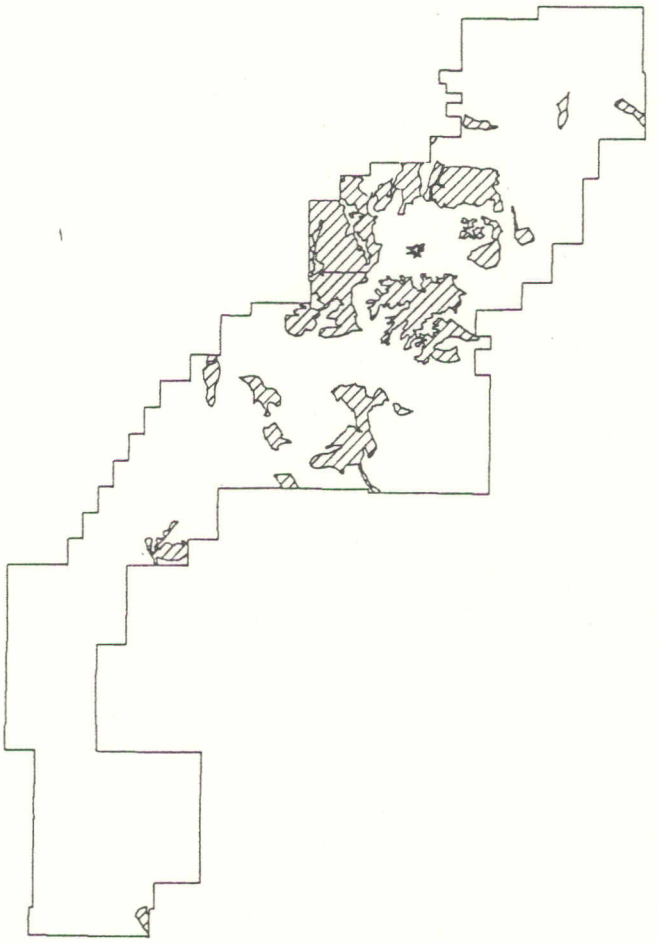


Fig. 24. Distribution of community type ROCKY MOUNTAIN JUNIPER / PONDEROSA PINE in Bryce Canyon National Park.

PONDEROSA PINE / WHITE FIR

The PONDEROSA PINE / WHITE FIR community type covers an area of about 1500 hectares, primarily in the southern end of the Park (Fig. 25). The PONDEROSA PINE / WHITE FIR community type is particularly interesting. By definition, this community type can only occur on sites moist enough to support white fir, and so represents some of the more moist sites in Bryce Canyon National Park. These areas are communities where ponderosa pine occurs in the overstory, typically as large individual trees, but where the dominant species is white fir. This pattern suggests a great deal about fire history in the Park. First, the fact that ponderosa pine is still present in moderate numbers on sites potentially dominated by white fir indicates at least moderate fire intensities in the past. Productivity, and fuel production, is sufficiently high on these sites that low intensity fires are less probable. Second, the fact that these sites are dominated by white fir rather than ponderosa pine indicates that fire return intervals are long enough to allow white fir to establish in high numbers and grow to moderate size between fires. While this scenario is certainly possible, a more probable scenario is that historically these sites were dominated by ponderosa pine under moderate fire return intervals, and that the current dominance of white fir is attributable to fire suppression over the last 100 years.

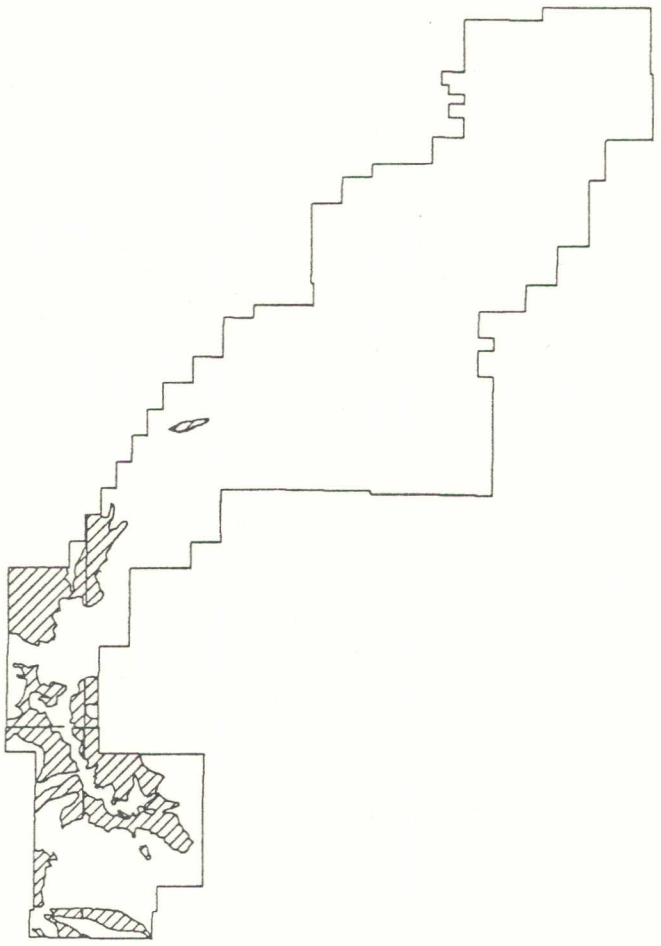


Fig. 25. Distribution of community type PONDEROSA PINE / WHITE FIR in Bryce Canyon National Park.

BLACK SAGE / NEEDLE-AND-THREAD

This community type is essentially identical to the BLACK SAGE / NEEDLE-AND-THREAD habitat type, which was not differentiated into community types. As noted in the type description, however, there are some data on the response of this community to burning. A small area in the east creek drainage was burned in 1984 to increase prairie dog habitat. In this site black sagebrush was severely reduced or removed by burning. Although no pre-burn data were available, it appears that viscid rabbitbrush has increased significantly after the burn, and may now have greater coverage than black sagebrush did before the fire. In some areas fringed sagebrush also appears to have increased. Other species typical of the burned area are blue flax (Linus perenne), pale agoseris (Agoseris glauca), Uinta groundsel (Senecio multilobatus), and Sandberg bluegrass (Poa sandbergii).

PONDEROSA PINE / DOUGLAS-FIR

The PONDEROSA PINE / DOUGLAS-FIR community type typically represents mid-seral communities on sites potentially dominated by white fir. Surprisingly little area was found where this community type occurred as a late-seral type on areas potentially dominated by Douglas-fir. The implication is that while Douglas-fir habitat types are more moist than ponderosa pine habitat types, they are still sufficiently dry that fires occur with sufficient frequency to favor ponderosa pine. Consequently, Douglas-fir does best as a mid-seral species on more moist sites in the white fir series. PONDEROSA PINE / DOUGLAS-FIR currently occupies over 500 hectares.

QUAKING ASPEN / VARIOUS

Quaking aspen community types represent a fairly small area of Bryce Canyon National Park (Fig 26). Judging from the distribution of habitat types in the Park, approximately 750 hectares of the Park could theoretically support quaking aspen. Currently, only approximately 215 hectares actually support quaking aspen, and only 35 hectares are dominated by aspen. Typically, sites moist enough to support quaking aspen are also moist enough to support closed canopies of more shade tolerant conifers. Accordingly, in the absence of fire quaking aspen will be shaded out and lost from these stands. There are sites with rocky soils which also support quaking aspen and which do not typically support fully closed canopies, but these sites are fairly restricted in distribution. Accordingly, to maintain or expand quaking aspen in the Park fire in the most mesic types will be required. These fires will typically kill most of the conifers present except for ponderosa pine, and should create enough light to regenerate quaking aspen stems from the existing root systems.

DOUGLAS-FIR / DOUGLAS-FIR

This community type represents sites where Douglas-fir is the climax dominant, or sites moist enough for white fir where Douglas-fir is currently dominant. Currently, this community type covers only about eighteen hectares. This limited distribution reflects two factors. The first factor is the relative rareness of climax Douglas-fir sites in Bryce Canyon National Park (about 1320 hectares). The second factor is the prevalence of fire which

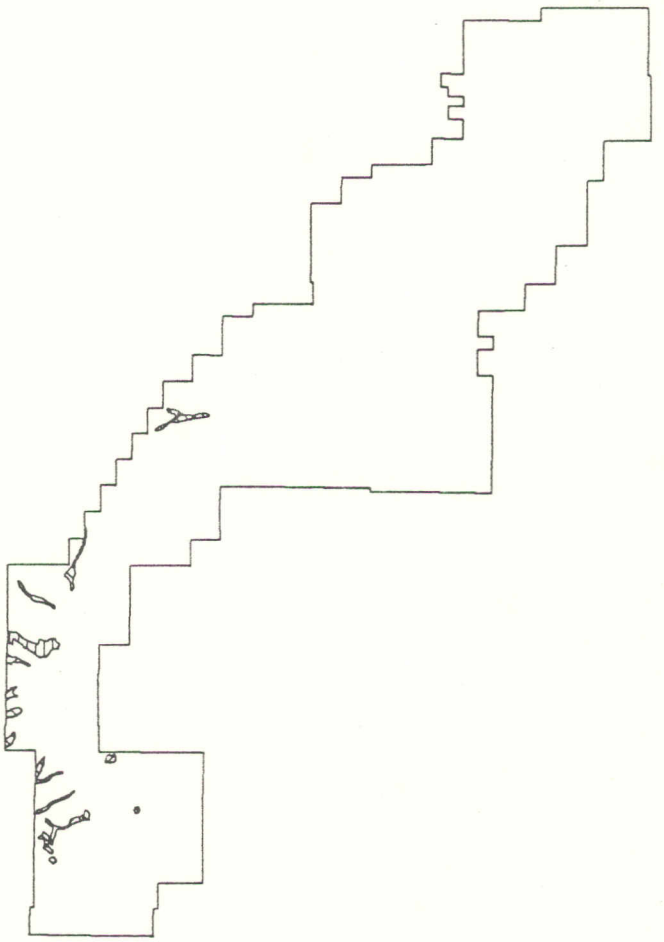


Fig. 26. Distribution of community types with quaking aspen as the indicator species.

QUAKING ASPEN / QUAKING ASPEN ..... ////

QUAKING ASPEN / PONDEROSA PINE ..... ||||

QUAKING ASPEN / WHITE FIR ..... \\\\

favors ponderosa pine.

As soil moisture availability increases, sites go from climax ponderosa pine to climax Douglas-fir, to climax white fir. In Bryce Canyon National Park, the climax Douglas-fir zone is very narrow, with white fir occupying surprisingly dry sites. On sites moist enough for white fir, in the absence of fire Douglas-fir is out-competed by white fir which becomes dominant. Thus, throughout the zone of potential DOUGLAS-FIR / DOUGLAS-FIR community type distribution most of the undisturbed sites are dominated by white fir.

With fire, ponderosa pine is the favored species on both climax Douglas-fir sites and climax white fir sites. Since, historically, fire was common throughout the forests of Bryce Canyon, ponderosa pine has dominated Douglas-fir on most sites moist enough to support Douglas-fir.

WHITE FIR / WHITE FIR

The WHITE FIR / WHITE FIR community type represents climax stands on the wettest forest sites in Bryce Canyon National Park. While one detailed sample plot did key to WHITE FIR / WHITE FIR, we did not map a single hectare of this type, despite a total potential area of approximately 3080 hectares. Again, this reflects two factors.

The first is that stands only key to this type if they are pure white fir. Even in the absence of fire, the competitive exclusion of all other species by white fir infrequently, despite the widespread occurrence of strong dominance by white fir.

The second factor is again fire. Throughout the white fir series, almost all sites show evidence of fire within the lifespan of the existing trees. This ubiquitous occurrence of fire again favors ponderosa pine or Douglas-fir

over white fir, and minimizes the occurrence of climax white fir stands.

VEGETATION MAPPING

Using the ground-truth and extrapolating procedures outlined in the methods section, we developed detailed maps of the habitat types (potential natural vegetation) and community types (current vegetation) for all of Bryce Canyon National Park. Resolution of types is approximately 2 hectares, although in areas with abundant ground truth patches as small as 0.5 hectare are delineated if practical.

For each of the seven USGS 1:24000 quadrangle maps which cover Bryce Canyon National Park we prepared a separate mylar overlay for habitat type, community type, and soil type. Each map type was color coded, with black lines for habitat type, green lines for community type, and red lines for soil class so that all mylar overlays could be superimposed to study co-distribution. The habitat type maps are submitted as plates 1A-7A, the community types as 1B-7B, and the soil type maps as 1C-7C for quadrangles Bryce Canyon, Tropic Canyon, Tropic Reservoir, Bryce Point, Cannonville, Podunk Creek, and Rainbow Point respectively.

After preparation of the mylar overlays, each map was digitized into a format suitable for SAGIS. The POLYDRAW program employed enabled hand digitizing with no slivers, using a digitizing resolution of 0.020 inches, corresponding to a ground resolution of about 15 m.

Because of the shape of Bryce Canyon National Park and the resolution of color graphics terminals and printers, the quadrangle maps were combined into regional maps and edge-matched. Specifically, separate habitat type, community type, and soil type maps were prepared for: (1) the northern region, consisting of the Bryce Canyon and Tropic Canyon quads, (2) the central region, consisting of the Tropic Reservoir, Bryce Point, and Cannonville

quads, and (3) the southern region, consisting of the Podunk Creek and Rainbow Point quads.

To enable an overview, the regional maps were combined by theme (habitat type, community type, and soil type) into maps of the entire Park. The files for these maps are large, and detail is not readily evident. Finally, to enable comparisons, the Park-wide maps of habitat type and community type were pooled into a single file for use with program WINDOWS. This program enables Boolean analyses of joint distribution.

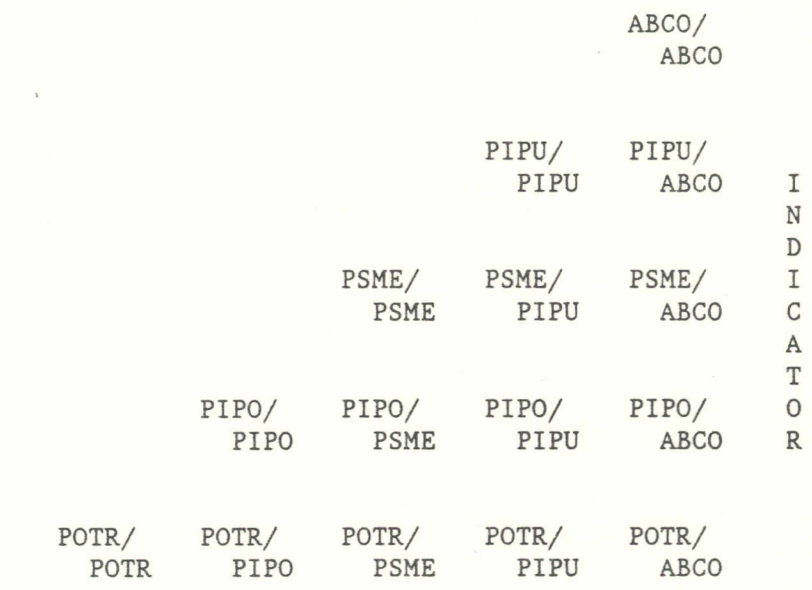
The plates and computer files are not included with all copies of this report. However, extracts of the computer maps are included as figures 11-20 and 22-26 in the presentation of habitat and community types. Appendix F provides the list of file names for the SAGIS files.

VITAL ATTRIBUTES SUCCESSION MODEL

The vital attributes model developed for Bryce Canyon is shown in the following example simulating successional development and disturbance response on the WHITE FIR / OREGON GRAPE habitat type. The community potentially consists of conifers ponderosa pine, Douglas-fir, white fir, and blue spruce, with angiosperm quaking aspen. Typical successional sequences begin with ponderosa pine or quaking aspen (depending on site history), and procede to mixed compositions of douglas-fir and white fir. Possible community types include those shown in Figure 27. Table 6 presents the vital attributes of th species as coded for the model. The conifers all reproduce from wind-dispersed seed; quaking aspen reproduces vegetatively. The shade-tolerance relation progresses from quaking aspen and ponderosa pine, to Douglas-fir, blue spruce, and white fir in order of increasing tolerance. Due to thick bark and a habit of self-pruning lower branches, ponderosa pine is generally fire resistant in mid to large diameters. Douglas-fir is moderately fire resistant in large diameters.

All simulations begin with early seral stands of quaking aspen in age classes from 10 to 40 years. Quaking aspen is assumed to have 80 years of carbohydrate storage for sprouting. The conifer species are assumed to have an available seed source. Simulated stands begin with 40 years fuel accumulation. Fire severity classes are reached at 20, 40, 60, 80, and 100 years for classes 1, 2, 3, 4, and 5 respectively.

Six simulations were run with mean fire return intervals of 25, 50, 100, 250, 500 years, and absence of fire. One hundred replicates were run for each fire return interval.



POTR = Populus tremuloides = quaking aspen
PIPO = Pinus ponderosa = ponderosa pine
PSME = Pseudotsuga menziesii = Douglas-fir
PIPU = Picea pungens = blue spruce
ABCO = Abies concolor = white fir

Fig. 27. Successional pyramid for community types in the WHITE FIR / OREGON GRAPE habitat type. The row of the pyramid is determined by the least shade-tolerant species present, called the indicator species. The column is determined by the dominant species (highest basal area).

Table 6. Vital attributes for species in Bryce Canyon National Park. These attributes are employed in the simulation model to determine the successional development and disturbance response in Bryce Canyon National Park forest communities.

Species	longevity	age of reproduction	shade tolerance	fire tolerance	method of reproduction
quaking aspen	140	10	2	0	vegetative
ponderosa pine	400	40	2	4	seed
Douglas-fir	300	40	3	3	seed
blue spruce	400	40	4	0	seed
white fir	300	40	5	0	seed

Species Abundance

Figures 28-30 present examples of the species mean abundance trajectories for three of the six fire return intervals simulated. In the absence of fire (Fig. 28), the model predicts a simple successional development from pure quaking aspen to pure white fir in about 450 years. In the absence of fire, the only stochastic element is the reproduction of species in a particular time step, and the results may be considered a charicature of Clementsian succession. The model assumes within-community homogeneity, and is incapable of simulating gap-phase relacements.

Introducing fire with a mean fire return interval of 500 years significantly affects the successional trajectory (Fig. 29). While white fir remains the dominant species, its relative abundance is reduced throughout the entire simulation. More importantly, where in the absence of fire all other species became locally extinct within 500 years, with a 500 year fire return interval no species go locally extinct. With a longevity of 140 years and a maximum of 130 years of carbohydrate storage, some communities burn often enough to maintain quaking aspen even on a 500 year mean fire return interval.

Halving the fire return interval to 250 years results in a reduced abundance of white fir after 130 years, with a generally increased abundance of all other species, particularly ponderosa pine and Douglas-fir. The composition is similar to a mixed-conifer forest composition on mesic sites.

At a mean fire return interval of 100 years a qualitatively different result is obtained (Fig. 30). Ponderosa pine emerges as the dominant species throughout most of the simulation period, followed by Douglas-fir and then white fir. With mean fire return intervals of 100 years or less,

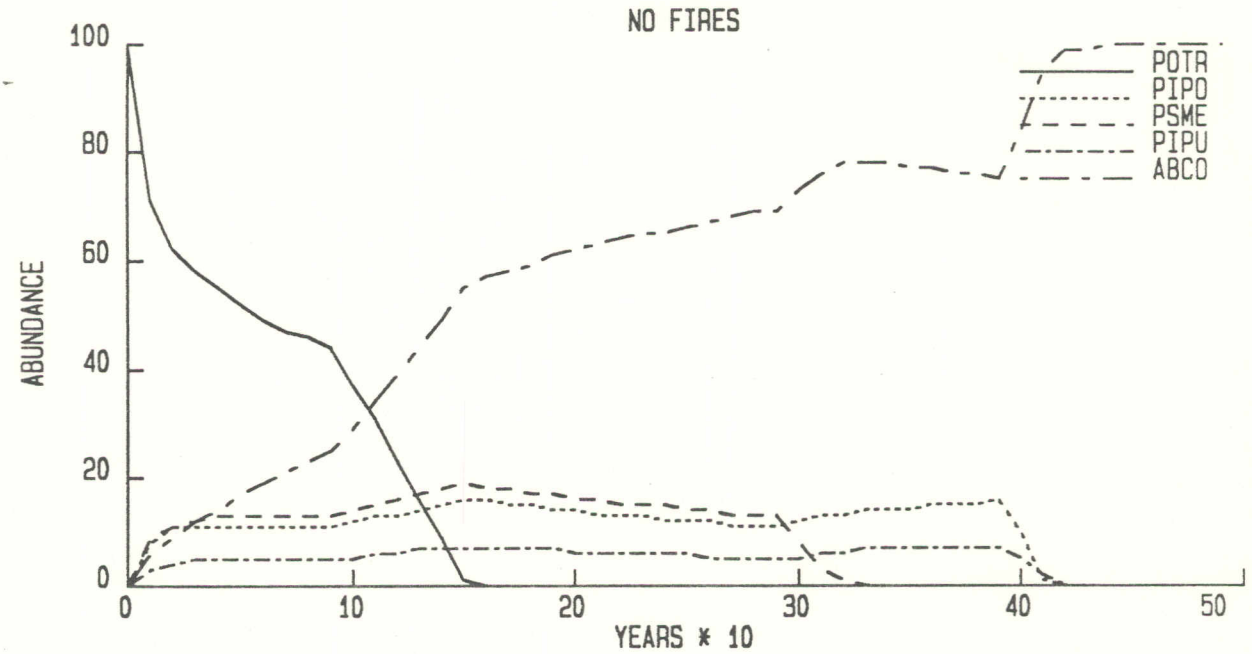


Fig. 28. Trajectory of species mean abundances over a 500 year simulation period. Initial stand is pure quaking aspen, and simulation shows successional development in the absence of fire.

POTR = Populus tremuloides = quaking aspen

PIPO = Pinus ponderosa = ponderosa pine

PSME = Pseudotsuga menziesii = Douglas-fir

PIPU = Picea pungens = blue spruce

ABCO = Abies concolor = white fir

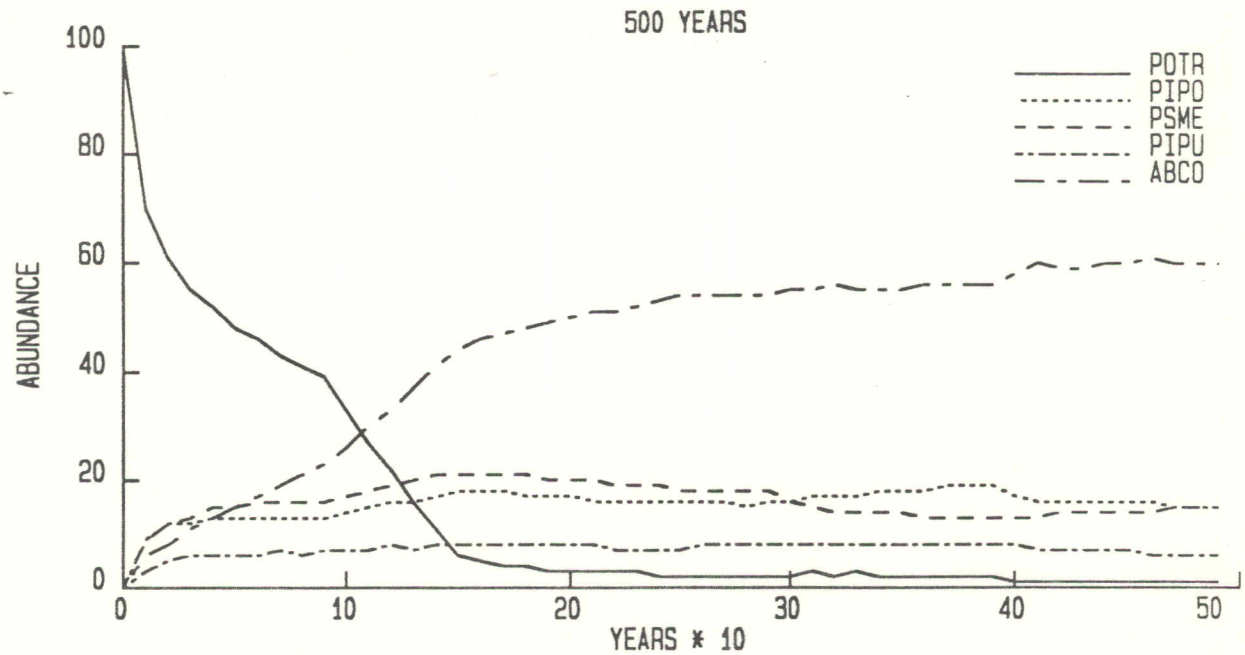


Fig. 29. Trajectory of species mean abundances over a 500 year simulation period. Initial stand is pure quaking aspen, and simulation shows successional development and disturbance response to fires occurring on an 500 year mean fire return interval.

POTR = Populus tremuloides = quaking aspen

PIPO = Pinus ponderosa = ponderosa pine

PSME = Pseudotsuga menziesii = Douglas-fir

PIPU = Picea pungens = blue spruce

ABCO = Abies concolor = white fir

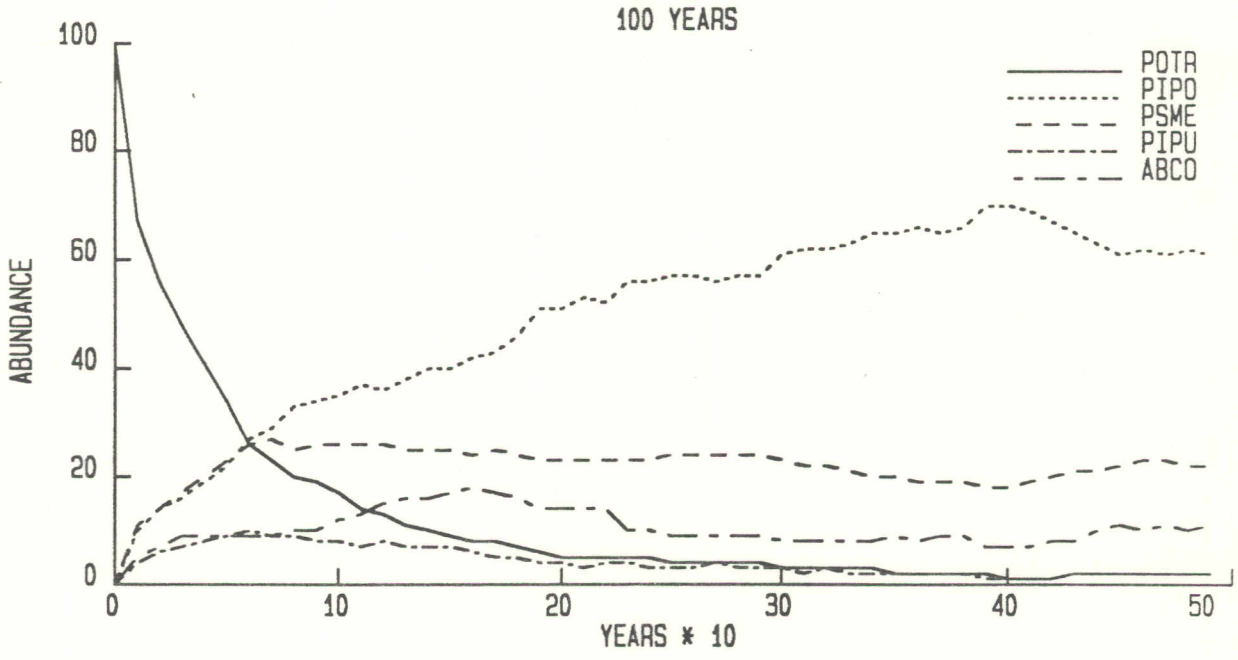


Fig. 30. Trajectory of species mean abundances over a 500 year simulation period. Initial stand is pure quaking aspen, and simulation shows successional development and disturbance response to fires occurring on a 100 year mean fire return interval.

POTR = Populus tremuloides = quaking aspen

PIPO = Pinus ponderosa = ponderosa pine

PSME = Pseudotsuga menziesii = Douglas-fir

PIPU = Picea pungens = blue spruce

ABCO = Abies concolor = white fir

fire-tolerance is more important than shade-tolerance in determining abundance.

Cutting the fire return interval to 50 years leads to a clear dominance of ponderosa pine with Douglas-fir of secondary importance, and white fir reduced to minimal importance. blue spruce goes locally extinct after about 350 years. Quaking aspen is absent for intervals of about 40 years, but continues to sprout under favorable conditions

Further decreasing the fire return interval to 25 years results in a further increase in the relative abundance of ponderosa pine at the expense of Douglas-fir. Other species have only minimal importance.

Community Type Membership Distribution

Of the fifteen possible community types only six occur with a high abundance (membership values > 0.20) during the simulations. Three of the types have quaking aspen present as the least shade-tolerant species (QUAKING ASPEN / QUAKING ASPEN, QUAKING ASPEN / PONDEROSA PINE, and QUAKING ASPEN / WHITE FIR), two have ponderosa pine present as least shade-tolerant (PONDEROSA PINE / PONDEROSA PINE and PONDEROSA PINE / WHITE FIR), and one type is pure white fir (WHITE FIR / WHITE FIR). Of the six types, quaking aspen is most abundant in one type (QUAKING ASPEN / QUAKING ASPEN), ponderosa pine is most abundant in two (PONDEROSA PINE / PONDEROSA PINE and QUAKING ASPEN / PONDEROSA PINE) and white fir is most abundant in three (QUAKING ASPEN / WHITE FIR, PONDEROSA PINE / WHITE FIR, and WHITE FIR / WHITE FIR).

Community type distributions are strongly affected by the simulated fire regimes, showing quantitative and qualitative changes determined by the underlying species dynamics. Figures 31-33 show examples of community type

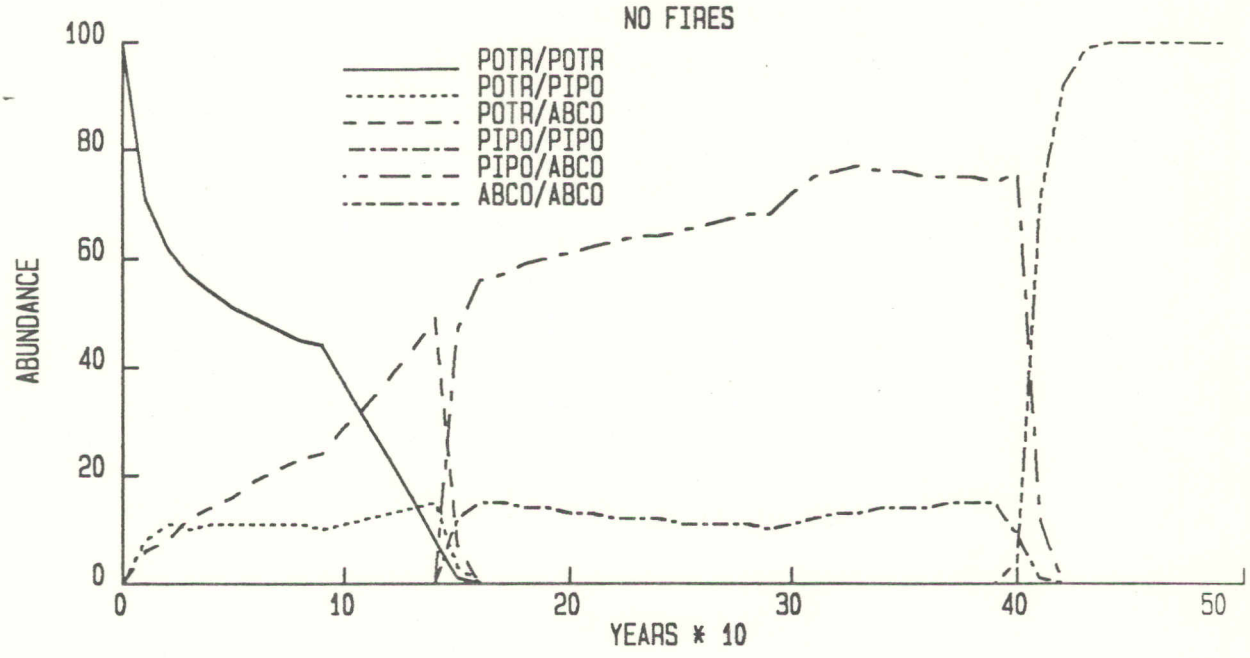


Fig. 31. Trajectory of six common community types over a 500 year simulation period. Initial stand is pure quaking aspen / quaking aspen. Simulation shows successional development in the absence of fire.

POTR/POTR = quaking aspen / quaking aspen

POTR/PIPO = quaking aspen / ponderosa pine

POTR/ABCO = quaking aspen / white fir

PIPO/PIPO = ponderosa pine / ponderosa pine

PIPO/ABCO = ponderosa pine / white fir

ABCO/ABCO = white fir / white fir

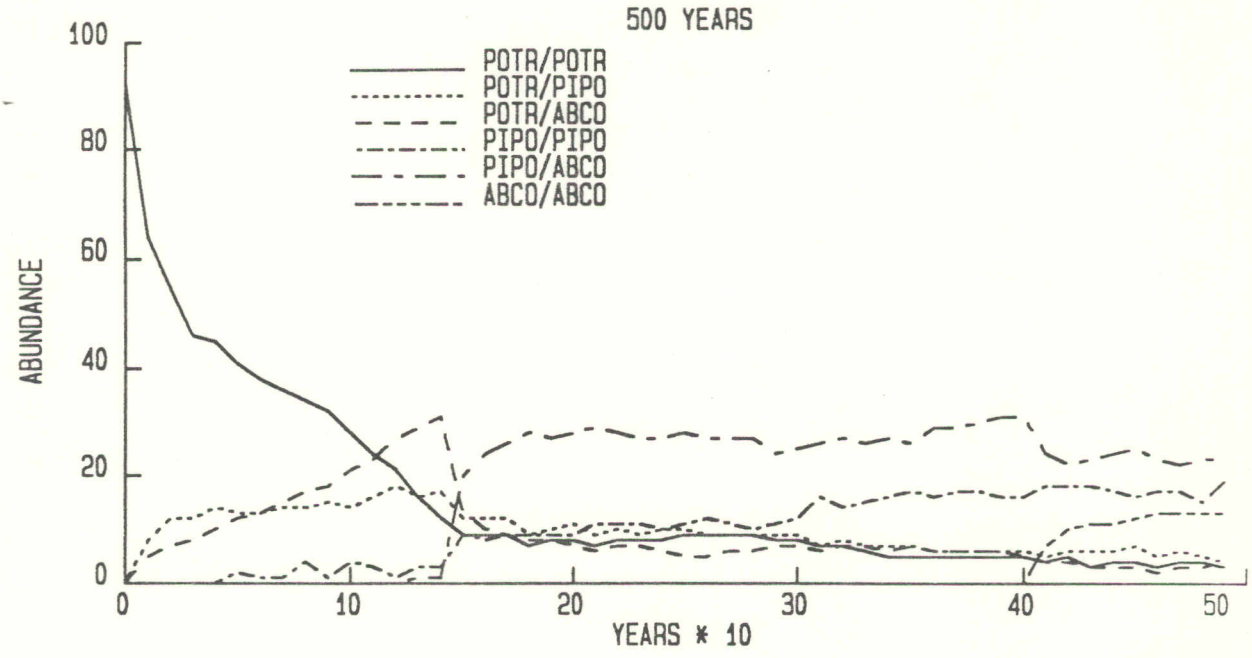


Fig. 32. Trajectory of six common community types over a 500 year simulation period. Initial stand is pure quaking aspen / quaking aspen. Simulation shows successional development and disturbance response to fires occuring on a 500 year mean fire return interval.

POTR/POTR = quaking aspen / quaking aspen

POTR/PIPO = quaking aspen / ponderosa pine

POTR/ABCO = quaking aspen / white fir

PIPO/PIPO = ponderosa pine / ponderosa pine

PIPO/ABCO = ponderosa pine / white fir

ABCO/ABCO = white fir / white fir

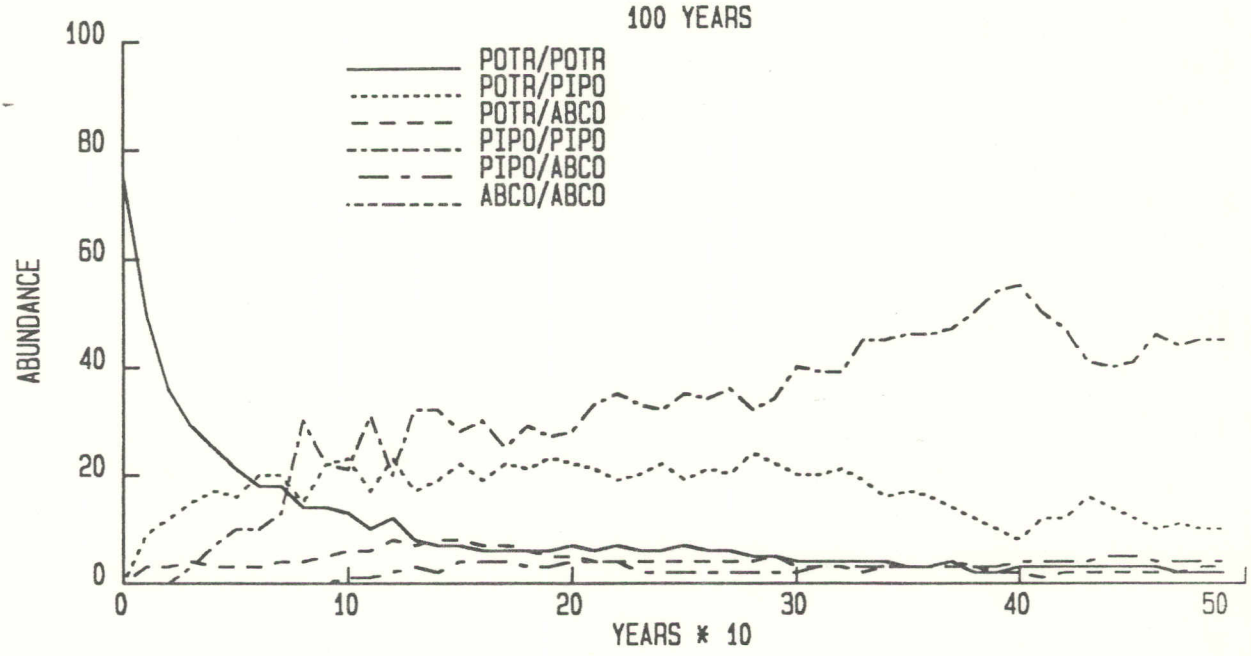


Fig. 33. Trajectory of six common community types over a 500 year simulation period. Initial stand is pure quaking aspen / quaking aspen. Simulation shows successional development and disturbance response to fires occuring on a 500 year mean fire return interval.

POTR/POTR = quaking aspen / quaking aspen

POTR/PIPO = quaking aspen / ponderosa pine

POTR/ABCO = quaking aspen / white fir

PIPO/PIPO = ponderosa pine / ponderosa pine

PIPO/ABCO = ponderosa pine / white fir

ABCO/ABCO = white fir / white fir

dynamics for three of the six simulated fire return intervals.

In the absence of fire, QUAKING ASPEN / QUAKING ASPEN (the initial type) rapidly declines, losing dominance after 100 years, and becomes absent at about 160 years (Fig. 31). After a brief dominance by QUAKING ASPEN / WHITE FIR from years 100 to 150, dominance shifts to PONDEROSA PINE / PONDEROSA PINE for a period of over 300 years. In the absence of fire ponderosa pine fails to reproduce, however, and dominance shifts to WHITE FIR / WHITE FIR at about 410 years. Generally, only two or three community types occur simultaneously throughout the simulation.

With a fire return interval of 500 years, a much more subtle and complex pattern of community types appears (Fig. 32). QUAKING ASPEN / QUAKING ASPEN again declines rapidly as species other than quaking aspen increase, but remains at low levels throughout the 500 year simulation. While most of the simulation is dominated by the PONDEROSA PINE / WHITE FIR community type, at least five community types are present at all times.

Decreasing the fire return interval to 250 years leads rapidly to a nearly equitable distribution of all community types except WHITE FIR / WHITE FIR which nevers occurs in simulations with fire return intervals shorter than 500 years.

Decreasing the fire return interval again to 100 years results in a qualitative shift (Fig. 33). After only 70 to 80 years, PONDEROSA PINE / PONDEROSA PINE becomes dominant, and maintains that dominance throughout the entire simulation period. QUAKING ASPEN / PONDEROSA PINE is the secondary dominant. Reducing the return interval to 50 or 25 years merely amplifies the same pattern

Diversity

Mean diversity was calculated for each time steo for each of the six fire return intervals (Fig. 34). Because all simulations started off with a mono-specific stand of few age classes, diversity in all simulations starts off low and increases for a period of approximately 100 years, as other species begin to invade the single species community. The maximum diversity attained differs, however, and the pattern of diversity following the initial increase is distinct for each fire return interval.

In the absence of fire, diversity increases to moderate levels at about 120 years, and then begins a steady decline, reaching zero at the mono-specific climax attained in about year 460. Introducing fires with return intervals of about 500 to 250 years leads to the maximum observed diversity, and the diversity is maintained at a steady high value throughout the simulation period. Reducing the fire return interval to 100, 50 or 25 years leads to progesssively lower maximum diversities, with repsectively lower maintained diversities as well.

Sensitivity Analysis

The model was analyzed for sensitivity at each of six fire return intervals according to three criteria: individual species abundance, community type membership distribution, and diversity. Tables 7-9 present the results of the sensitivity analysis for these three criteria respectively.

Sensitivity of species relative abundance

Significant trends are evident when analysing the sensitivity of individual species abundance (Tab. 7). At short fire return intervals, the model is extremely sensitive to the fire tolerance ratings given to the

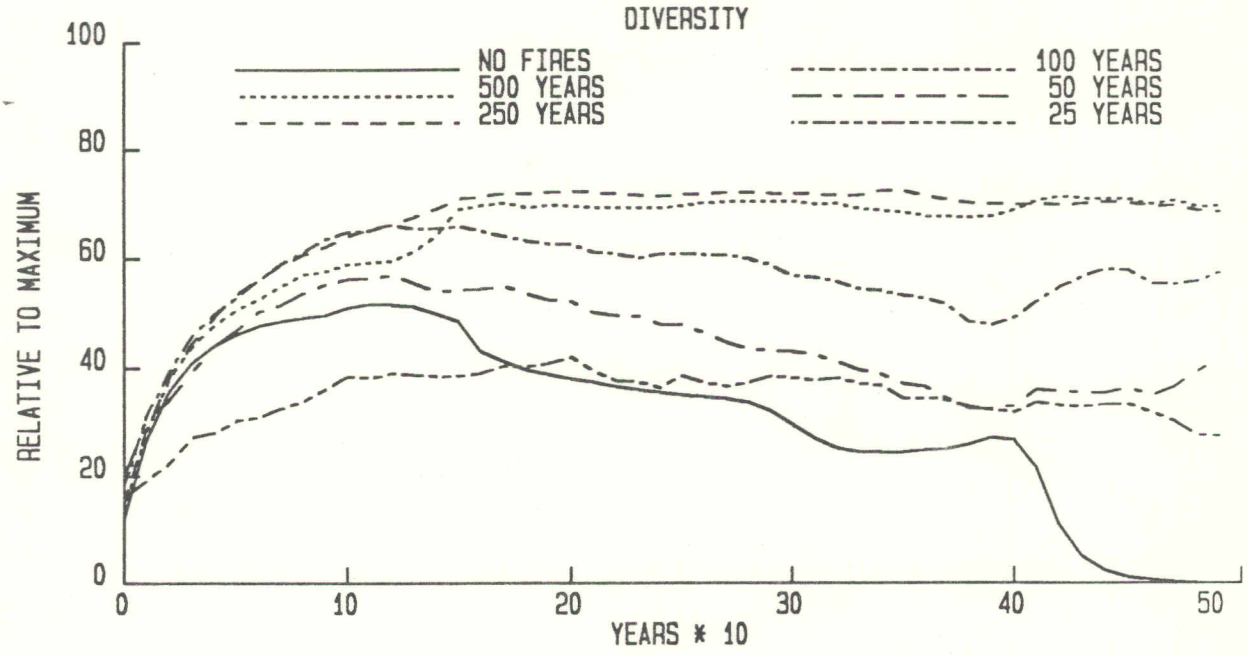


Fig. 34. Trajectory of community diversity for a 500 year simulation period under six different fire regimes. Initial stand is pure quaking aspen in all simulations. Simulations vary only in the mean fire return interval, varying from no fires to fires every 25 years.

Table 7. Sensitivity of species abundances in simulation model to changes in vital attributes for six fire regimes. See text for description of sensitivity analysis.

	FIRE REGIME					
VITAL ATTRIBUTE	25	50	100	250	500	none
longevity	0.2	0.4	0.0	0.0	0.2	0.6
shade tolerance	0.4	0.4	0.4	0.4	0.6	0.4
age of reproduction	0.0	0.0	0.0	0.0	0.0	0.0
fire tolerance	1.0	1.0	0.8	0.4	0.0	0.0

Table 8. Sensitivity of community type abundances in simulation model to changes in vital attributes for six fire regimes. See text for description of sensitivity analysis.

	FIRE REGIME					
VITAL ATTRIBUTE	25	50	100	250	500	none
longevity	0.00	0.33	0.20	0.13	0.33	0.46
shade tolerance	0.40	0.53	0.60	0.73	0.80	0.66
age of reproduction	0.26	0.06	0.06	0.00	0.06	0.00
fire tolerance	0.60	0.73	0.73	0.60	0.33	0.00

Table 9. Sensitivity of species abundances in simulation model to changes in vital attributes for six fire regimes. See text for description of sensitivity analysis.

	FIRE REGIME					
VITAL ATTRIBUTE	25	50	100	250	500	none
longevity	0	0	0	0	0	1
shade tolerance	0	0	0	0	0	1
age of reproduction	0	0	0	0	0	0
fire tolerance	1	1	0	0	0	0

species. Increasing or decreasing the fire-tolerance of individual species leads to significant differences in species abundance up to fire return intervals as long as 250 years. This is a reflection of the relative survivorship of mature trees through frequent fires which reduce the available fuel load and never achieve high intensity. Additionally, the most fire-tolerant species are relatively shade-intolerant, and changing the fire-tolerance of more shade-tolerant species leads to the removal of these species due to shading.

The model is moderately sensitive to the shade-tolerance rankings at all fire return intervals. The lack of interaction of shade-tolerance and fire return interval is interesting in light of the strong variation in relative effects of fire-tolerance and shade-tolerance at different fire return intervals.

The sensitivity of the model to maximum age of species shows a bimodal distribution with respect to fire frequency. At short fire return intervals, the longevity of the fire-tolerant species affects the relative abundance of species. At long fire return intervals, the longevity of shade-intolerant species affects the relative abundances following the relatively infrequent disturbances.

Sensitivity of community type membership

With respect to community type membership, in contrast to the species abundance criterion, the model appears most sensitive to shade-tolerance, rather than fire-tolerance (Tab. 8). Also, the sensitivity to shade-tolerance shows a stronger relation to fire return interval, being relatively more sensitive at longer intervals. At long fire return intervals, increasing the shade tolerance of relatively intolerant species (or reducing the tolerance of

the most tolerant species) results in ties for maximum shade tolerance, leading in turn to communities co-dominated by more than one species. Alternatively, at short fire return intervals, increasing the tolerance of shade-intolerant species allows them to regenerate beneath the canopy of mature fire-tolerant species which normally suppress them.

The distribution of community type membership is moderately sensitive to changes in longevity, and generally insensitive to changes in age of first reproduction except at very short fire return intervals.

Sensitivity of Diversity

In contrast to the sensitivity measures for species abundance and community type, the measure of sensitivity for diversity is relatively crude, being measured on a binary scale rather than a numeric scale (Tab. 9). In general, the measure of community diversity appears most sensitive to fire-tolerance at short fire return intervals and longevity or shade tolerance only in the absence of fire.

Model Behavior

The objective is not to find the most computationally-efficient model, but rather the most parsimonious ecological model suitable for simulation. The model appears to largely meet this objective. Using the best-guess estimates of species vital attributes, the model generates realistic patterns of community composition dynamics under a variety of disturbance regimes.

Evaluating the species abundance results and sensitivity analyses in an ecological sense, the model identifies critical ecological characteristics for survival and dominance in environments of varying disturbance regime. In rarely disturbed environments, tolerance of competition and the ability to

reproduce in competitive conditions eventually confers competitive superiority. In these conditions, age of first reproduction is relatively unimportant compared to longevity. In frequently-disturbed environments, disturbance-tolerance will over-compensate for poor competitive ability and confer dominance. Surprisingly, the model did not identify an early age of reproduction as important in frequently disturbed environments. However, the range of ages considered and the level of modification were both fairly small and may not have been sufficient to exhibit a significant difference.

Calculating the community type classification from the pyramid also proved useful. Because the community types are determined in a simple quantitative manner, the classification algorithm can be directly incoporated into the simulation model. By calculating and plotting the community types as well as species a great deal of information about community composition can be determined. Species which are co-dominant in mean outputs could each occur in single species stands in different replicates, or in mixed species stands during all replicates. Calculating the community types during each replicate distinguishes these conditions simply without maintaining a wealth of detail on each simulation. Additionally, a fair amount of information about community structure can also be inferred. Knowing the shade-tolerance relations of the species, the overstory/understory characteristics of the community types present can be determined approximately.

The relatively higher sensitivity values for community types as opposed to species suggests that in some cases the mean species abundances were insensitive to modifications of vital attributes while community compositions were not. This in turn implies a greater between-replicate variability when modifying these traits.

Finally, calculating diversity on the basis of community type abundance distributions provided interesting insights on the role of disturbance in forest communities. The model makes clear that maximum diversity is attained under moderate disturbance regimes which allow disturbance-sensitive species to reach large populations but which still produce conditions for reproduction of shade-intolerant species. Interestingly, maximum diversity is attained with mean fire return intervals of roughly the same order as the longevity of most of the species. Either the absence of disturbance or too frequent disturbance reduces diversity. The model is too simple to simulate gap phase replacement within communities and thus underestimates the diversity of "climax" stands, but the general trend of diversity with disturbance is probably not affected by this underestimation.

With respect to disturbance response, the model is too simplified for direct comparison to more detailed conceptual models. There is no consideration of moisture or nutrient availability following disturbance, for example. The disturbance considered by the model results in direct mortality of individual age classes of species, and controls the severity of subsequent disturbances. The model's prediction of highest diversity under intermediate disturbance regimes agrees with the conceptual model presented by Denslow (1985) who reviewed the role of disturbance periodicity and severity in determining community diversity for a wide range of communities.

COMPARISON TO BRYCE CANYON NATIONAL PARK COMMUNITY TYPES

The simulation model outputs can be compared to the existing community type distributions for mesic sites in Bryce Canyon National Park. On these sites, the existing community type distribution shows a dominance of PONDEROSA

PINE / WHITE FIR community types followed by PONDEROSA PINE / PONDEROSA PINE. This distribution agrees well with a predicted fire return interval between 100 and 250 years. The sample plots in these moist sites typically show evidence of fire within the lifespan of the existing trees, with maximum ages of several hundered years. Qualitatively, the agreement is good. Second, the model predicts that WHITE FIR / WHITE FIR community types will not exist with fire return intervals as long as 500 years. This agrees with the absence of this community type noted previously. Finally, the model predicts fairly low abundance of quaking aspen community types under most fore regimes. Again, this appears to agree well with the limited distribution of quaking aspen community types even on these relatively moist sites.

While a more rigorous validation of the model is desirable, the fit of the model to the available data and the qualitative analysis of model behavior are both encouraging. Code for the simulation model is included as appendix C.

DISTRIBUTION OF RARE PLANTS

Of the thirty-two candidate rare or endangered species identified in Kane or Garfield County, six were listed for Bryce Canyon National Park by Buchanan and Graybosch (1981) or Graybosch and Buchanan (1983). Of these six, we have observed two in Bryce Canyon National Park: Paria breadroot (Pediomelum pariense Welsh & Atwood [= Psoralea pariensis Welsh & Atwood]) and tushar paintbrush (Castilleja parvula var. revealii (N. Holmgren) Atwood).

Paria breadroot was observed in six locations on the rim of the breaks south of Paria View. A detailed study and map of the habitat to Paria breadroot was undertaken and is presented in Appendix E.

Paria breadroot was found in the PONDEROSA PINE / GREENLEAF MANZANITA and WHITE FIR / GREENLEAF MANZANITA habitat types. In the PONDEROSA PINE / GREENLEAF MANZANITA habitat type, most plots were currently in the PONDEROSA PINE / PONDEROSA PINE community type, with one plot in the ROCKY MOUNTAIN JUNIPER / ROCKY MOUNTAIN JUNIPER COMMUNITY TYPE. Plots in the WHITE FIR / GREENLEAF MANZANITA habitat types were in the ROCKY MOUNTAIN JUNIPER / DOUGLAS-FIR and PONDEROSA PINE / PONDEROSA PINE community types. Generally, these last two sites are early seral with little development of the climax species.

Paria breadroot typically occurs in a community dominated by greenleaf manzanita, with Ross's sedge also typically present. Associated species included Oregon grape, squirreltail, Indian ricegrass, Fendler sandwort (Arenaria fendleri), stemless woolybase (Hymenoxys acaulis), and rock goldenrod.

From an analysis of the habitat requirements of Paria breadroot and the successional development of the sample plots, Hallsten and Roberts (Appendix E) believe that future successional development which leads to more closed canopies may jeopordize the populations of Paria breadroot. The best populations of Paria breadroot appear in sites with low total basal area.

Tushar paintbrush was observed twice: once outside the Park adjacent to the Park boundary, and once within the Park. The first population was observed in the upper reaches of a side drainage of Dave's hollow (T36S, R4W, NE1/4,SE1/4 S 26) on eroded red limestone. Associated vegetation was bristlecone pine and limber pine, in the PIFL/PILO habitat type.

The second population was observed out in open rolling terrain on the red beds east of Queen's Garden. Orienteering difficulties prevent citing a more specific location for this population, and a map was not prepared.

Similar to Paria breadroot, Tushar paintbrush appears to avoid areas where successional development has permitted closed canopies. However, the site where we observed Tushar paintbrush were so severe that development of closed canopies is very unlikely in any case.

Tushar paintbrush maybe more common in Bryce Canyon National Park than we observed. Typically, this species occupies harsh xeric sites where its phenology must develop rapidly in the spring. It is subsequently often dried up and indiscernable by the time the typical field season begins in mid-June.

DISTRIBUTION OF UNDISTURBED PLANT COMMUNITIES

Depsite the presence of late seral community types throughout Bryce Canyon National Park, we observed no areas suitable for preservation as research natural areas. Areas below the rim often had evidence of trepass grazing in the recent past. Sites above the rim often had numerous stumps from timber cutting during the current stand development. Thus, despite the fact that early successional community types were absent in some habitat types, suitable undisturbed communities were not observed. This assessment was shared with and confirmed by field ecologists from the Nature Reserve Heritage Program (Van Pelt, personal communication). Apparently, the relatively recent declaration of Bryce Canyon National Park, coupled with the long narrow shape and high perimeter to area ratio has made undisturbed areas rare.

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APPENDIX A

Common name to scientific name translations for all known species in Bryce Canyon National Park. Common names and scientific nomenclature follow Welsh et al. 1987.

Abajo daisy	Erigeron abajoensis
African mustard	Malcolmia africana
alcove goldenrod	Solidago sparsiflora
alderleaf mountain mahogany	Cercocarpus montanus
alfalfia	Medicago sativa
alkali saccaton	Sporobolus airoides
alpine bistort	Polygonum viviparum
American brookline	Veronica americana
American vetch	Vicia americana
Anderson larkspur	Delphinium andersonii var.scaposum
annual monkey-flower	Mimulus rubellus
antelope bitterbrush	Purshia tridentata
Apache plume	Fallugia paradoxa
Arizona thistle	Cirsium arizonicum var. nidulum
Arizona thistle	Cirsium arizonicum
arrowleaf balsamroot	Balsamorhiza sagittata
asparagus	Asparagus officinalis
Baker cryptanth	Cryptantha bakeri
ball-head gilia	Gilia congesta
basin saltbrush	Atriplex gardneri var. tridentata
bastard toad flax	Commandra umbellata
beach dock	Rumex salicifolius
beaded sedge	Carex rostrata
beaked spikerush	Eleocharis rostellata
bear daisy	Erigeron ursinus
Bebb willow	Salix bebbiana
big sagebrush	Artemisia tridentata
bigtooth maple	Acer grandidentatum
bindweed	Convolvulus arvensis
black creeper sedge	Carex praegracilis
black groundsel	Senecio atratus
black sagebrush	Artemisia nova
Blazing star	Mentzelia multiflora var. multiflora
Bloomer ricegrass	Stipa x Bloomeri
blue Jacob's ladder	Polemonium caeruleum
blue elderberry	Sambucus coerulea
blue flax	Linum perenne
blue grama	Bouteloua gracilis
blue lettuce	Lactuca tatarica
blue spruce	Picea pungens
blue violet	Viola adunca
blue wildrye	Elymus glacus
blue-eyed grass	Sisyrinchium demissum

bluebells of Scotland	Campanula rotundifolia
bluebunch wheatgrass	Elymus spicatus
blueleaf aster	Aster glaucodes
bracken fern	Pteridium aquilinum
breaks bladderpod	Lesquerella rubicundula
breaks draba	Draba subalpina
breaks pussytoes	Antennaria rosulata
Bridges evening-primrose	Oenothera longissima
Bridges penstemon	Penstemon rostriflorus
bristlecone pine	Pinus longaeva
broom flax	Linum aristatum
broom groundsel	Senecio spartioides
broom snakeweed	Gutierrezia sarothrae
bull thistle	Cirsium vulgare
busy knotweed	Polygonum ramosissimum
Cainville thistle	Cirsium calcareum var. pulchellum
Canada bluegrass	Poa compressa
Canada wildrye	Elymus canadensis
carruth wormwood	Artemisia carruthii
Cedar Breaks goldenbush	Haplopappus zionis
chamisso arnica	Arnica chamissonis
cheatgrass	Bromus tectorum
chickweed	Stellaria jamesiana
chokecherry	Prunus virginiana
claretcup	Echinocereus triglochidiatus
cliffrose	Purshia mexicana
coast goldenrod	Solidago spathulata
Colorado columbine	Aquilegia caerulea
Colorado rubberweed	Hymenoxys richardsonii
Columbia needlegrass	Stipa nelsonii
common horehound	Marrubium vulgare
common juniper	Juniperus communis
common paintbrush	Castilleja chromosa
common pussytoes	Antennaria parvifolia
common sunflower	Helianthus annuus
corymb buckwheat	Eriogonum corymbosum
creeping nailwort	Paronchyia sessiliflora
creeping phlox	Phlox condensata
creeping spearwort	Ranunculus flammula
creeping spikerush	Eleocharis palustris
cresent milkvetch	Astragalus amphioxys
crested wheatgrass	Agropyron cristatum
crownbeard	Verbesina encelioides
curleaf mountain mahogany	Cercocarpus ledifolius
curled dock	Rumex crispus
curly gumweed	Grindelia squarrosa
cutleaf groundsel	Senecio cymbalarioides
cutleaf nightshade	Solanum triflorum
cutleaf water-parsnip	Berula erecta
dandelion	Taraxacum officinale
dense cress	Lepidium densiflorum

Desert parsley	Lomatium kingii var. alpinum
desert phlox	Phlox austromontana
dogwood	Cornus sericea
Douglas dusty-maiden	Chaenactis douglasii
Douglas-fir	Pseudotsuga menziesii
Douglas knotweed	Polygonum douglasii
Douglas sedge	Carex douglasii
Douglas-fir dwarf mistletoe	Arceuthobium douglasii
drab buttercup	Ranunculus inamoenus
dragon head	Dracocephalum parviflorum
drummond catchfly	Lychnis drummondii
drummond willow	Salix drummondiana
dusty penstemon	Penstemon comarrhenus
dwarf cryptanth	Cryptantha humilus
dwarf rabbitbrush	Chrysothamnus depressus
Eaton aster	Aster eatonii
Eaton daisy	Erigeron eatoni
Eaton penstemon	Penstemon eatonii
edible valerian	Valeriana edulis
elegant death camas	Zigadenus elegans
elkweed	Swertia radiata
false phlox	Linanthastrum nuttallii
false Solomons's seal	Smilacina stellata
fee lipfern	Cheilanthes feei
Fendler cryptanth	Cryptantha fendleri
Fendler euphorb	Euphorbia fendleri
Fendler meadowrue	Thalictrum fendleri
Fendler mountain-lilac	Ceanothus fendleri
Fendler rockcress	Arabis holboellii var. fendleri
Fendler sandwort	Arenaria fendleri
fern-leaf daisy	Erigeron compositus
field milkvetch	Astragalus agrestis
field pennycress	Thlaspi arvense
field wormwood	Artemisia campestris
Fish Lake cryptanth	Cryptantha setosissima
four-wing saltbrush	Atriplex canescens
fowl mannagrass	Glyceria striata
foxtail barley	Hordeum jubatum
foxtail muhly	Muhlenbergia andina
fragant sand-verbena	Abronia fragrans
Fremont Cottonwood	Populus fremontii
Fremont barberry	Berberis fremontii
fringed brome	Bromus ciliatus
fringed sagebrush	Artemisia frigida
galleta	Hilaria jamesii
Gamble oak	Quercus gambelii
geyer willow	Salix geyeriana
giant evening primrose	Oenothera brachycarpa
giant reed	Arundo donax

globemallow	Sphaeralcea coccinea
goatsbeard	Tragapogon dubius
golden corydalis	Corydalus aurea
golden cryptanth	Cryptantha confertifolia
golden current	Ribes aureum
golden sedge	Carex aurea
goosefoot	Chenopodium fremontii var. incanum
grass-of-Parnassus	Parnassia parviflora
gray horsebrush	Tetradymia canescens
greasewood	Sarcobatus vermiculatus
Great Basin phlox	Phlox tumulosa
great bladdery milkvetch	Astragalus megacarpus
great rushy milkvetch	Astragalus lonchocarpus
green daisy	Erigeron simplex
green sedge	Carex oederi
greenish wintergreen	Pyrola virens
greenleaf manzanita	Arctostaphylos patula
grey hawksbeard	Crepis intermedia
grey thistle	Cirsium undulatum
ground smoke	Gayophytum lasiospermum
ground smoke	Gayophytum racemosum
groundcover milkvetch	Astragalus humistratus
gumweed aster	Machaeranthera grindelioides
hair-tuft cinquefoil	Potentilla crinata
hairy goldenaster	Heterotheca villosa
hall milkvetch	Astragalus hallii
hares-ear mustard	Conringia orientalis
Harriman yucca	Yucca harrimaniae
Hart groundsel	Senecio hartianus
heal-all	Prunella vulgaris
heartleaf arnica	Arnica cordifolia
helleborine	Epipactis gigantea
hoary aster	Machaeranthera canescens
Hoary aster	Machaeranthera canescens var. aristata
hoary daisy	Erigeron canus
hoary townsendia	Townsendia incana
hop clover	Medicago lupulina
horseweed	Conyza canadensis
hyalineherb	Hymenopappus filifolius
indian ricegrass	Stipa hymenoides
James cryptanth	Cryptantha cinerea
Jones gentian	Gentianella tortuosa
Jones goldenaster	Heterotheca jonesii
Jones oxytrope	Oxytropis jonesii
Jones reedgrass	Calamagrostis scopulorum
junegrass	Koeleria macrantha
juniper mistletoe	Phoradendron juniperum

kentrophyta	Astragalus kentrophyta
Kentucky bluegrass	Poa pratensis
King bladderpod	Lesquerella kingii
King lupine	Lupinus kingii
king's birdsbeak	Cordylanthus kingii
kinnikinnick	Arctostaphylos uvaMursi
knotweed	Polygonum aviculare
lanceleaf plantain	Plantago lanceolata
lapland gentian	Gentianella tenella
lavender-leaf primrose	Calylophus lavandulaefolia
least lomatium	Lomatium minimum
least townsendia	Townsendia montana var. minima
lemmon spring parsley	Cymopterus lemmonii
leopard lily	Fritillaria atropurpurea
lesser rushy milkvetch	Astragalus convallarius
lesser wallflower	Erysimum inconspicuum
Letterman needlegrass	Stipa lettermanii
limber pine	Pinus flexilis
limber pine dwarf mistletoe	Arceuthobium cyanocarpus
little seed ricegrass	Oryzopsis micrantha
liver-leaf wintergreen	Pyrola asarifolia
long stalked starwort	Stellaria longipes
longleafed phlox	Phlox longifolia
longstyle rush	Juncus longistylis
lousewort	Pedicularis centranthera
Lousisiana wormwood	Artemisia ludoviciana
low cryptanth	Cryptantha abata
low pussytoes	Antennaria dimorpha
low sagebrush	Artemisia arbuscula
low sand-verbena	Abronia nana
Maguire campion	Silene petersonii
Markagunt penstemon	Penstemon leiophyllus
marsh arrowgrass	Triglochin palustris
marsh buttercup	Ranunculus cymbalaria
martime arrowgrass	Triglochin maritima
mat muhly	Muhlenbergia richardsonis
mat penstemon	Penstemon caespitosus
meadow Horsetail	Equisetum arvense
meadow barley	Hordeum brachyantherum
meadow chess	Bromus japonicus
meadow fescue	Festuca pratensis
meadow gentian	Gentianopsis dentonsa
meadow hawksbeard	Crepis runcinata
meadow milkvetch	Astragalus argophyllus
missing thistle	Cirsium canovirens
Missouri goldenrod	Solidago missouriensis
Missouri iris	Iris missouriensis
mock pennyroyal	Hedeoma drummondii
Mohave brickellbush	Brickellia oblongifolia
monardella	Monardella odoratissima

monkey-flower	Mimulus guttatus
monkshood	Aconitum columbianum
morning-lily	Oenothera caespitosa
moss phlox	Phlox muscoides
mountain brome	Bromus carinatus
mountain goosefoot	Chenopodium atrovirens
mountain lover	Pachistima myrsinites
mountain lupine	Lupinus argenteus var. rubricaulis
mountain muhly	Muhlenbergia montana
mountain oxytrope	Oxytropis oreophila
mountain pepperweed	Lepidium montanum
muttongrass	Poa fendleriana
narrow leaf paintbrush	Castilleja linariaefolia
narrow-leaf willow	Salix exigua
narrow-leafed yucca	Yucca angustissima
narrowleaf cottonwood	Populus angustifolia
narrowleaf goosefoot	Chenopodium lepthophyllum
narrowleafed sedge	Carex stenophylla
Nebraska sedge	Carex nebraskensis
needle-and-thread grass	Stipa comata
Nelson globemallow	Sphaeralcea parvifolia
New Mexico thistle	Cirsium neomexicanum
Newberry Twinpod	Physaria newberryi
nodding bluegrass	Poa reflexa
nodding brome	Bromus anomalous
northern gentian	Gentianella amarella
northern reedgrass	Calamagrostis stricta
northern sweetvetch	Hedysarum boreale
northern willowherb	Epilobium ciliatum
Nutka rose	Rosa nutkana
Nuttall sandwort	Arenaria nuttallii
ocean spray	Holodiscus dumosus
one head sunflower	Helianthella uniflora
orange agoseris	Agoseris aurantiaca
orchard grass	Dactylis glomerata
Oregon daisy	Erigeron speciosus
Oregon grape	Mahonia repens
Pacific aster	Aster chilensis
pale agoseris	Agoseris glauca
pale evening-primrose	Oenothera pallida
pale sedge	Carex canescens
Panguitch buckwheat	Eriogonum panguicense
Paria breadroot	Pediomelum pariensis
Parry bellflower	Campanula parryi
Parry goldenrod	Solidago parryi
Parry rabbitbrush	Chrysothamnus parryi
Payson daisy	Erigeron vagus
pgymy sagebrush	Artemisia pygmaea
pine violet	Viola purpurea
pinedrops	Pterospora andromedea

pinewoods needlegrass	Stipa pinetorum
pinion pine	Pinus edulis
Platte cinquefoil	Potentilla plattensis
platy penstemon	Penstemon bracteatus
ponderosa pine	Pinus ponderosa
poverty weed	Iva axillaris
pretty cinquefoil	Potentilla concinna
pretty stoneseed	Lithospermum multiflorum
prickly lettuce	Lactuca serriola
prickly pear cactus	Opuntia erinacea
prickly phlox	Leptodactylon pungens
prince's plume	Stanleya pinnata
prostrate pigweed	Amaranthus blitoides
prostrate vervain	Verbena bracteata
pseudobedstraw	Kelloggia galioides
pulse milkvetch	Astragalus tenellus
purple three-awn	Aristida purpurea
purple-white clover	Orthocarpus purpureoMalbus
quaking aspen	Populus tremuloides
redroot buckwheat	Eriogonum racemosum
redtop	Agrostis stolonifera
redwool plantain	Plantago eriopoda
Richardson geranium	Geranium richardsonii
Richardson tansy mustard	Descurainia richardsonii
rock columbine	Aquilegia scopulorum
rock goldenrod	Petradoria pumila
rock jasmine	Androsace septentrionalis
rockcress	Arabis holboellii
rockcress	Arabis demissa
Rocky Mountain gentian	Gentiana affinis
Rocky Mountain juniper	Juniperus scopulorum
Rocky Mountain maple	Acer glabrum
Rocky Mountain penstemon	Penstemon strictus
rootstock evening-primrose	Oenothera coronopifolia
rose-heath	Leucelene ericoides
ross sedge	Carex rossii
rosy pussytoes	Antennaria microphylla
roundleaf buffaloberry	Shepherdia rotundifolia
rubber rabbitbrush	Chrysothamnus nauseosus
Russian knapweed	Centaurea repens
Russian thistle	Salsola iberica
Russian wildrye	Elymus junceus
Rydberg penstemon	Penstemon rydbergii
Rydberg sweetpea	Lathyrus brachycalyx
Salina wildrye	Elymus salinus
sand dropseed	Sporobolus cryptandrus
Sandburg bluegrass	Poa secunda
sandhill muhly	Muhlenbergia pungens
scarlet gilia	Gilia aggregata
scratchgrass	Muhlenbergia asperifolia
Sevier ivesia	Ivesia sabulosa

shadscale	Atriplex confertifolia
sheep fescue	Festuca ovina
shepherds purse	Capsella bursaMpastoris
shooting star	Dodecatheon pulchellum
shorthorn spurge	Euphorbia brachycera
showy goldeneye	Viguiera multiflora
showy milkweed	Asclepias speciosa
showy rushpink	Lygodesmia grandiflora
showy stoneseed	Lithospermum incisum
shrubby cinquefoil	Potentilla fruticosa
silky lupine	Lupinus sericeus
silver buffaloberry	Shepherdia argentea
silverweed	Potentilla anserina
silvery lupine	Lupinus argenteus
Simpson foot cactus	Pediocactus simpsonii
sixweek fescue	Festuca octoflora
skunkbush	Rhus aromatica var. trilobata
slender buckwheat	Eriogonum microthecum
slender cinquefoil	Potentilla gracilis
slender wheatgrass	Elymus trachycaulus
slender wirelettuce	Stephanomeria tenuifolia
slender wood-landstar	Lithophragma tenella
slender-beaked sedge	Carex athrostachrya
small bedstraw	Galium trifidum
small flower bird-beak	Cordylanthus parviflorus
small leafed geranium	Geranium caespitosum
small leafed geranium	Geranium caespitosum
small-wing sedge	Carex microptera
smooth brome	Bromus inermis
smooth scouringrush	Equisetum laevigatum
snowberry	Symphoricarpos oreophilous
soapberry	Shepherdia canadensis
southern ligusticum	Ligusticum porteri
southwestern dwarf mistletoe	Arceithobium vaginatum
spider milkweed	Asclepias asperula
spikerush	Eleocharis pauciflorus
spindlestem	Caulanthus crassicaulis
spindly goldenbush	Haplopappus scopulorum
spotted coralroot	Corallorhiza maculata
spreading daisy	Erigeron divergens
spreading dogbane	Apocynum androsaemifolium
spreading phlox	Phlox diffusa
spreading rabbitbrush	Chrysothamnus linifolius
spreading wheatgrass	Elymus scribneri
spurge	Euphorbia lurida
squaw apple	Peraphyllum ramosissimum
squirreltail	Elymus elymoides
star-lily	Leucocrinum montanum
starvling strawberry	Fragaria vesca
stemless townsendia	Townsendia exscapa
stemless woollybase	Hymenoxys acaulis
stemmed oxytrope	Oxytropis deflexa
stickseed	Lappula occidentalis

sticky geranium	Geranium viscosissimum
stokes buckwheat	Eriogonum subreniforme
striped coralroot	Corallorhiza striata
sulfur buckwheat	Eriogonum umbellatum
swordleaf rush	Juncus ensifolius
tamarisk	Tamarix ramoisima
tansy	Tanacetum vulgare
tansy mustard	Descurainia sophia
tansy mustard	Descurainia obtusa
thelypody	Thelypodiopsis sagittata
thickspike wheatgrass	Elymus lanceolatus
thickstem aster	Aster integrifolius
thorn wirelettuce	Stephanameria spinosa
thrifty goldenweed	Haplopappus armerioides
timothy	Phleum pratense
toad rush	Juncus bufonius
Torrey milkvetch	Astragalus calycosus
Torrey rush	Juncus torreyi
trailing daisy	Erigeron flagellaris
tufted hairgrass	Deschampsia cespitosa
tumble mustard	Schoencrambe suffrutescens
Tushar paintbrush	Castilleja parvula var. revealii
twinpod	Physaria chambersii
twist flower	Streptanthus cordatus
two-groved milkvetch	Astragalus bisulcatus
Unita groundsel	Senecio multilobatus
Utah juniper	Juniperus osteosperma
Utah mountain-lilac	Ceanothus martinii
Utah penstemon	Penstemon utahensis
Utah segolily	Calochortus nuttallii
Utah serviceberry	Amelanchier utahensis
Utah trefoil	Lotus utahensis
valerian	Valeriana acutiloba
variable spring parsley	Cymopterus purpureus
Vasey rabbitbrush	Chrysothamnus vaseyi
Vernal daisy	Erigeron pumilus
virgin's bower	Clematis columbiana
viscid Jacob's ladder	Polemonium viscosum
viscid rabbitbrush	Chrysothamnus viscidiflorus
wallflower	Erysimum asperum
water birch	Betula occidentalis
water groundsel	Senecio hydrophilus
water hemlock	Cicuta maculata
Watson bladderpod	Lesquerella intermedia
Watson bog-orchid	Habenaria sparsiflora
wax current	Ribes cereum
weedy milkvetch	Astragalus miser
westerm hawksbeard	Crepis occidentalis
western aster	Aster occidentalis

western wheatgrass	Elymus smithii
whiplash willow	Salix lasiandra
Whipple fishhook	Sclerocactus whipplei
white bog-orchid	Habenaria dilitata
white clover	Trifolium repens
white fir	Abies concolor
white virgin's bower	Clematis ligusticifolia
wild onion	Allium nevadensis
wild onion	Allium acuminatum
wild raspberry	Rubus idaeus
windflower	Anemone multifida
winged buckwheat	Eriogonum alatum
winterfat	Ceratoides lanata
wiregass	Juncus arcticus
woods rose	Rosa woodsii
woolly mullein	Verbascum thapsus
yarrow	Achillea millefolium
yellow bee-plant	Cleome lutea
yellow cancerroot	Orobanche fasciculata
yellow cryptanth	Cryptantha flava
yellow evening-primrose	Oenothera flava
yellow flax	Linum kingii
yellow owl-clover	Orthocarpus luteus
yellow sweet-clover	Melilotus officinalis
yellow-hair cryptanth	Cryptantha fulvocanescens
yellowish cryptanth	Cryptantha ochroleuca

Scientific name to common name translation for all known species in Bryce Canyon National Park. Scientific nomenclature and common names follow Welsh et al. 1987.

Abies concolor	white fir
Abronia fragrans	fragant sand-verbena
Abronia nana	low sand-verbena
Acer glabrum	Rocky Mountain maple
Acer grandidentatum	bigtooth maple
Achillea millefolium	yarrow
Aconitum columbianum	monkshood
Agoseris aurantiaca	orange agoseris
Agoseris glauca	pale agoseris
Agropyron cristatum	crested wheatgrass
Agrostis stolonifera	redtop
Allium acuminatum	wild onion
Allium nevadensis	wild onion
Amaranthus blitoides	prostrate pigweed
Amelanchier utahensis	Utah serviceberry
Androsace septentrionalis	rock jasmine
Anemone multifida	windflower
Antennaria dimorpha	low pussytoes
Antennaria microphylla	rosy pussytoes
Antennaria parvifolia	common pussytoes
Antennaria rosulata	breaks pussytoes
Apocynum androsaemifolium	spreading dogbane
Aquilegia caerulea	Colorado columbine
Aquilegia scopulorum	rock columbine
Arabis demissa	rockcress
Arabis holboellii	rockcress
Arabis holboellii var. fendleri	Fendler rockcress
Arceithobium vaginatum	southwestern dwarf mistletoe
Arceuthobium cyanocarpus	limber pine dwarf
Arceuthobium douglasii	Douglas-fir dwarf mistletoe
Arctostaphylos patula	greenleaf manzanita
Arctostaphylos uvaMursi	kinnikinnick
Arenaria fendleri	Fendler sandwort
Arenaria nuttallii	Nuttall sandwort
Aristida purpurea	purple three-awn
Arnica chamissonis	chamisso arnica
Arnica cordifolia	heartleaf arnica
Artemisia arbuscula	low sagebrush
Artemisia campestris	field wormwood
Artemisia carruthii	Carruth wormwood
Artemisia frigida	fringed sagebrush
Artemisia ludoviciana	Lousisiana wormwood
Artemisia nova	black sagebrush
Artemisia pygmaea	pgymy sagebrush
Artemisia tridentata	big sagebrush
Arundo donax	giant reed
Asclepias asperula	spider milkweed
Asclepias speciosa	showy milkweed
Asparagus officinalis	asparagus

Aster chilensis	pacific aster
Aster eatonii	Eaton aster
Aster glaucodes	blueleaf aster
Aster integrifolius	thickstem aster
Aster occidentalis	western aster
Astragalus agrestis	field milkvetch
Astragalus amphioxys	cresent milkvetch
Astragalus argophyllus	meadow milkvetch
Astragalus bisulcatus	two-groved milkvetch
Astragalus calycosus	Torrey milkvetch
Astragalus convallarius	lesser rushy milkvetch
Astragalus hallii	hall milkvetch
Astragalus humistratus	groundcover milkvetch
Astragalus kentrophyta	kentrophyta
Astragalus lonchocarpus	great rushy milkvetch
Astragalus megacarpus	great bladdery milkvetch
Astragalus miser	weedy milkvetch
Astragalus tenellus	pulse milkvetch
Atriplex canescens	four-wing saltbrush
Atriplex confertifolia	shadscale
Atriplex gardneri var. tridentata	basin saltbrush
Balsamorhiza sagittata	arrowleaf balsamroot
Berberis fremontii	Fremont barberry
Berula erecta	cutleaf water-parsnip
Betula occidentalis	water birch
Bouteloua gracilis	blue grama
Brickellia oblongifolia	Mohave brickellbush
Bromus anomalous	nodding brome
Bromus carinatus	mountain brome
Bromus ciliatus	fringed brome
Bromus inermis	smooth brome
Bromus japonicus	meadow chess
Bromus tectorum	cheatgrass
Calamagrostis scopulorum	Jones reedgrass
Calamagrostis stricta	northern reedgrass
Calochortus nuttallii	Utah segolily
Calylophus lavandulaefolia	lavender-leaf primrose
Campanula parryi	Parry bellflower
Campanula rotundifolia	bluebells of Scotland
Capsella bursa-pastoris	shepherds purse
Carex athrostachrya	slender-beaked sedge
Carex aurea	golden sedge
Carex canescens	pale sedge
Carex douglasii	Douglas sedge
Carex microptera	small-wing sedge
Carex nebraskensis	Nebraska sedge
Carex oederi	green sedge
Carex praegracilis	black creeper sedge
Carex rossii	Ross sedge
Carex rostrata	beaded sedge
Carex stenophylla	narrowleafed sedge
Castilleja chromosa	common paintbrush

Castilleja linariaefolia	narrow leaf paintbrush
Castilleja parvula var. revealii	Tushar paintbrush
Caulanthus crassicaulis	spindlestem
Ceanothus fendleri	Fendler mountain-lilac
Ceanothus martinii	utah mountain-lilac
Centaurea repens	Russian knapweed
Ceratoides lanata	winterfat
Cercocarpus ledifolius	curleaf mountain mahogany
Cercocarpus montanus	alderleaf mountain mahogany
Chaenactis douglasii	Douglas dusty-maiden
Cheilanthes feei	fee lipfern
Chenopodium atrovirens	mountain goosefoot
Chenopodium fremontii var. incanum	Fremont goosefoot
Chenopodium lepthophyllum	narrowleaf goosefoot
Chrysothamnus depressus	dwarf rabbitbrush
Chrysothamnus linifolius	spreading rabbitbrush
Chrysothamnus nauseosus	rubber rabbitbrush
Chrysothamnus parryi	Parry rabbitbrush
Chrysothamnus vaseyi	Vasey rabbitbrush
Chrysothamnus viscidiflorus	viscid rabbitbrush
Cicuta maculata	water hemlock
Cirsium arizonicum	Arizona thistle
Cirsium arizonicum var. nidulum	Arizona thistle
Cirsium calcareum var. pulchellum	Cainville thistle
Cirsium canovirens	missing thistle
Cirsium neomexicanum	New Mexico thistle
Cirsium undulatum	grey thistle
Cirsium vulgare	bull thistle
Clematis columbiana	virgin's bower
Clematis ligusticifolia	white virgin's bower
Cleome lutea	yellow bee-plant
Commandra umbellata	bastard toad flax
Conringia orientalis	hares-ear mustard
Convolvulus arvensis	bindweed
Conyza canadensis	horseweed
Corallorhiza maculata	spotted coralroot
Corallorhiza striata	striped coralroot
Cordylanthus kingii	Kings birdsbeak
Cordylanthus parviflorus	small flower bird-beak
Cornus sericea	dogwood
Corydalus aurea	golden corydalis
Crepis intermedia	grey hawksbeard
Crepis occidentalis	westerm hawksbeard
Crepis runcinata	meadow hawksbeard
Cryptantha abata	low cryptanth
Cryptantha bakeri	Baker cryptanth
Cryptantha cinerea	James cryptanth
Cryptantha confertifolia	golden cryptanth
Cryptantha fendleri	Fendler cryptanth
Cryptantha flava	yellow cryptanth
Cryptantha fulvocanescens	yellow-hair cryptanth
Cryptantha humilus	dwarf cryptanth
Cryptantha ochroleuca	yellowish cryptanth
Cryptantha setosissima	Fish lake cryptanth

Cymopterus lemmonii	lemmon spring parsley
Cymopterus purpureus	variable spring parsley
Dactylis glomerata	orchard grass
Delphinium andersonii var. scaposum	Anderson larkspur
Deschampsia cespitosa	tufted hairgrass
Descurainia obtusa	tansy mustard
Descurainia richardsonii	Richardson tansy mustard
Descurainia sophia	tansy mustard
Dodecatheon pulchellum	shooting star
Draba subalpina	breaks draba
Dracocephalum parviflorum	dragon head
Echinocereus triglochidiatus	claretcup
Eleocharis palustris	creeping spikerush
Eleocharis pauciflorus	spikerush
Eleocharis rostellata	beaked spikerush
Elymus canadensis	Canada wildrye
Elymus elymoides	squirreltail
Elymus glacus	blue wildrye
Elymus junceus	Russian wildrye
Elymus lanceolatus	thickspike wheatgrass
Elymus salinus	Salina wildrye
Elymus scribneri	spreading wheatgrass
Elymus smithii	western wheatgrass
Elymus spicatus	bluebunch wheatgrass
Elymus trachycaulus	slender wheatgrass
Epilobium ciliatum	northern willowherb
Epipactis gigantea	helleborine
Equisetum arvense	meadow Horsetail
Equisetum laevigatum	smooth scouringrush
Erigeron abajoensis	Abajo daisy
Erigeron canus	hoary daisy
Erigeron compositus	fern-leaf daisy
Erigeron divergens	spreading daisy
Erigeron eatoni	Eaton daisy
Erigeron flagellaris	trailing daisy
Erigeron pumilus	vernal daisy
Erigeron simplex	green daisy
Erigeron speciosus	Oregon daisy
Erigeron ursinus	bear daisy
Erigeron vagus	Payson daisy
Eriogonum alatum	winged buckwheat
Eriogonum corymbosum	corymb buckwheat
Eriogonum microthecum	slender buckwheat
Eriogonum panguicense	Panguitch buckwheat
Eriogonum racemosum	redroot buckwheat
Eriogonum subreniforme	Stokes buckwheat
Eriogonum umbellatum	sulfur buckwheat
Erysimum asperum	wallflower
Erysimum inconspicuum	lesser wallflower
Euphorbia brachycera	shorthorn spurge
Euphorbia fendleri	Fendler euphorb
Euphorbia lurida	spurge

Eallugia paradoxa	Apache plume
Festuca octoflora	sixweek fescue
Festuca ovina	sheep fescue
Festuca pratensis	meadow fescue
Fragaria vesca	starvling strawberry
Fritillaria atropurpurea	leopard lily
Galium trifidum	small bedstraw
Gayophytum lasiospermum	ground smoke
Gayophytum racemosum	ground smoke
Gentiana affinis	Rocky Mountain gentian
Gentianella amarella	northern gentian
Gentianella tenella	lapland gentian
Gentianella tortuosa	Jones gentian
Gentianopsis dentonsa	meadow gentian
Geranium caespitosum	small leafed geranium
Geranium caespitosum	small leafed geranium
Geranium richardsonii	Richardson geranium
Geranium viscosissimum	sticky geranium
Gilia aggregata	scarlet gilia
Gilia congesta	ball-head gilia
Glyceria striata	fowl mannagrass
Grindelia squarrosa	curly gumweed
Gutierrezia sarothrae	broom snakeweed
Habenaria dilitata	white bog-orchid
Habenaria sparsiflora	Watson bog-orchid
Haplopappus armerioides	thrifty goldenweed
Haplopappus scopulorum	spindly goldenbush
Haplopappus zionis	Cedar Breaks goldenbush
Hedeoma drummondii	mock pennyroyal
Hedysarum boreale	northern sweetvetch
Helianthella uniflora	one head sunflower
Helianthus annuus	common sunflower
Heterotheca jonesii	Jones goldenaster
Heterotheca villosa	hairy goldenaster
Hilaria jamesii	galleta
Holodiscus dumosus	ocean spray
Hordeum brachyantherum	meadow barley
Hordeum jubatum	foxtail barley
Hymenopappus filifolius	hyalineherb
Hymenoxys acaulis	stemless woollybase
Hymenoxys richardsonii	Colorado rubberweed
Iris missouriensis	Missouri iris
Iva axillaris	poverty weed
Ivesia sabulosa	Sevier ivesia
Juncus arcticus	wiregass
Juncus bufonius	toad rush
Juncus ensifolius	swordleaf rush
Juncus longistylis	longstyle rush
Juncus torreyi	Torrey rush
Juniperus communis	common juniper

Juniperus osteosperma	Utah juniper
Juniperus scopulorum	Rocky Mountain juniper
Kelloggia galioides	pseudobedstraw
Koeleria macrantha	junegrass
Lactuca serriola	prickly lettuce
Lactuca tatarica	blue lettuce
Lappula occidentalis	stickseed
Lathyrus brachycalyx	Rydberg sweetpea
Lepidium densiflorum	dense cress
Lepidium montanum	mountain pepperweed
Leptodactylon pungens	prickly phlox
Lesquerella intermedia	Watson bladderpod
Lesquerella kingii	King bladderpod
Lesquerella rubicundula	breaks bladderpod
Leucelene ericoides	rose-heath
Leucocrinum montanum	star-lily
Ligusticum porteri	southern ligusticum
Linanthastrum nuttallii	false phlox
Linum aristatum	broom flax
Linum kingii	yellow flax
Linum perenne	blue flax
Lithophragma tenella	slender wood-landstar
Lithospermum incisum	showy stoneseed
Lithospermum multiflorum	pretty stoneseed
Lomatium kingii var. alpinum	desert parsley
Lomatium minimum	least lomatium
Lotus utahensis	Utah trefoil
Lupinus argenteus	silvery lupine
Lupinus argenteus var. rubricaulis	mountain lupine
Lupinus kingii	King lupine
Lupinus sericeus	silky lupine
Lychnis drummondii	Drummond catchfly
Lygodesmia grandiflora	showy rushpink
Machaeranthera canescens var. aristata	hoary aster
Machaeranthera canescens	hoary aster
Machaeranthera grindelioides	gumweed aster
Mahonia repens	Oregon grape
Malcolmia africana	african mustard
Marrubium vulgare	common horehound
Medicago lupulina	hop clover
Medicago sativa	alfalfa
Melilotus officinalis	yellow sweet-clover
Mentzelia multiflora var. multiflora	blazing star
Mimulus guttatus	monkey-flower
Mimulus rubellus	annual monkey-flower
Monardella odoratissima	monardella
Muhlenbergia andina	foxtail muhly
Muhlenbergia asperifolia	scratchgrass
Muhlenbergia montana	mountain muhly
Muhlenbergia pungens	sandhill muhly
Muhlenbergia richardsonis	mat muhly

Oenothera brachycarpa	giant evening primrose
Oenothera caespitosa	morning-lily
Oenothera coronopifolia	rootstock evening-primrose
Oenothera flava	yellow evening-primrose
Oenothera longissima	Bridges evening-primrose
Oenothera pallida	pale evening-primrose
Opuntia erinacea	prickly pear cactus
Orobanche fasciculata	yellow cancerroot
Orthocarpus luteus	yellow owl-clover
Orthocarpus purpureoMalbus	purple-white clover
Oryzopsis micrantha	little seed ricegrass
Oxytropis deflexa	stemmed oxytrope
Oxytropis jonesii	Jones oxytrope
Oxytropis oreophila	mountain oxytrope
Pachystima myrsinites	mountain lover
Parnassia parviflora	grass-of-Parnassus
Paronchyia sessiliflora	creeping nailwort
Pedicularis centranthera	lousewort
Pediocactus simpsonii	Simpson foot cactus
Pediomelum pariensis	paria breadroot
Penstemon bracteatus	platy penstemon
Penstemon caespitosus	mat penstemon
Penstemon comarrhenus	dusty penstemon
Penstemon eatonii	Eaton penstemon
Penstemon leiophyllus	Markagunt penstemon
Penstemon rostriflorus	Bridges penstemon
Penstemon rydbergii	rydberg penstemon
Penstemon strictus	Rocky Mountain penstemon
Penstemon utahensis	Utah penstemon
Peraphyllum ramosissimum	squaw apple
Petradoria pumila	rock goldenrod
Phleum pratense	timothy
Phlox austromontana	desert phlox
Phlox condensata	creeping phlox
Phlox diffusa	spreading phlox
Phlox longifolia	longleafed phlox
Phlox muscoides	moss phlox
Phlox tumulosa	Great Basin phlox
Phoradendron juniperum	juniper mistletoe
Physaria chambersii	twinpod
Physaria newberryi	Newberry Twinpod
Picea pungens	blue spruce
Pinus edulis	pinion pine
Pinus flexilis	limber pine
Pinus longaeva	bristlecone pine
Pinus ponderosa	ponderosa pine
Plantago eriopoda	redwool plantain
Plantago lanceolata	lanceleaf plantain
Poa compressa	Canada bluegrass
Poa fendleriana	muttongrass
Poa pratensis	Kentucky bluegrass
Poa reflexa	nodding bluegrass

Poa secunda	Sandburg bluegrass
Polemonium caeruleum	blue Jacob's ladder
Polemonium viscosum	viscid Jacob's ladder
Polygonum aviculare	knotweed
Polygonum douglasii	Douglas knotweed
Polygonum ramosissimum	busy knotweed
Polygonum viviparum	alpine bistort
Populus angustifolia	narrowleaf cottonwood
Populus fremontii	Fremont Cottonwood
Populus tremuloides	quaking aspen
Potentilla anserina	silverweed
Potentilla concinna	pretty cinquefoil
Potentilla crinata	hair-tuft cinquefoil
Potentilla fruticosa	shrubby cinquefoil
Potentilla gracilis	slender cinquefoil
Potentilla plattensis	Platte cinquefoil
Prunella vulgaris	heal-all
Prunus virginiana	chokecherry
Pseudotsuga menziesii	Douglas-fir
Pteridium aquilinum	bracken fern
Pterospora andromedea	pinedrops
Purshia mexicana	cliffrose
Purshia tridentata	antelope bitterbrush
Pyrola asarifolia	liver-leaf wintergreen
Pyrola virens	greenish wintergreen
Quercus gambelii	Gamble oak
Ranunculus cymbalaria	marsh buttercup
Ranunculus flammula	creeping spearwort
Ranunculus inamoenus	drab buttercup
Rhus aromatica var. trilobata	skunkbush sumac
Ribes aureum	golden current
Ribes cereum	wax current
Rosa nutkana	Nutka rose
Rosa woodsii	woods rose
Rubus idaeus	wild raspberry
Rumex crispus	curled dock
Rumex salicifolius	beach dock
Salix bebbiana	Bebb willow
Salix drummondiana	Drummond willow
Salix exigua	narrow-leaf willow
Salix geyeriana	geyer willow
Salix lasiandra	whiplash willow
Salsola iberica	Russian thistle
Sambucus coerulea	blue elderberry
Sarcobatus vermiculatus	greasewood
Schoencrambe suffrutescens	tumble mustard
Scirpus americanus	
Sclerocactus whipplei	Whipple fishhook
Senecio atratus	black groundsel
Senecio cymbalarioides	cutleaf groundsel
Senecio hartianus	Hart groundsel

Senecio hydrophilus	water groundsel
Senecio multilobatus	Unita groundsel
Senecio spartioides	broom groundsel
Shepherdia argentea	silver buffaloberry
Shepherdia canadensis	soapberry
Shepherdia rotundifolia	roundleaf buffaloberry
Silene petersonii	Maguire campion
Sisyrinchium demissum	blue-eyed grass
Smilacina stellata	false solomons's seal
Solanum triflorum	cutleaf nightshade
Solidago missouriensis	Missouri goldenrod
Solidago parryi	Parry goldenrod
Solidago sparsiflora	alcove goldenrod
Solidago spathulata	coast goldenrod
Sphaeralcea coccinea	globemallow
Sphaeralcea parvifolia	Nelson globemallow
Sporobolus airoides	alkali saccaton
Sporobolus cryptandrus	sand dropseed
Stanleya pinnata	prince's plume
Stellaria jamesiana	chickweed
Stellaria longipes	long stalked starwort
Stephanameria spinosa	thorn wirelettuce
Stephanomeria tenuifolia	slender wirelettuce
Stipa comata	needle-and-thread grass
Stipa hymenoides	indian ricegrass
Stipa lettermanii	Letterman needlegrass
Stipa nelsonii	columbia needlegrass
Stipa pinetorum	pinewoods needlegrass
Stipa x bloomeri	Bloomer ricegrass
Streptanthus cordatus	twist flower
Swertia radiata	elkweed
Symphoricarpos oreophilous	snowberry
Tamarix ramoisima	tamarisk
Tanacetum vulgare	tansy
Taraxacum officinale	dandelion
Tetradymia canescens	gray horsebrush
Thalictrum fendleri	Fendler meadowrue
Thelypodiopsis sagittata	thelypody
Thlaspi arvense	field pennycress
Townsendia exscapa	stemless townsendia
Townsendia incana	hoary townsendia
Townsendia montana var. minima	least townsendia
Tragapogon dubius	goatsbeard
Trifolium repens	white clover
Triglochin maritima	martime arrowgrass
Triglochin palustris	marsh arrowgrass
Valeriana acutiloba	valerian
Valeriana edulis	edible valerian
Verbascum thapsus	woolly mullein
Verbena bracteata	prostrate vervain
Verbesina encelioides	crownbeard
Veronica americana	American brookline

Vicia americana	American vetch
Viguiera multiflora	showy goldeneye
Viola adunca	blue violet
Viola purpurea	pine violet
Yucca angustissima	narrow-leafed yucca
Yucca harrimaniae	harriman yucca
Zigadenus elegans	elegant death camas

APPENDIX B
CONSTANCY/COVERAGE TABLE

Constancy/Coverage data for common species in Bryce Canyon National Park. Number preceding parentheses is constancy, the percentage of sample plots a species occurs in. Number inside parentheses is mean cover for those plots where species occurs.

	ERCO/ELSA	ARTR/ATCA	ARNO/STCO	JUAR/CARO
********** SHRUBS **********				
Amelanchier utahensis	0(0)	0(0)	0(0)	0(0)
Arctostaphylos patula	0(0)	0(0)	0(0)	0(0)
Artemisia tridentata	0(0)	100(21)	0(0)	0(0)
Atriplex canescens	100(2)	100(8)	0(0)	0(0)
Berberis fremontii	0(0)	20(1)	0(0)	0(0)
Ceanothus martinii	0(0)	0(0)	0(0)	0(0)
Ceratoides lanata	100(15)	40(1)	0(0)	0(0)
Cercocarpus ledifolius	0(0)	0(0)	0(0)	0(0)
Cercocarpus montanus	0(0)	0(0)	0(0)	0(0)
Chrysothamnus parryi	0(0)	0(0)	13(5)	0(0)
Chrysothamnus viscidiflorus	0(0)	60(1)	88(2)	60(1)
Juniperus communis	0(0)	0(0)	0(0)	0(0)
Pachistima myrsinites	0(0)	0(0)	0(0)	0(0)
Purshia tridentata	0(0)	0(0)	16(2)	0(0)
Quercus gambelii	0(0)	0(0)	0(0)	0(0)
Ribes cereum	0(0)	0(0)	0(0)	0(0)
Rosa woodsii	0(0)	0(0)	3(1)	0(0)
Sambucus coerulea	0(0)	0(0)	0(0)	0(0)
Shepherdia rotundifolia	0(0)	0(0)	0(0)	0(0)
Symphoricarpos oreophilous	0(0)	0(0)	0(0)	0(0)
********** SUBSHRUBS **********				
Artemisia frigida	0(0)	0(0)	28(1)	60(5)
Artemisia nova	0(0)	0(0)	97(19)	20(1)
Eriogonum corymbosum	100(3)	0(0)	0(0)	0(0)
Gutierrezia sarothrae	0(0)	0(0)	0(0)	0(0)
Mahonia repens	0(0)	0(0)	0(0)	0(0)
Tetradymia canescens	0(0)	0(0)	66(1)	0(0)

	ERCO/ELSA	ARTR/ATCA	ARNO/STCO	JUAR/CARO
********** GRAMINOIDS **********				
Agropyron cristatum	0(0)	30(1)	0(0)	0(0)
Bouteloua gracilis	0(0)	20(8)	50(1)	0(0)
Bromus anomalous	0(0)	0(0)	28(4)	0(0)
Bromus ciliatus	0(0)	0(0)	0(0)	0(0)
Bromus inermis	0(0)	0(0)	3(1)	40(1)
Carex rossii	0(0)	0(0)	0(0)	80(20)
Elymus elymoides	50(1)	100(14)	66(1)	0(0)
Elymus lanceolatus	50(1)	10(3)	22(3)	0(0)
Elymus salinus	50(1)	0(0)	6(15)	0(0)
Elymus smithii	50(1)	40(5)	13(1)	60(18)
Festuca ovina	0(0)	0(0)	6(1)	0(0)
Juncus arcticus	0(0)	0(0)	3(1)	100(3)
Koeleria macrantha	0(0)	0(0)	66(1)	60(1)
Muhlenbergia montana	0(0)	0(0)	22(6)	0(0)
Oryzopsis micrantha	0(0)	0(0)	0(0)	0(0)
Poa fendleriana	0(0)	10(1)	69(3)	20(1)
Poa pratensis	0(0)	0(0)	9(6)	60(14)
Poa secunda	0(0)	0(0)	9(1)	40(19)
Stipa comata	0(0)	10(1)	100(10)	0(0)
Stipa hymenoides	50(1)	90(1)	28(1)	0(0)
Stipa pinetorum	0(0)	0(0)	34(1)	0(0)
********** FORBS **********				
Achillea millefolium	0(0)	0(0)	6(1)	60(1)
Agoseris glauca	0(0)	0(0)	38(1)	40(1)
Antennaria microphylla	0(0)	0(0)	19(1)	0(0)
Apocynum androsaemifolium	0(0)	0(0)	0(0)	0(0)
Arabis holboellii	0(0)	0(0)	9(1)	0(0)
Artemisia ludoviciana	0(0)	0(0)	0(0)	0(0)
Astragalus agrestis	0(0)	0(0)	9(1)	20(1)
Astragalus convallarius	0(0)	0(0)	0(0)	0(0)
Astragalus humistratus	0(0)	0(0)	31(1)	0(0)
Astragalus kentrophyta	0(0)	0(0)	13(1)	0(0)
Astragalus megacarpus	0(0)	0(0)	0(0)	0(0)
Astragalus miser	0(0)	0(0)	0(0)	0(0)
Calylophus lavandulaefolia	0(0)	0(0)	63(1)	0(0)
Calochortus nuttallii	0(0)	70(1)	56(1)	0(0)
Castilleja chromosa	0(0)	10(1)	44(1)	0(0)

	ERCO/ELSA	ARTR/ATCA	ARNO/STCO	JUAR/CARO
********** FORBS (cont.) **********				
Castilleja linariaefolia	0(0)	10(1)	13(1)	0(0)
Chaenactis douglasii	0(0)	0(0)	9(1)	0(0)
Cirsium neomexicanum	0(0)	40(1)	0(0)	0(0)
Commandra umbellata	0(0)	0(0)	16(1)	0(0)
Cordylanthus kingii	0(0)	0(0)	44(1)	0(0)
Cryptantha confertifolia	0(0)	0(0)	0(0)	0(0)
Dracocephalum parviflorum	0(0)	40(1)	0(0)	0(0)
Draba subalpina	0(0)	0(0)	0(0)	0(0)
Eriogonum alatum	0(0)	0(0)	25(1)	0(0)
Erigeron canus	0(0)	0(0)	9(1)	0(0)
Erigeron flagellaris	0(0)	0(0)	19(1)	60(1)
Eriogonum panguicense	0(0)	0(0)	0(0)	0(0)
Erigeron pumilus	0(0)	20(1)	19(1)	0(0)
Eriogonum racemosum	0(0)	0(0)	66(1)	0(0)
Eriogonum umbellatum	0(0)	0(0)	31(1)	0(0)
Euphorbia brachycera	0(0)	0(0)	16(1)	0(0)
Euphorbia fendleri	0(0)	0(0)	6(1)	0(0)
Euphorbia lurida	0(0)	0(0)	0(0)	0(0)
Geranium viscosissimum	0(0)	0(0)	0(0)	0(0)
Gilia aggregata	0(0)	0(0)	9(1)	0(0)
Gilia congesta	0(0)	0(0)	0(0)	0(0)
Haplopappus armerioides	0(0)	0(0)	0(0)	0(0)
Hymenoxys acaulis	0(0)	0(0)	6(1)	0(0)
Hymenopappus filifolius	0(0)	0(0)	3(1)	0(0)
Hymenoxys richardsonii	0(0)	10(1)	19(1)	0(0)
Leptodactylon pungens	0(0)	0(0)	69(1)	0(0)
Lesquerella intermedia	0(0)	0(0)	34(1)	0(0)
Linum kingii	0(0)	0(0)	0(0)	0(0)
Linum perenne	0(0)	0(0)	47(1)	40(1)
Lithospermum multiflorum	0(0)	0(0)	0(0)	0(0)
Lotus utahensis	0(0)	0(0)	34(1)	0(0)
Lupinus kingii	0(0)	0(0)	13(1)	0(0)
Lupinus sericeus	0(0)	0(0)	19(1)	0(0)
Lygodesmia grandiflora	0(0)	0(0)	16(1)	0(0)
Machaeranthera grindelioides	0(0)	0(0)	0(0)	0(0)
Oenothera brachycarpa	0(0)	0(0)	3(1)	0(0)
Oenothera caespitosa	0(0)	0(0)	0(0)	0(0)
Oenothera coronopifolia	0(0)	0(0)	16(1)	0(0)
Opuntia erinacea	0(0)	10(1)	13(1)	0(0)
Orobanche fasciculata	0(0)	0(0)	9(1)	0(0)

	ERCO/ELSA	ARTR/ATCA	ARNO/STCO	JUAR/CARO
********** FORBS (cont.) **********				
Pedicularis centranthera	0(0)	0(0)	3(1)	0(0)
Pediocactus simpsonii	0(0)	0(0)	6(1)	0(0)
Penstemon caespitosus	0(0)	0(0)	34(1)	0(0)
Penstemon comarrhenus	0(0)	10(1)	44(1)	0(0)
Phlox longifolia	0(0)	0(0)	6(1)	20(1)
Physaria chambersii	0(0)	0(0)	0(0)	0(0)
Potentilla crinata	0(0)	0(0)	9(1)	20(1)
Potentilla gracilis	0(0)	0(0)	9(1)	0(0)
Pterospora andromedea	0(0)	0(0)	0(0)	0(0)
Sclerocactus whipplei	0(0)	20(1)	0(0)	0(0)
Senecio multilobatus	0(0)	0(0)	78(1)	0(0)
Sphaeralcea coccinea	0(0)	80(1)	13(1)	0(0)
Stephanomeria tenuifolia	0(0)	0(0)	0(0)	0(0)
Swertia radiata	0(0)	0(0)	0(0)	0(0)
Taraxacum officinale	0(0)	0(0)	6(1)	40(1)
Tragapogon dubius	0(0)	30(5)	22(1)	0(0)

APPENDIX B (cont.)
CONSTANCY/COVERAGE TABLE

Constancy/Coverage data for common species in Bryce Canyon National Park. Number preceding parentheses is constancy, the percentage of sample plots a species occurs in. Number inside parentheses is mean cover for those plots where species occurs.

	PIED/JUOS	PIPO/PUTR	PIPO/ARNO	PIPO/ARPA
********** SHRUBS **********				
Amelanchier utahensis	0(0)	0(0)	0(0)	26(3)
Arctostaphylos patula	21(1)	25(1)	0(0)	95(48)
Artemisia tridentata	11(1)	0(0)	0(0)	5(1)
Atriplex canescens	0(0)	0(0)	0(0)	0(0)
Berberis fremontii	11(1)	0(0)	0(0)	11(0)
Ceanothus martinii	0(0)	100(1)	0(0)	74(2)
Ceratoides lanata	0(0)	0(0)	0(0)	0(0)
Cercocarpus ledifolius	5(1)	0(0)	0(0)	0(0)
Cercocarpus montanus	95(4)	0(0)	0(0)	53(1)
Chrysothamnus parryi	0(0)	0(0)	50(15)	0(0)
Chrysothamnus viscidiflorus	0(0)	0(0)	50(3)	0(0)
Juniperus communis	0(0)	0(0)	0(0)	11(1)
Pachistima myrsinites	0(0)	25(1)	0(0)	16(1)
Purshia tridentata	74(2)	100(17)	100(3)	47(3)
Quercus gambelii	58(3)	0(0)	0(0)	32(16)
Ribes cereum	0(0)	25(1)	0(0)	0(0)
Rosa woodsii	0(0)	0(0)	0(0)	0(0)
Sambucus coerulea	0(0)	0(0)	0(0)	16(1)
Shepherdia rotundifolia	37(1)	0(0)	0(0)	0(0)
Symphoricarpos oreophilous	37(1)	50(1)	0(0)	63(1)
********** SUBSHRUBS **********				
Artemisia frigida	0(0)	0(0)	0(0)	0(0)
Artemisia nova	5(1)	25(1)	100(39)	0(0)
Eriogonum corymbosum	11(1)	0(0)	0(0)	0(0)
Gutierrezia sarothrae	5(1)	25(1)	100(1)	21(1)
Mahonia repens	0(0)	25(1)	0(0)	74(1)
Tetradymia canescens	0(0)	100(2)	100(1)	11(1)

	PIED/JUOS	PIPO/PUTR	PIPO/ARNO	PIPO/ARPA
********** GRAMINOIDS **********				
Agropyron cristatum	0(0)	0(0)	0(0)	0(0)
Bouteloua gracilis	11(1)	0(0)	0(0)	0(0)
Bromus anomalous	0(0)	0(0)	0(0)	0(0)
Bromus ciliatus	0(0)	0(0)	50(1)	0(0)
Bromus inermis	0(0)	0(0)	0(0)	0(0)
Carex rossii	5(1)	75(1)	100(3)	100(1)
Elymus elymoides	0(0)	50(1)	0(0)	5(1)
Elymus lanceolatus	0(0)	0(0)	0(0)	0(0)
Elymus salinus	11(1)	25(1)	0(0)	0(0)
Elymus smithii	0(0)	0(0)	0(0)	0(0)
Festuca ovina	0(0)	0(0)	0(0)	0(0)
Juncus arcticus	0(0)	0(0)	0(0)	0(0)
Koeleria macrantha	5(1)	25(1)	0(0)	0(0)
Muhlenbergia montana	0(0)	0(0)	0(0)	0(0)
Oryzopsis micrantha	0(0)	25(1)	0(0)	11(1)
Poa fendleriana	16(1)	25(1)	50(1)	5(1)
Poa pratensis	0(0)	0(0)	0(0)	0(0)
Poa secunda	0(0)	0(0)	0(0)	0(0)
Stipa comata	0(0)	0(0)	0(0)	0(0)
Stipa hymenoides	37(1)	25(1)	100(1)	11(1)
Stipa pinetorum	0(0)	0(0)	0(0)	0(0)
********** FORBS **********				
Achillea millefolium	0(0)	0(0)	0(0)	11(1)
Agoseris glauca	0(0)	0(0)	0(0)	0(0)
Antennaria microphylla	0(0)	0(0)	0(0)	0(0)
Apocynum androsaemifolium	0(0)	0(0)	0(0)	11(1)
Arabis holboellii	0(0)	0(0)	0(0)	0(0)
Artemisia ludoviciana	0(0)	0(0)	50(1)	5(1)
Astragalus agrestis	0(0)	0(0)	0(0)	0(0)
Astragalus convallarius	0(0)	50(1)	0(0)	32(1)
Astragalus humistratus	0(0)	0(0)	0(0)	0(0)
Astragalus kentrophyta	0(0)	25(1)	0(0)	0(0)
Astragalus megacarpus	0(0)	0(0)	0(0)	5(1)
Astragalus miser	0(0)	0(0)	0(0)	0(0)
Calylophus lavandulaefolia	0(0)	0(0)	50(1)	5(1)
Calochortus nuttallii	0(0)	0(0)	0(0)	0(0)
Castilleja chromosa	0(0)	0(0)	0(0)	0(0)

	PIED/JUOS	PIPO/PUTR	PIPO/ARNO	PIPO/ARPA
********** FORBS (cont.) **********				
Castilleja linariaefolia	0(0)	50(1)	50(1)	26(1)
Chaenactis douglasii	0(0)	25(1)	0(0)	11(1)
Cirsium neomexicanum	0(0)	0(0)	0(0)	0(0)
Commandra umbellata	0(0)	0(0)	0(0)	0(0)
Cordylanthus kingii	21(1)	0(0)	0(0)	0(0)
Cryptantha confertifolia	37(1)	0(0)	0(0)	5(1)
Dracocephalum parviflorum	0(0)	0(0)	0(0)	0(0)
Draba subalpina	0(0)	0(0)	0(0)	21(1)
Eriogonum alatum	16(1)	50(1)	100(1)	32(1)
Erigeron canus	0(0)	0(0)	0(0)	0(0)
Erigeron flagellaris	0(0)	0(0)	0(0)	0(0)
Eriogonum panguicense	0(0)	0(0)	0(0)	11(1)
Erigeron pumilus	0(0)	0(0)	0(0)	0(0)
Eriogonum racemosum	5(1)	50(1)	100(1)	11(1)
Eriogonum umbellatum	0(0)	0(0)	0(0)	0(0)
Euphorbia brachycera	5(1)	0(0)	0(0)	5(1)
Euphorbia fendleri	11(1)	50(1)	100(1)	21(1)
Euphorbia lurida	0(0)	25(1)	0(0)	37(1)
Geranium viscosissimum	0(0)	0(0)	0(0)	0(0)
Gilia aggregata	0(0)	0(0)	0(0)	0(0)
Gilia congesta	0(0)	0(0)	50(1)	11(1)
Haplopappus armerioides	32(1)	0(0)	0(0)	16(1)
Hymenoxys acaulis	0(0)	25(1)	0(0)	32(1)
Hymenopappus filifolius	16(1)	25(1)	0(0)	26(1)
Hymenoxys richardsonii	16(1)	75(1)	50(1)	42(1)
Leptodactylon pungens	0(0)	0(0)	0(0)	0(0)
Lesquerella intermedia	11(1)	50(1)	50(1)	5(1)
Linum kingii	0(0)	0(0)	0(0)	21(1)
Linum perenne	0(0)	0(0)	50(1)	11(1)
Lithospermum multiflorum	0(0)	25(1)	0(0)	32(1)
Lotus utahensis	0(0)	0(0)	50(1)	5(1)
Lupinus kingii	0(0)	0(0)	0(0)	0(0)
Lupinus sericeus	0(0)	0(0)	0(0)	0(0)
Lygodesmia grandiflora	0(0)	0(0)	0(0)	0(0)
Machaeranthera grindelioides	11(1)	75(1)	0(0)	53(1)
Oenothera brachycarpa	0(0)	25(1)	50(1)	21(1)
Oenothera caespitosa	0(0)	0(0)	50(1)	16(1)
Oenothera coronopifolia	0(0)	0(0)	0(0)	0(0)
Opuntia erinacea	47(1)	0(0)	100(1)	0(0)
Orobanche fasciculata	0(0)	0(0)	0(0)	0(0)

	PIED/JUOS	PIPO/PUTR	PIPO/ARNO	PIPO/ARPA
********** FORBS (cont.) **********				
Pedicularis centranthera	21(1)	25(1)	0(0)	37(1)
Pediocactus simpsonii	5(1)	0(0)	0(0)	0(0)
Penstemon caespitosus	5(1)	25(1)	100(1)	5(1)
Penstemon comarrhenus	0(0)	0(0)	0(0)	0(0)
Phlox longifolia	0(0)	0(0)	0(0)	0(0)
Physaria chambersii	0(0)	0(0)	0(0)	21(1)
Potentilla crinata	0(0)	0(0)	0(0)	0(0)
Potentilla gracilis	0(0)	0(0)	0(0)	0(0)
Pterospora andromedea	0(0)	0(0)	0(0)	16(1)
Sclerocactus whipplei	5(1)	0(0)	0(0)	0(0)
Senecio multilobatus	11(1)	50(1)	50(1)	37(1)
Sphaeralcea coccinea	0(0)	0(0)	0(0)	0(0)
Stephanomeria tenuifolia	0(0)	25(1)	0(0)	11(1)
Swertia radiata	0(0)	0(0)	0(0)	32(1)
Taraxacum officinale	0(0)	0(0)	0(0)	0(0)
Tragapogon dubius	0(0)	0(0)	0(0)	0(0)

APPENDIX B (cont.)
CONSTANCY/COVERAGE TABLE

Constancy/Coverage data for common species in Bryce Canyon National Park. Number preceding parentheses is constancy, the percentage of sample plots a species occurs in. Number inside parentheses is mean cover for those plots where species occurs.

	PSME/ARPA	PSME/MARE	PIPU/JUCO	ABCO/SYOR
********** SHRUBS **********				
Amelanchier utahensis	22(1)	50(1)	50(1)	0(0)
Arctostaphylos patula	100(43)	50(1)	50(1)	100(3)
Artemisia tridentata	0(0)	0(0)	0(0)	0(0)
Atriplex canescens	0(0)	0(0)	0(0)	0(0)
Berberis fremontii	0(0)	0(0)	0(0)	0(0)
Ceanothus martinii	78(2)	50(1)	50(1)	0(0)
Ceratoides lanata	0(0)	0(0)	0(0)	0(0)
Cercocarpus ledifolius	11(2)	0(0)	0(0)	0(0)
Cercocarpus montanus	22(1)	0(0)	0(0)	0(0)
Chrysothamnus parryi	0(0)	0(0)	0(0)	0(0)
Chrysothamnus viscidiflorus	0(0)	0(0)	0(0)	0(0)
Juniperus communis	39(1)	100(1)	50(3)	100(3)
Pachistima myrsinites	44(1)	100(1)	50(1)	100(1)
Purshia tridentata	72(1)	50(1)	50(1)	0(0)
Quercus gambelii	22(4)	0(0)	0(0)	0(0)
Ribes cereum	33(1)	50(1)	50(1)	100(1)
Rosa woodsii	0(0)	0(0)	0(0)	0(0)
Sambucus coerulea	6(1)	50(1)	0(0)	100(1)
Shepherdia rotundifolia	0(0)	0(0)	0(0)	0(0)
Symphoricarpos oreophilous	94(1)	100(2)	100(1)	100(3)
********** SUBSHRUBS **********				
Artemisia frigida	0(0)	0(0)	0(0)	0(0)
Artemisia nova	0(0)	0(0)	0(0)	0(0)
Eriogonum corymbosum	0(0)	0(0)	0(0)	0(0)
Gutierrezia sarothrae	11(1)	0(0)	50(1)	0(0)
Mahonia repens	67(1)	100(3)	100(1)	100(3)
Tetradymia canescens	22(1)	50(1)	0(0)	0(0)

	PSME/ARPA	PSME/MARE	PIPU/JUCO	ABCO/SYOR
********** GRAMINOIDS **********				
Agropyron cristatum	0(0)	0(0)	0(0)	0(0)
Bouteloua gracilis	0(0)	0(0)	0(0)	0(0)
Bromus anomalous	0(0)	0(0)	0(0)	0(0)
Bromus ciliatus	0(0)	0(0)	50(1)	0(0)
Bromus inermis	0(0)	0(0)	0(0)	0(0)
Carex rossii	94(1)	100(1)	100(2)	100(3)
Elymus elymoides	11(1)	0(0)	50(1)	100(1)
Elymus lanceolatus	0(0)	0(0)	0(0)	0(0)
Elymus salinus	0(0)	0(0)	0(0)	0(0)
Elymus smithii	0(0)	0(0)	0(0)	0(0)
Festuca ovina	0(0)	0(0)	50(1)	0(0)
Juncus arcticus	0(0)	0(0)	0(0)	0(0)
Koeleria macrantha	0(0)	0(0)	50(1)	0(0)
Muhlenbergia montana	0(0)	0(0)	0(0)	0(0)
Oryzopsis micrantha	6(1)	0(0)	0(0)	0(0)
Poa fendleriana	0(0)	0(0)	0(0)	0(0)
Poa pratensis	0(0)	0(0)	0(0)	0(0)
Poa secunda	0(0)	0(0)	0(0)	0(0)
Stipa comata	0(0)	0(0)	0(0)	0(0)
Stipa hymenoides	17(1)	0(0)	50(3)	0(0)
Stipa pinetorum	0(0)	0(0)	0(0)	0(0)
********** FORBS **********				
Achillea millefolium	33(1)	0(0)	50(1)	100(1)
Agoseris glauca	0(0)	0(0)	0(0)	0(0)
Antennaria microphylla	0(0)	0(0)	0(0)	0(0)
Apocynum androsaemifolium	11(1)	0(0)	0(0)	0(0)
Arabis holboellii	0(0)	0(0)	0(0)	0(0)
Artemisia ludoviciana	0(0)	50(1)	0(0)	100(1)
Astragalus agrestis	0(0)	0(0)	0(0)	0(0)
Astragalus convallarius	33(1)	0(0)	0(0)	0(0)
Astragalus humistratus	0(0)	0(0)	0(0)	0(0)
Astragalus kentrophyta	0(0)	0(0)	0(0)	0(0)
Astragalus megacarpus	22(1)	50(1)	0(0)	0(0)
Astragalus miser	33(1)	50(1)	50(1)	0(0)
Calylophus lavandulaefolia	0(0)	0(0)	0(0)	0(0)
Calochortus nuttallii	0(0)	0(0)	0(0)	0(0)
Castilleja chromosa	0(0)	0(0)	0(0)	0(0)

	PSME/ARPA	PSME/MARE	PIPU/JUCO	ABCO/SYOR
********** FORBS (cont.) **********				
Castilleja linariaefolia	17(1)	0(0)	0(0)	0(0)
Chaenactis douglasii	17(1)	0(0)	50(1)	0(0)
Cirsium neomexicanum	0(0)	0(0)	0(0)	0(0)
Commandra umbellata	0(0)	0(0)	0(0)	0(0)
Cordylanthus kingii	0(0)	0(0)	0(0)	0(0)
Cryptantha confertifolia	0(0)	0(0)	0(0)	0(0)
Dracocephalum parviflorum	0(0)	0(0)	0(0)	0(0)
Draba subalpina	33(1)	0(0)	100(1)	0(0)
Eriogonum alatum	28(1)	0(0)	0(0)	0(0)
Erigeron canus	0(0)	0(0)	0(0)	0(0)
Erigeron flagellaris	0(0)	0(0)	0(0)	0(0)
Eriogonum panguicense	0(0)	0(0)	50(1)	0(0)
Erigeron pumilus	0(0)	0(0)	0(0)	0(0)
Eriogonum racemosum	17(1)	0(0)	0(0)	100(1)
Eriogonum umbellatum	0(0)	0(0)	0(0)	0(0)
Euphorbia brachycera	0(0)	0(0)	0(0)	0(0)
Euphorbia fendleri	0(0)	0(0)	0(0)	0(0)
Euphorbia lurida	33(1)	50(1)	0(0)	0(0)
Geranium viscosissimum	6(1)	0(0)	50(1)	0(0)
Gilia aggregata	0(0)	0(0)	0(0)	0(0)
Gilia congesta	17(1)	50(1)	0(0)	100(1)
Haplopappus armerioides	0(0)	0(0)	0(0)	0(0)
Hymenoxys acaulis	22(1)	0(0)	50(1)	0(0)
Hymenopappus filifolius	22(1)	0(0)	50(1)	0(0)
Hymenoxys richardsonii	28(1)	0(0)	50(1)	0(0)
Leptodactylon pungens	0(0)	0(0)	0(0)	0(0)
Lesquerella intermedia	6(1)	0(0)	50(1)	0(0)
Linum kingii	22(1)	0(0)	50(3)	0(0)
Linum perenne	6(1)	0(0)	0(0)	0(0)
Lithospermum multiflorum	17(1)	0(0)	0(0)	100(1)
Lotus utahensis	6(1)	50(1)	50(1)	100(1)
Lupinus kingii	0(0)	0(0)	0(0)	0(0)
Lupinus sericeus	0(0)	0(0)	0(0)	0(0)
Lygodesmia grandiflora	0(0)	0(0)	0(0)	0(0)
Machaeranthera grindelioides	22(1)	0(0)	0(0)	0(0)
Oenothera brachycarpa	6(1)	0(0)	50(1)	0(0)
Oenothera caespitosa	6(1)	0(0)	0(0)	0(0)
Oenothera coronopifolia	0(0)	0(0)	0(0)	0(0)
Opuntia erinacea	0(0)	0(0)	0(0)	0(0)
Orobanche fasciculata	0(0)	0(0)	0(0)	0(0)

	PSME/ARPA	PSME/MARE	PIPU/JUCO	ABCO/SYOR
********** FORBS (cont.) **********				
Pedicularis centranthera	44(1)	50(1)	0(0)	0(0)
Pediocactus simpsonii	0(0)	0(0)	0(0)	0(0)
Penstemon caespitosus	6(1)	0(0)	50(1)	0(0)
Penstemon comarrhenus	0(0)	0(0)	0(0)	0(0)
Phlox longifolia	0(0)	0(0)	0(0)	0(0)
Physaria chambersii	6(1)	0(0)	0(0)	0(0)
Potentilla crinata	0(0)	0(0)	0(0)	0(0)
Potentilla gracilis	0(0)	0(0)	0(0)	0(0)
Pterospora andromedea	17(1)	0(0)	0(0)	0(0)
Sclerocactus whipplei	0(0)	0(0)	0(0)	0(0)
Senecio multilobatus	44(1)	50(1)	50(1)	100(1)
Sphaeralcea coccinea	0(0)	0(0)	0(0)	0(0)
Stephanomeria tenuifolia	6(1)	0(0)	0(0)	0(0)
Swertia radiata	50(1)	0(0)	50(1)	0(0)
Taraxacum officinale	0(0)	0(0)	0(0)	0(0)
Tragapogon dubius	0(0)	0(0)	0(0)	0(0)

APPENDIX B (cont.)
CONSTANCY/COVERAGE TABLE

Constancy/Coverage data for common species in Bryce Canyon National Park. Number preceding parentheses is constancy, the percentage of sample plots a species occurs in. Number inside parentheses is mean cover for those plots where species occurs.

	ABCO/ARPA	ABCO/MARE-MARE	ABCO/MARE-JUCO	ABCO/JUCO
********** SHRUBS **********				
Amelanchier utahensis	27(1)	36(1)	0(0)	50(1)
Arctostaphylos patula	100(31)	45(1)	0(0)	50(2)
Artemisia tridentata	0(0)	0(0)	0(0)	0(0)
Atriplex canescens	0(0)	0(0)	0(0)	0(0)
Berberis fremontii	0(0)	0(0)	0(0)	0(0)
Ceanothus martinii	91(2)	18(1)	0(0)	50(1)
Ceratoides lanata	0(0)	0(0)	0(0)	0(0)
Cercocarpus ledifolius	9(1)	0(0)	0(0)	0(0)
Cercocarpus montanus	5(3)	0(0)	0(0)	0(0)
Chrysothamnus parryi	5(1)	0(0)	0(0)	0(0)
Chrysothamnus viscidiflorus	0(0)	0(0)	0(0)	0(0)
Juniperus communis	59(3)	82(1)	0(0)	100(18)
Pachistima myrsinites	73(1)	100(1)	100(1)	100(1)
Purshia tridentata	55(1)	9(1)	0(0)	25(1)
Quercus gambelii	9(2)	0(0)	0(0)	0(0)
Ribes cereum	55(1)	36(1)	100(1)	50(1)
Rosa woodsii	5(1)	0(0)	0(0)	25(1)
Sambucus coerulea	5(1)	9(1)	0(0)	0(0)
Shepherdia rotundifolia	0(0)	0(0)	0(0)	0(0)
Symphoricarpos oreophilous	100(1)	100(1)	100(1)	100(1)
********** SUBSHRUBS **********				
Artemisia frigida	0(0)	0(0)	0(0)	0(0)
Artemisia nova	0(0)	0(0)	0(0)	0(0)
Eriogonum corymbosum	0(0)	0(0)	0(0)	0(0)
Gutierrezia sarothrae	9(1)	0(0)	0(0)	0(0)
Mahonia repens	91(2)	100(5)	100(3)	75(1)
Tetradymia canescens	5(1)	0(0)	0(0)	0(0)

	ABCO/ARPA	ABCO/MARE-MARE	ABCO/MARE-JUCO	ABCO/JUCO
********** GRAMINOIDS **********				
Agropyron cristatum	0(0)	0(0)	0(0)	0(0)
Bouteloua gracilis	0(0)	0(0)	0(0)	0(0)
Bromus anomalous	0(0)	0(0)	0(0)	0(0)
Bromus ciliatus	0(0)	9(1)	0(0)	25(1)
Bromus inermis	0(0)	0(0)	0(0)	0(0)
Carex rossii	95(1)	91(1)	100(1)	75(1)
Elymus elymoides	14(1)	9(1)	0(0)	50(1)
Elymus lanceolatus	0(0)	0(0)	0(0)	0(0)
Elymus salinus	0(0)	0(0)	0(0)	0(0)
Elymus smithii	0(0)	0(0)	0(0)	0(0)
Festuca ovina	0(0)	0(0)	0(0)	0(0)
Juncus arcticus	0(0)	0(0)	0(0)	0(0)
Koeleria macrantha	0(0)	0(0)	0(0)	0(0)
Muhlenbergia montana	0(0)	0(0)	0(0)	0(0)
Oryzopsis micrantha	0(0)	0(0)	0(0)	0(0)
Poa fendleriana	5(1)	9(1)	0(0)	25(1)
Poa pratensis	0(0)	0(0)	0(0)	0(0)
Poa secunda	0(0)	0(0)	0(0)	0(0)
Stipa comata	0(0)	0(0)	0(0)	0(0)
Stipa hymenoides	18(1)	9(1)	0(0)	0(0)
Stipa pinetorum	0(0)	0(0)	0(0)	0(0)
********** FORBS **********				
Achillea millefolium	36(1)	0(0)	100(1)	50(1)
Agoseris glauca	0(0)	0(0)	0(0)	0(0)
Antennaria microphylla	5(1)	0(0)	0(0)	0(0)
Apocynum androsaemifolium	9(1)	0(0)	0(0)	0(0)
Arabis holboellii	0(0)	0(0)	0(0)	0(0)
Artemisia ludoviciana	5(1)	0(0)	0(0)	0(0)
Astragalus agrestis	0(0)	0(0)	0(0)	0(0)
Astragalus convallarius	0(0)	0(0)	0(0)	25(1)
Astragalus humistratus	0(0)	0(0)	0(0)	0(0)
Astragalus kentrophyta	0(0)	0(0)	0(0)	0(0)
Astragalus megacarpus	18(1)	0(0)	0(0)	0(0)
Astragalus miser	50(1)	55(1)	100(1)	75(1)
Calylophus lavandulaefolia	0(0)	0(0)	0(0)	0(0)
Calochortus nuttallii	0(0)	0(0)	0(0)	0(0)
Castilleja chromosa	0(0)	0(0)	0(0)	0(0)

	ABCO/ARPA	ABCO/MARE-MARE	ABCO/MARE-JUCO	ABCO/JUCO
********** FORBS (cont.) **********				
Castilleja linariaefolia	23(1)	0(0)	0(0)	25(1)
Chaenactis douglasii	5(1)	0(0)	0(0)	0(0)
Cirsium neomexicanum	0(0)	0(0)	0(0)	0(0)
Commandra umbellata	0(0)	0(0)	0(0)	0(0)
Cordylanthus kingii	0(0)	0(0)	0(0)	0(0)
Cryptantha confertifolia	0(0)	0(0)	0(0)	0(0)
Dracocephalum parviflorum	0(0)	0(0)	0(0)	0(0)
Draba subalpina	18(1)	27(1)	0(0)	25(1)
Eriogonum alatum	9(1)	0(0)	0(0)	0(0)
Erigeron canus	5(1)	0(0)	0(0)	0(0)
Erigeron flagellaris	0(0)	0(0)	0(0)	0(0)
Eriogonum panguicense	0(0)	0(0)	0(0)	0(0)
Erigeron pumilus	0(0)	0(0)	0(0)	0(0)
Eriogonum racemosum	9(1)	18(1)	0(0)	0(0)
Eriogonum umbellatum	0(0)	0(0)	0(0)	0(0)
Euphorbia brachycera	0(0)	0(0)	0(0)	0(0)
Euphorbia fendleri	0(0)	0(0)	0(0)	0(0)
Euphorbia lurida	41(1)	0(0)	0(0)	25(1)
Geranium viscosissimum	14(1)	9(1)	0(0)	25(1)
Gilia aggregata	0(0)	0(0)	0(0)	0(0)
Gilia congesta	18(1)	0(0)	0(0)	25(1)
Haplopappus armerioides	0(0)	0(0)	0(0)	0(0)
Hymenoxys acaulis	5(1)	0(0)	0(0)	0(0)
Hymenopappus filifolius	5(1)	0(0)	0(0)	0(0)
Hymenoxys richardsonii	14(1)	9(1)	0(0)	0(0)
Leptodactylon pungens	0(0)	0(0)	0(0)	0(0)
Lesquerella intermedia	0(0)	0(0)	0(0)	0(0)
Linum kingii	0(0)	9(1)	0(0)	0(0)
Linum perenne	9(1)	0(0)	0(0)	0(0)
Lithospermum multiflorum	14(1)	9(1)	0(0)	0(0)
Lotus utahensis	32(1)	27(1)	100(1)	0(0)
Lupinus kingii	0(0)	0(0)	0(0)	0(0)
Lupinus sericeus	0(0)	0(0)	0(0)	0(0)
Lygodesmia grandiflora	0(0)	0(0)	0(0)	0(0)
Machaeranthera grindelioides	5(1)	0(0)	0(0)	0(0)
Oenothera brachycarpa	0(0)	0(0)	0(0)	0(0)
Oenothera caespitosa	5(1)	0(0)	0(0)	0(0)
Oenothera coronopifolia	0(0)	0(0)	0(0)	0(0)
Opuntia erinacea	0(0)	0(0)	0(0)	0(0)
Orobanche fasciculata	0(0)	0(0)	0(0)	0(0)

	ABCO/ARPA	ABCO/MARE-JUCO		
		ABCO/MARE-MARE		ABCO/JUCO
********** FORBS (cont.) **********				
Pedicularis centranthera	45(1)	18(1)	0(0)	0(0)
Pediocactus simpsonii	0(0)	0(0)	0(0)	0(0)
Penstemon caespitosus	5(1)	0(0)	0(0)	0(0)
Penstemon comarrhenus	0(0)	0(0)	0(0)	0(0)
Phlox longifolia	0(0)	0(0)	0(0)	0(0)
Physaria chambersii	0(0)	0(0)	0(0)	0(0)
Potentilla crinata	0(0)	0(0)	0(0)	0(0)
Potentilla gracilis	0(0)	0(0)	0(0)	0(0)
Pterospora andromedea	5(1)	0(0)	0(0)	0(0)
Sclerocactus whipplei	0(0)	0(0)	0(0)	0(0)
Senecio multilobatus	77(1)	36(1)	100(1)	50(1)
Sphaeralcea coccinea	0(0)	0(0)	0(0)	0(0)
Stephanomeria tenuifolia	5(1)	0(0)	0(0)	0(0)
Swertia radiata	18(1)	18(1)	100(1)	50(1)
Taraxacum officinale	0(0)	0(0)	0(0)	0(0)
Tragapogon dubius	0(0)	0(0)	0(0)	0(0)

APPENDIX C FORTRAN CODE FOR VITAL ATTRIBUTE SIMULATION MODEL

```
C*************************************************************************
C
C       PROGRAM STANDSIM
C
C       A vegetation simulator based on vital attributes
C       theory and fuzzy systems theory.
C
C*************************************************************************
C
      PARAMETER (MAXSPC = 5)              ! maximum number of species
      PARAMETER (MAXHT = 3)               ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)             ! max. number of states (comm.types)
                                          ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)             ! maximum number of age classes
                                          ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)            ! maximum number of replicates
      PARAMETER (MAXITR = 100)            ! max. number of iterations (years/10)
                                          ! MAXITR = max years / 10
C
C* STRUCTURE SPECIES
C
      CHARACTER*16 SPCNAM(MAXSPC)         ! species names
      INTEGER*2    LONGEV(MAXSPC)         ! species longevity
      INTEGER*2    MATURE(MAXSPC)         ! age of sexual maturity
      BYTE         SHDTOL(MAXSPC)         ! shade tolerance
      BYTE         FIRTOL(MAXSPC)         ! fire tolerance
      BYTE         RPOMED(MAXSPC)         ! reproductive method
C
C* STRUCTURE HT
C
      CHARACTER*16 HTNAME(MAXHT)          ! habitat type names
      INTEGER*2    FIRINT(MAXHT)          ! fire return interval
      REAL*4       PRORPO(MAXHT,MAXSPC)   ! probability of repro. by species
      INTEGER*2    FULCRV(MAXHT,5)        ! fuel curve step function
C
C* STRUCTURE SITE
C
      CHARACTER*16 SITNAM                 ! site name (optional)
      INTEGER*2    SITNUM                 ! site number
      INTEGER*2    HT                     ! habitat type
      INTEGER*2    AREA                   ! size
      INTEGER*2    LSTDST                 ! year of last disturbance
      INTEGER*2    PROPAG(MAXSPC)         ! presence of propagules
      BYTE         AGECLS(MAXSPC,MAXACL)  ! age class distribution by species
C
```

```
C* STRUCTURE SYSTEM
C
      INTEGER*4    ABUNDA(MAXITR,MAXSPC) ! abundance of species / iteration
      INTEGER*2    STATE(MAXITR,MAXSTS)  ! community type distribution
      INTEGER*2    MXSTAT(MAXITR)        ! most abundant community type
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                ! number of species in run
      INTEGER*2    NUMHT                 ! number of habitat types
      INTEGER*2    NUMSIT                ! number of sites
      INTEGER*2    NUMREP                ! number of replicates
      INTEGER*2    NUMITR                ! number of iterations
      INTEGER*2    REPNUM                ! current replicate number
      INTEGER*2    ITRNUM                ! current iteration number
C
C* PASSED
C
      INTEGER*4 SPCTOT(MAXITR,MAXSPC)
C
C* LOCAL
C
      INTEGER*4    MNSTAT(MAXITR,MAXSTS)  ! mean community type
      REAL*4       GAMMAD(MAXITR)         ! gamma (community) diversity
      REAL*4       MAXGAM                 ! maximum diversity
      REAL*4       INTFCT                 ! fire return muntiplier
      INTEGER*2    NUMBER
      INTEGER*2    STACK
      INTEGER*2    STKPNT
      INTEGER*2    DFACTR                 ! fire return factor
      INTEGER*2    FIRST                  ! first element of succ. pyramid
      INTEGER*2    LAST                   ! last element of succ. pyramid
      INTEGER*2    THRESH
      INTEGER*4    SEED                   ! random number seed
      INTEGER*4    TOTARE                 ! total area
      INTEGER*2    NUMSTS                 ! number of community typess
      INTEGER*2    PRIME                  ! successional pyramid function
      INTEGER*2    YEAR                   ! current year
      CHARACTER*20 INFILE                 ! input file name
      CHARACTER*20 OUTFIL                 ! output file name
      CHARACTER*20 MAPFIL                 ! map file name
      CHARACTER*1  CHARAC(MAXSTS)
      CHARACTER*1  LINE(100)
      CHARACTER*1  TICK(100)
C
      COMMON / SPECIE / SPCNAM,LONGEV,MATURE,SHDTOL,FIRTOL,RPOMED
      COMMON / HT / HTNAME,PRORPO,FIRINT,FULCRV
      COMMON / SITE / SITNAM,SITNUM,HT,AREA,LSTDST,PROPAG,AGECLS
      COMMON / SYSTEM / ABUNDA,STATE,MXSTAT
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,ITRNUM
C
```

```
C* STANDSIM ************************* ONE ******************************
C
C       Block one prompts the user for characteristics of the current
C       simulation.  Certain values are bounded by defaults to prevent
C       entering unrealistic values.
C
C***********************************************************************
C
   11 WRITE(6,100)
      READ(5,110,ERR=11) NUMYRS
      IF (NUMYRS .GT. MAXITR*10) NUMYRS = MAXITR*10
      NUMITR = NUMYRS / 10
C
   12 WRITE(6,120)
      READ(5,110,ERR=22) NUMREP
      IF (NUMREP .GT. MAXREP) NUMREP = MAXREP
C
   13 WRITE(6,130)
      READ(5,110,ERR=13) DFACTR
      IF (DFACTR .GT. 5) DFACTR = 5
      IF (DFACTR .LT. 0) DFACTR = 0
C
      WRITE(6,131)
      READ(5,132) INTFCT
C
   14 WRITE(6,140)
      READ(5,110,ERR=14) THRESH
      IF (THRESH .LT. 0) THRESH = 0
      IF (THRESH .GT. 50) THRESH = 50
C
   15 WRITE(6,150)
      READ(5,110,ERR=15) SEED
C
   16 WRITE(6,160)
      READ(5,170,ERR=16) INFILE
C
   17 WRITE(6,180)
      READ(5,170,ERR=17) OUTFIL
C
  100 FORMAT (' ENTER NUMBER OF YEARS TO SIMULATE',T40,' : ',$)
  110 FORMAT (I6)
  120 FORMAT (' ENTER NUMBER OF REPLICATES',T40,' : ',$)
  130 FORMAT (' ENTER DISTURBANCE FACTOR',T40,' : ',$)
  131 FORMAT (' ENTER FIRE RETURN MULTIPLIER',T40,' : ',$)
  132 FORMAT (F5.2)
  140 FORMAT (' ENTER THRESHOLD',T40,' : ',$)
  150 FORMAT (' ENTER RANDOM NUMBER SEED',T40,' : ',$)
  160 FORMAT (' ENTER INPUT FILE NAME',T40,' : ',$)
  170 FORMAT (A20)
  180 FORMAT (' ENTER OUTPUT FILE NAME',T40,' : ',$)
  190 FORMAT (' ENTER MAP FILE NAME',T40,' : ',$)
```

```
C
C STANDSIM ********************************* TWO **********************
C
C     Block two gets the species vital attributes and the habitat type
C     infromation, and writes some header information to the output file
C
C*************************************************************************
C
      CALL SGETSP
      NUMSTS = PRIME(NUMSPC)
C
      CALL SGETHT
C
      DO 26 I=1,NUMHT
      FIRINT(I) = FIRINT(I) * INTFCT
   26 CONTINUE
C
      OPEN (UNIT=1,FILE=INFILE,STATUS='OLD',SHARED,READONLY,ERR=21)
      OPEN (UNIT=2,FILE=OUTFIL,STATUS='NEW',CARRIAGECONTROL='FORTRAN',
     +      ERR=22)
      GOTO 24
C
   21 WRITE(6,200) INFILE
      STOP
   22 WRITE(6,200) OUTFILE
      STOP
C
   24 WRITE(2,210) NUMYRS
      WRITE(2,220) NUMREP
      WRITE(2,230) DFACTR
      WRITE(2,240) SEED
C
  200 FORMAT (' ','ERROR OPENING FILE',A20,' CHECK THE FILE')
  210 FORMAT (' ','NUMBER OF YEARS SIMULATED ',T40,I4)
  220 FORMAT (' ','NUMBER OF REPLICATES',T40,I4)
  230 FORMAT (' ','DISTURBANCE FACTOR',T40,I4)
  240 FORMAT (' ','RANDOM NUMBER SEED',T40,I6)
C
```

```
C* STANDSIM ********************** THREE ******************************
C
C     Block three is the basic loop of the simulation model.  Loop 30
C     controls how many replicate simulations are performed.  CALL SGETST
C     initiates each simulation with identical statrting conditions.  Loop
C     31 controls how many iterations (years/10) that the model simulates
C
C*************************************************************************
C
      DO 30 REPNUM=1,NUMREP                  ! loop for replicates
      CALL SGETST (TOTARE)                   ! get initial conditions
        DO 31 ITRNUM=1,NUMITR                ! loop for eacg iteration
        CALL SGROW                           ! grow trees 10 years
        CALL SDIST (DFACTR,SEED)             ! calculate disturbance effects
        CALL SREPRO (SEED)                   ! reproduce trees
   31   CONTINUE
      CALL SSYSTT (SPCTOT)                   ! determine replicate community
   30 CONTINUE                               !      type distribution
C
C* STANDSIM ********************** FOUR ***********************************
C
C     Block four calculates some of the summary statistics of the simulation,
C     prints out the community type distribution graph, and sets up the line
C     printer graph (l.p.) for some of the outputs.
C
C*************************************************************************
C
      CALL SETCHR(CHARAC)                    ! set up line printer output
      CALL SETTCK(TICK)                      !
      CALL CLEAR(LINE)                       !
C
      DO 40 I=1,NUMITR                       ! for each iteration
        DO 41 J=1,NUMSTS                     ! for all states (community types)
        MNSTAT(I,J) = 0                      ! initialize mean state
   41   CONTINUE
C
        DO 42 J=1,NUMSTS                     ! for all states
        MNSTAT(I,J) = MNSTAT(I,J) + STATE(I,J) / NUMREP ! calculate means
   42   CONTINUE
   40 CONTINUE
C
      WRITE(2,400)
      WRITE(2,410) (TICK(I),I=1,100)
C
```

```
      YEAR = 0
      DO 43 I=1,NUMITR                    !  / iteration
      YEAR = YEAR + 10
        DO 44 J=1,NUMSTS                  ! for all states
        IF (MNSTAT(I,J) .GT. 0 .AND. MNSTAT(I,J) .LE. 100) THEN
          LINE(MNSTAT(I,J)) = CHARAC(J)   ! l.p. graph for comm. types.
          P = FLOAT(MNSTAT(I,J)) / 100.0
          GAMMAD(I) = GAMMAD(I) + ( -P * LOG(P)) ! l.p. graph for diversity
        ENDIF
   44   CONTINUE
      WRITE(2,420) YEAR,LINE
      CALL CLEAR(LINE)
   43 CONTINUE
C
  400 FORMAT ('0',' PLOT OF FUZZY SYSTEM TRAJECTORY')
  410 FORMAT (7X,100A1)
  420 FORMAT (1X,I4,2X,100A1)
C
C* STANDSIM ********************** FIVE ********************************
C
C     Block five relativizes and smooths the diversity output data
C
C*************************************************************************
C
      MAXGAM = LOG(FLOAT(NUMSTS))
C
      DO 62 I=1,NUMITR
      GAMMAD(I) = (GAMMAD(I) * 100) / MAXGAM
   62 CONTINUE
C
      GAMMAD(1) = (2 * GAMMAD(1) + GAMMAD(2)) / 3
      GAMMAD(2) = (GAMMAD(1) + 2 * GAMMAD(2)) / 3
      DO 63 I=3,NUMITR-2
      GAMMAD(I) = (GAMMAD(I-2) + 2*GAMMAD(I-1) + 3*GAMMAD(I) +
     +             2*GAMMAD(I+1) + GAMMAD(I+2)) / 9
   63 CONTINUE
      GAMMAD(NUMITR-1) = (2*GAMMAD(NUMITR-1) + GAMMAD(NUMITR)) / 3
      GAMMAD(NUMITR) = (GAMMAD(NUMITR-1) + 2*GAMMAD(NUMITR)) / 3
C
```

```
C* STANDSIM ***************************** SEVEN ****************************
C
C     Block seven prints out the gamma diversity line printer graph
C
C*******************************************************************************
C
      WRITE(2,700)
      CALL CLEAR(LINE)
      WRITE(2,710) TICK
C
      YEAR = 0
      DO 70 I=1,NUMITR
      YEAR = YEAR + 10
C
      IF (GAMMAD(I) .LT. 1.0) THEN
        LINE(1) = 'G'
      ELSE IF (GAMMAD(I) .GT. 100) THEN
        LINE(100) = 'G'
      ELSE
        LINE(GAMMAD(I)) = 'G'
      ENDIF
C
      WRITE(2,720) YEAR,(LINE(J),J=1,100)
      CALL CLEAR(LINE)
   70 CONTINUE
C
  700 FORMAT ('1',' PLOT OF GAMMA DIVERSITY (G)',
     +            ' AS PERCENT OF MAXIMUM POSSIBLE',/)
  710 FORMAT (7X,100A1)
  720 FORMAT (1X,I4,2X,100A1)
C
```

```
C* STANDSIM ********************** EIGHT ********************************
C
C     Block eight prints out the individual species abundance curves for
C     the simulation.  Curves are RELATIVE species abundance.
C
C*****************************************************************************
C
      WRITE(2,930)
      WRITE(2,940) (TICK(I),I=1,100)
C
      YEAR = 0
      DO 96 I=1,NUMITR
      TOTPYR = 0
        DO 97 J=1,NUMSPC
        TOTPYR = TOTPYR + SPCTOT(I,J)
   97   CONTINUE
C
      IF (TOTPYR .EQ. 0) TOTPYR = 1
C
        DO 98 J=1,NUMSPC
        SPCTOT(I,J) = SPCTOT(I,J) * 100 / TOTPYR
        IF (SPCTOT(I,J) .GT. 0) LINE(SPCTOT(I,J)) = CHARAC(J)
   98   CONTINUE
C
      WRITE(2,950) I*10,LINE
      CALL CLEAR(LINE)
   96 CONTINUE
C
  930 FORMAT ('1',' PLOT OF SPECIES ABUNDANCE ',/)
  940 FORMAT (7X,100A1)
  950 FORMAT (I4,3X,100A1)
C
      END
C
```

```
C* LANDSIM/GETSPC ************ SUBROUTINE SGETSP ************************
C
C     SUBROUTINE SGETSP gets the vital attribute data for each species
C     included in the simulation.  These data reside in file SPECIES.DAT,
C     and can be simply modified with a text editor.
C
C*************************************************************************
C
      SUBROUTINE SGETSP
C
      PARAMETER (MAXSPC = 5)              ! maximum number of species
      PARAMETER (MAXHT = 3)               ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)             ! max. number of states (comm.types)
                                          ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)             ! maximum number of age classes
                                          ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)            ! maximum number of replicates
      PARAMETER (MAXITR = 100)            ! max. number of iterations (years/10)
                                          ! MAXITR = max years / 10
C
C* STRUCTURE SPECIES
C
      CHARACTER*16 SPCNAM(MAXSPC)         ! species names
      INTEGER*2    LONGEV(MAXSPC)         ! species longevity
      INTEGER*2    MATURE(MAXSPC)         ! age of sexual maturity
      BYTE         SHDTOL(MAXSPC)         ! shade tolerance
      BYTE         FIRTOL(MAXSPC)         ! fire tolerance
      BYTE         RPOMED(MAXSPC)         ! reproductive method
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                 ! number of species in run
      INTEGER*2    NUMHT                  ! number of habitat types
      INTEGER*2    NUMSIT                 ! number of sites
      INTEGER*2    NUMREP                 ! number of replicates
      INTEGER*2    NUMITR                 ! number of iterations
      INTEGER*2    REPNUM                 ! current replicate number
      INTEGER*2    ITRNUM                 ! current iteration number
C
      COMMON / SPECIE / SPCNAM,LONGEV,MATURE,SHDTOL,FIRTOL,RPOMED
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,YEAR
C
```

```
      OPEN (UNIT=1,FILE='SPECIES.DAT',STATUS='OLD',SHARED,
     +      READONLY,ERR=12)
C
      NUMSPC = 0
   10 READ(1,100,END=11,ERR=13) SPCNAM(NUMSPC+1),LONGEV(NUMSPC+1),
     +                          MATURE(NUMSPC+1),SHDTOL(NUMSPC+1),
     +                          FIRTOL(NUMSPC+1),RPOMED(NUMSPC+1)
      IF (NUMSPC .LT. MAXSPC) THEN          ! check to make sure room
        NUMSPC = NUMSPC + 1                 ! if so, add to list
        GOTO 10
      ELSE
        WRITE(6,110) SPCNAM(NUMSPC+1)       ! if not, warn and exit
        GOTO 11
      ENDIF
C
   12 WRITE(6,120)                          ! error message for file open
      STOP
   13 WRITE(6,130) SPCNAM(NUMSPC)           ! error message for file read
      STOP
C
   11 CLOSE (1)
      RETURN
C
  100 FORMAT (A16,T20,4(I5),4X,A1)
  110 FORMAT (' TOO MANY SPECIES, AFTER ',A16,' IGNORED')
  120 FORMAT (' ERROR OPENING SPECIES.DAT ')
  130 FORMAT (' ERROR READING SPECIES.DAT, LAST SPECIES READ = ',A16)
C
      END
C
C* LANDSIM/GETSIT ****************** SUBROUTINE SGETST **************
C
C     SUBROUTINE SGETST gets the site data for the site to be simulated.
C     Data reside in a file specified by the user at run time.  This file
C     re-read at the beginning of each replicate
C
C*********************************************************************
C
      SUBROUTINE SGETST (TOTARE)
C
      PARAMETER (MAXSPC = 5)            ! maximum number of species
      PARAMETER (MAXHT = 3)             ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)           ! max. number of states (comm.types)
                                        ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)           ! maximum number of age classes
                                        ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)          ! maximum number of replicates
      PARAMETER (MAXITR = 100)          ! max. number of iterations (years/10)
```

```
C
C* STRUCTURE SITE
C
      CHARACTER*16 SITNAM                ! site name (optional)
      INTEGER*2    SITNUM                ! site number
      INTEGER*2    HT                    ! habitat type
      INTEGER*2    AREA                  ! size
      INTEGER*2    LSTDST                ! year of last disturbance
      INTEGER*2    PROPAG(MAXSPC)        ! presence of propagules
      BYTE         AGECLS(MAXSPC,MAXACL) ! age class distribution by species
C                                        ! MAXITR = max years / 10
C* STRUCTURE SPECIES
C
      CHARACTER*16 SPCNAM(MAXSPC)       ! species names
      INTEGER*2    LONGEV(MAXSPC)       ! species longevity
      INTEGER*2    MATURE(MAXSPC)       ! age of sexual maturity
      BYTE         SHDTOL(MAXSPC)       ! shade tolerance
      BYTE         FIRTOL(MAXSPC)       ! fire tolerance
      BYTE         RPOMED(MAXSPC)       ! reproductive method
C
C* STRUCTURE HT
C
      CHARACTER*16 HTNAME(MAXHT)         ! habitat type names
      INTEGER*2    FIRINT(MAXHT)         ! fire return interval
      REAL*4       PRORPO(MAXHT,MAXSPC)  ! probability of repro. by species
      INTEGER*2    FULCRV(MAXHT,5)       ! fuel curve step function
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                ! number of species in run
      INTEGER*2    NUMHT                 ! number of habitat types
      INTEGER*2    NUMSIT                ! number of sites
      INTEGER*2    NUMREP                ! number of replicates
      INTEGER*2    NUMITR                ! number of iterations
      INTEGER*2    REPNUM                ! current replicate number
      INTEGER*2    ITRNUM                ! current iteration number
C
C* LOCAL
C
      CHARACTER*16 TEMHT
      CHARACTER*16 TSPNAM
      INTEGER*4    TOTARE
      INTEGER*2    NSPSTD
      INTEGER*2    TEMPRO
      BYTE         TAGCLS(MAXACL)
C
      COMMON / SITE / SITNAM,SITNUM,HT,AREA,LSTDST,PROPAG,AGECLS
      COMMON / SPECIE / SPCNAM,LONGEV,MATURE,SHDTOL,FIRTOL,RPOMED
      COMMON / HT / HTNAME,PRORPO,FIRINT,FULCRV
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,ITRNUM
C
```

```
      REWIND (1)
C
      WRITE(6,170) REPNUM                ! replicate counter to output device
C
      TOTARE = 0
      READ(1,100,ERR=12) SITNUM,SITNAM,          ! read basic data
     +                   TEMHT,LSTDST,
     +                   NUMNBR,NSPSTD,AREA
C
      TOTARE = TOTARE + AREA
        DO 13 J=1,NUMHT
        IF (TEMHT .EQ. HTNAME(J)) THEN     ! determine habitat type number
          HT = J
          GOTO 14
        ENDIF
   13   CONTINUE
C
        WRITE(6,110) SITNUM,TEMHT          ! habitat type not found in list
        STOP
   12   WRITE(6,120) SITNUM                ! error reading site data file
        STOP
C
   14  LSTDST = -LSTDST                    ! set last disturbance date
C
        DO 15 J=1,NSPSTD                   ! for each species in stand
C
        READ(1,140) TSPNAM,TEMPRO,(TAGCLS(K),K=1,MAXACL)
          DO 16 K=1,NUMSPC                 ! for all possible species
          IF (TSPNAM .EQ. SPCNAM(K)) THEN  ! chech against species list
            IF (PRORPO(HT,K) .GT. 0) THEN  ! check for repro. potential
              PROPAG(K) = TEMPRO           ! establish propagules
              DO 17 L=1,MAXACL             ! set up age class structure
              AGECLS(K,L) = TAGCLS(L)
   17         CONTINUE
              GOTO 15
            ELSE                           ! zero out if not in type
              DO 18 L=1,MAXACL
              AGECLS(K,L) = 0
   18         CONTINUE
              GOTO 15
            ENDIF
          ENDIF
   16     CONTINUE
C
        WRITE(6,150) SITNUM,TSPNAM         ! species name not recognized
        STOP
C
   15   CONTINUE
C
      RETURN
C
```

```
  100 FORMAT (I4,2(2X,A16),4I4)
  110 FORMAT (' ERROR IN FILE, SITE ',I4,' OF ',I4,' HT ',A16)
  120 FORMAT (' ERROR READING SITE FILE, LAST PLOT READ = ',I4)
  130 FORMAT (10I4)
  140 FORMAT (A16,2X,I2,2X,50I1)
  150 FORMAT (' ERROR IN FILE, SITE ',I4,' SPECIES ',A16)
  160 FORMAT (' TOO MANY SITES, LAST SITE READ = ',I4)
  170 FORMAT ('0',' STARTING REPLICATE ',I3)
  180 FORMAT (' ',I3,' PLOTS READ ')
C
      END
C
C* LANDSIM/GROW ********************** SUBROUTINE GROW ********************
C
C     SUBROUTINE SGROW grows each species for 10 years by updating age class
C     distribution
C
C*************************************************************************
C
      SUBROUTINE SGROW
C
      PARAMETER (MAXSPC = 5)              ! maximum number of species
      PARAMETER (MAXHT = 3)               ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)             ! max. number of states (comm.types)
                                          ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)             ! maximum number of age classes
                                          ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)            ! maximum number of replicates
      PARAMETER (MAXITR = 100)            ! max. number of iterations (years/10)
                                          ! MAXITR = max years / 10
C
C* STRUCTURE SPECIES
C
      CHARACTER*16 SPCNAM(MAXSPC)         ! species names
      INTEGER*2    LONGEV(MAXSPC)         ! species longevity
      INTEGER*2    MATURE(MAXSPC)         ! age of sexual maturity
      BYTE         SHDTOL(MAXSPC)         ! shade tolerance
      BYTE         FIRTOL(MAXSPC)         ! fire tolerance
      BYTE         RPOMED(MAXSPC)         ! reproductive method
C
C* STRUCTURE SITE
C
      CHARACTER*16 SITNAM                  ! site name (optional)
      INTEGER*2    SITNUM                  ! site number
      INTEGER*2    HT                      ! habitat type
      INTEGER*2    AREA                    ! size
      INTEGER*2    LSTDST                  ! year of last disturbance
      INTEGER*2    PROPAG(MAXSPC)          ! presence of propagules
      BYTE         AGECLS(MAXSPC,MAXACL)   ! age class distribution by species
C
```

```
C* STRUCTURE SYSTEM
C
      INTEGER*4    ABUNDA(MAXITR,MAXSPC) ! abundance of species  / iteration
      INTEGER*2    STATE(MAXITR,MAXSTS)  ! community type distribution
      INTEGER*2    MXSTAT(MAXITR)        ! most abundant community type
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                ! number of species in run
      INTEGER*2    NUMHT                 ! number of habitat types
      INTEGER*2    NUMSIT                ! number of sites
      INTEGER*2    NUMREP                ! number of replicates
      INTEGER*2    NUMITR                ! number of iterations
      INTEGER*2    REPNUM                ! current replicate number
      INTEGER*2    ITRNUM                ! current iteration number
C
C* LOCAL
C
      INTEGER*2    MAXAGE(MAXSPC)
C
      COMMON / SPECIE / SPCNAM,LONGEV,MATURE,SHDTOL,FIRTOL,RPOMED
      COMMON / SITE / SITNAM,SITNUM,HT,AREA,LSTDST,PROPAG,AGECLS
      COMMON / SYSTEM / ABUNDA,STATE,MXSTAT
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,ITRNUM
C
C* LANDSIM/GROW ***************************************************
C
      DO 10 I=1,NUMSPC                    ! for each species
      MAXAGE(I) = 0                       ! zero out maximum age
        DO 11 J=LONGEV(I)/10,2,-1         ! for all age classes
        AGECLS(I,J) = AGECLS(I,J-1)       ! update age class
        IF (AGECLS(I,J) .NE. 0) THEN      ! establish max age class
          MAXAGE(I) = MAX(MAXAGE(I),J*10)
        ENDIF
   11  CONTINUE
C
      IF (RPOMED(I) .EQ. 'V') THEN            ! if vege reproducer
        IF (MAXAGE(I) .GT. MATURE(I)) THEN    ! see if mature and set props.
          PROPAG(I) = MIN(LONGEV(I)-MATURE(I),PROPAG(I)+10)
        ELSE
          PROPAG(I) = MAX(0,PROPAG(I) - 10)   ! if not mature, decre storage
        ENDIF
      ELSE IF (RPOMED(J) .EQ. 'C') THEN       ! if serot. cone
        IF (MAXAGE(I) .GE. MATURE(I)) PROPAG(I) = 30   ! if mature, set to 30
      ELSE IF (RPOMED(J) .EQ. 'D') THEN
        IF (MAXAGE(I) .GE. MATURE(I)) PROPAG(I) = 10   ! if not mature, decre
      ENDIF
C
```

```
      ABUNDA(ITRNUM,I) = 0                          ! zero out abundance
        DO 12, J=1,MAXAGE(I)/10                     ! for all age classes
        ABUNDA(ITRNUM,I) = ABUNDA(ITRNUM,I) + AGECLS(I,J)*J  ! sum if present
   12   CONTINUE
C
   10 CONTINUE
C
      RETURN
C
      END
C
C* STANDSIM/DIST ********** SUBROUTINE SDIST ******************************
C
C     SUBROUTINE SDIST calculates the occurrence and effects of disturbance
C     (fire).
C
C*************************************************************************
C
      SUBROUTINE SDIST(DFACTR,SEED)
C
      PARAMETER (MAXSPC = 5)              ! maximum number of species
      PARAMETER (MAXHT = 3)               ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)             ! max. number of states (comm.types)
                                          ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)             ! maximum number of age classes
                                          ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)            ! maximum number of replicates
      PARAMETER (MAXITR = 100)            ! max. number of iterations (years/10)
                                          ! MAXITR = max years / 10
C
C* STRUCTURE SPECIES
C
      CHARACTER*16 SPCNAM(MAXSPC)         ! species names
      INTEGER*2    LONGEV(MAXSPC)         ! species longevity
      INTEGER*2    MATURE(MAXSPC)         ! age of sexual maturity
      BYTE         SHDTOL(MAXSPC)         ! shade tolerance
      BYTE         FIRTOL(MAXSPC)         ! fire tolerance
      BYTE         RPOMED(MAXSPC)         ! reproductive method
C
C* STRUCTURE HT
C
      CHARACTER*16 HTNAME(MAXHT)          ! habitat type names
      INTEGER*2    FIRINT(MAXHT)          ! fire return interval
      REAL*4       PRORPO(MAXHT,MAXSPC)   ! probability of repro. by species
      INTEGER*2    FULCRV(MAXHT,5)        ! fuel curve step function
C
```

```
C* STRUCTURE SITE
C
      CHARACTER*16 SITNAM                ! site name (optional)
      INTEGER*2    SITNUM                ! site number
      INTEGER*2    HT                    ! habitat type
      INTEGER*2    AREA                  ! size
      INTEGER*2    LSTDST                ! year of last disturbance
      INTEGER*2    PROPAG(MAXSPC)        ! presence of propagules
      BYTE         AGECLS(MAXSPC,MAXACL) ! age class distribution by species
C
C* STRUCTURE SYSTEM
C
      INTEGER*4    ABUNDA(MAXITR,MAXSPC) ! abundance of species  / iteration
      INTEGER*2    STATE(MAXITR,MAXSTS)  ! community type distribution
      INTEGER*2    MXSTAT(MAXITR)        ! most abundant community type
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                ! number of species in run
      INTEGER*2    NUMHT                 ! number of habitat types
      INTEGER*2    NUMSIT                ! number of sites
      INTEGER*2    NUMREP                ! number of replicates
      INTEGER*2    NUMITR                ! number of iterations
      INTEGER*2    REPNUM                ! current replicate number
      INTEGER*2    ITRNUM                ! current iteration number
C
C* LOCAL
C
      INTEGER*2    TIME
      INTEGER*2    YEAR
      INTEGER*2    DFACTR
      INTEGER*4    SEED
C
      COMMON / SPECIE / SPCNAM,LONGEV,MATURE,SHDTOL,FIRTOL,RPOMED
      COMMON / HT / HTNAME,PRORPO,FIRINT,FULCRV
      COMMON / SITE / SITNAM,SITNUM,HT,AREA,LSTDST,PROPAG,AGECLS
      COMMON / SYSTEM / ABUNDA,STATE,MXSTAT
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,ITRNUM
C
      YEAR = ITRNUM * 10
      TIME = 0
      PROB = (1.0 - (FLOAT(DFACTR) / FLOAT(FIRINT(HT)))) ** 10
      TEST = RAN(SEED)                   ! set random number
      IF (TEST .GE. PROB) THEN           ! test against probability
        TIME = YEAR - LSTDST             ! FIRE! set up
        LSTDST = YEAR
      ENDIF
C
```

```
C* STANDSIM/DIST ****************** TWO ****************************
C
      IF (TIME .NE. 0) THEN           ! determine severity class
        SEVERE = 1
        DO 31 I=1,5
        IF (TIME .GE. FULCRV(HT,I)) SEVERE = I
   31  CONTINUE
C
        DO 32 I=1,NUMSPC                    ! for each species
        IF (SEVERE .GT. FIRTOL(I)) THEN     ! severity gt tolerance
          DO 33 J=1,LONGEV(I)/10            !    kill all age classes
          AGECLS(I,J) = 0
   33     CONTINUE
        ELSE                                ! severity lt tolerance
          DO 34 J=1,(6-(FIRTOL(I)-SEVERE))  !    kill young age classes
          AGECLS(I,J) = 0
   34     CONTINUE
        ENDIF
C
        ABUNDA(ITRNUM,I) = 0                ! recalculate abundance
        DO 35 J=1,LONGEV(I)/10
          ABUNDA(ITRNUM,I) = ABUNDA(ITRNUM,I) + AGECLS(I,J)*J
   35     CONTINUE
   32   CONTINUE
      ENDIF
C
      RETURN
C
      END
C
C* LANDSIM/REPROD ************ SUBROUTINE SREPRO ************************
C
C     SUBROUTINE SREPRO establishes reproduction for each species
C
C*******************************************************************************
C
      SUBROUTINE SREPRO (SEED)
C
      PARAMETER (MAXSPC = 5)            ! maximum number of species
      PARAMETER (MAXHT = 3)             ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)           ! max. number of states (comm.types)
                                        ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)           ! maximum number of age classes
                                        ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)          ! maximum number of replicates
      PARAMETER (MAXITR = 100)          ! max. number of iterations (years/10)
                                        ! MAXITR = max years / 10
C
```

```
C* STRUCTURE SPECIES
C
      CHARACTER*16 SPCNAM(MAXSPC)        ! species names
      INTEGER*2    LONGEV(MAXSPC)        ! species longevity
      INTEGER*2    MATURE(MAXSPC)        ! age of sexual maturity
      BYTE         SHDTOL(MAXSPC)        ! shade tolerance
      BYTE         FIRTOL(MAXSPC)        ! fire tolerance
      BYTE         RPOMED(MAXSPC)        ! reproductive method
C
C* STRUCTURE HT
C
      CHARACTER*16 HTNAME(MAXHT)          ! habitat type names
      INTEGER*2    FIRINT(MAXHT)          ! fire return interval
      REAL*4       PRORPO(MAXHT,MAXSPC)   ! probability of repro. by species
      INTEGER*2    FULCRV(MAXHT,5)        ! fuel curve step function
C
C* STRUCTURE SITE
C
      CHARACTER*16 SITNAM                 ! site name (optional)
      INTEGER*2    SITNUM                 ! site number
      INTEGER*2    HT                     ! habitat type
      INTEGER*2    AREA                   ! size
      INTEGER*2    LSTDST                 ! year of last disturbance
      INTEGER*2    PROPAG(MAXSPC)         ! presence of propagules
      BYTE         AGECLS(MAXSPC,MAXACL)  ! age class distribution by species
C
C* STRUCTURE SYSTEM
C
      INTEGER*4    ABUNDA(MAXITR,MAXSPC)  ! abundance of species  / iteration
      INTEGER*2    STATE(MAXITR,MAXSTS)   ! community type distribution
      INTEGER*2    MXSTAT(MAXITR)         ! most abundant community type
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                 ! number of species in run
      INTEGER*2    NUMHT                  ! number of habitat types
      INTEGER*2    NUMSIT                 ! number of sites
      INTEGER*2    NUMREP                 ! number of replicates
      INTEGER*2    NUMITR                 ! number of iterations
      INTEGER*2    REPNUM                 ! current replicate number
      INTEGER*2    ITRNUM                 ! current iteration number
C
C* LOCAL
C
      INTEGER*4 SEED
      INTEGER*2 SHADE
      INTEGER*2 TOLERA
C
```

```
      COMMON / SPECIE / SPCNAM,LONGEV,MATURE,SHDTOL,FIRTOL,RPOMED
      COMMON / HT / HTNAME,PRORPO,FIRINT,FULCRV
      COMMON / SITE / SITNAM,SITNUM,HT,AREA,LSTDST,PROPAG,AGECLS
      COMMON / SYSTEM / ABUNDA,STATE,MXSTAT
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,ITRNUM
C
C* LANDSIM/REPROD ******************** ONE ************************
C
      SHADE = 0
      DO 10 I=1,NUMSPC                          ! for each species
      IF (ABUNDA(ITRNUM,I) .GE. 6)  THEN        ! if abundant
        TOLERA = SHDTOL(I)
        SHADE = MAX(SHADE,TOLERA)               ! determine shadiness
      ENDIF
   10 CONTINUE
C
      DO 11 I=1,NUMSPC                          ! for each species
      TEST = RAN(SEED)                          ! get random number
      AGECLS(I,1) = 0
      IF (PRORPO(HT,I) .GT. TEST) THEN          ! if repro possible
        IF (SHDTOL(I) .GE. SHADE .AND.          ! if not too shady
     +          SHDTOL(I)-SHADE .LE. 4) THEN
          IF (PROPAG(I) .GT. 0) AGECLS(I,1) = 1         ! estab repro
          IF (RPOMED(I) .EQ. 'D') AGECLS(I,1) = 1       ! estab repro
        ENDIF
      ENDIF
   11 CONTINUE
C
      RETURN
C
      END
C
C* LANDSIM/SYSTAT ********** SUBROUTINE SYSTAT ************************
C
C     SUBROUTINE SSUSTT calculates the community type distribution at
C     the end of each simulation replicate
C
C*********************************************************************
C
      SUBROUTINE SSYSTT (SPCTOT)
C
      PARAMETER (MAXSPC = 5)              ! maximum number of species
      PARAMETER (MAXHT = 3)               ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)             ! max. number of states (comm.types)
                                          ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)             ! maximum number of age classes
                                          ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)            ! maximum number of replicates
      PARAMETER (MAXITR = 100)            ! max. number of iterations (years/10)
                                          ! MAXITR = max years / 10
```

```
C
C* STRUCTURE SITE
C
      CHARACTER*16 SITNAM                ! site name (optional)
      INTEGER*2    SITNUM                ! site number
      INTEGER*2    HT                    ! habitat type
      INTEGER*2    AREA                  ! size
      INTEGER*2    LSTDST                ! year of last disturbance
      INTEGER*2    PROPAG(MAXSPC)        ! presence of propagules
      BYTE         AGECLS(MAXSPC,MAXACL) ! age class distribution by species
C
C* STRUCTURE SYSTEM
C
      INTEGER*4    ABUNDA(MAXITR,MAXSPC) ! abundance of species  / iteration
      INTEGER*2    STATE(MAXITR,MAXSTS)  ! community type distribution
      INTEGER*2    MXSTAT(MAXITR)        ! most abundant community type
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                ! number of species in run
      INTEGER*2    NUMHT                 ! number of habitat types
      INTEGER*2    NUMSIT                ! number of sites
      INTEGER*2    NUMREP                ! number of replicates
      INTEGER*2    NUMITR                ! number of iterations
      INTEGER*2    REPNUM                ! current replicate number
      INTEGER*2    ITRNUM                ! current iteration number
C
C* LOCAL
C
      INTEGER*4 TOTAL
      INTEGER*2 FIRST
      INTEGER*2 LAST
      INTEGER*2 LEAST
      INTEGER*2 PRIME
      INTEGER*4 SPCTOT(MAXITR,MAXSPC)
C
      COMMON / SITE / SITNAM,SITNUM,HT,AREA,LSTDST,PROPAG,AGECLS
      COMMON / SYSTEM / ABUNDA,STATE,MXSTAT
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,ITRNUM
C
```

```
C* LANDSIM/SYSTAT ************** ONE ***********************************
C
      DO 10 I=1,NUMITR                                  ! for each iteration
      TOTAL = 0
        DO 11 J=1,NUMSPC                                ! for each species
        SPCTOT(I,J) = SPCTOT(I,J) + ABUNDA(I,J)         ! calc. species total
        TOTAL = TOTAL + ABUNDA(I,J)                     ! calculate total
   11   CONTINUE
C
        IF (TOTAL .EQ. 0) TOTAL = 1
C
        DO 12 J=1,NUMSPC                                ! for each species
        ABUNDA(I,J) = (ABUNDA(I,J) * 100) / TOTAL       ! relativize total
   12   CONTINUE
   10 CONTINUE
C
C* LANDSIM/SYSTAT ******************* TWO ***************************
C
      DO 20 I=1,NUMITR                                  ! for each iteration
        DO 21 J=1,NUMSPC                                ! for each species
        IF (ABUNDA(I,J) .GT. 0.0) THEN                  ! if present, calc pyramid
          LEAST = J
          FIRST = PRIME(NUMSPC) - PRIME(NUMSPC-(J-1)) + 1
          LAST = FIRST + PRIME(NUMSPC-(J-1)) - PRIME(NUMSPC-J) - 1
          GOTO 22
        ENDIF
   21   CONTINUE
C
        LEAST = 1                                       ! default pyramid
        FIRST = 1
        LAST = NUMSPC
   22   MAXPNT = 0
        DO 23 J=FIRST,LAST                              ! calc. comm. type dist.
        STATE(I,J) = STATE(I,J) +
     +                          ABUNDA(I,LEAST)
        IF (ABUNDA(I,LEAST) .GT. MAXPNT) THEN           ! calc. most common
          MXSTAT(I) = J
          MAXPNT = ABUNDA(I,LEAST)
        ENDIF
        LEAST = LEAST + 1
   23   CONTINUE
   20 CONTINUE
C
      RETURN
C
      END
C
```

```
C* LANDSIM/SETCHR ************ SUBROUTINE SETCHR **************
C
      SUBROUTINE SETCHR(CHARAC)
C
      PARAMETER (MAXSTS = 50)
C
      CHARACTER*1 CHARAC(MAXSTS)
C
      DO 10 I=1,26
      CHARAC(I) = CHAR(I+64)
   10 CONTINUE
C
      DO 11 I=27,MAXSTS
      CHARAC(I) = CHAR(I+70)
   11 CONTINUE
C
      RETURN
C
      END
C
C* LANDSIM/SETTCK ************** SUBROUTINE SETTCK ********************
C
      SUBROUTINE SETTCK(TICK)
C
      CHARACTER*1 TICK(100)
C
      DO 10 I=1,100
      TICK(I) = ' '
   10 CONTINUE
C
      DO 11 I=10,100,10
      TICK(I) = '+'
   11 CONTINUE
C
      RETURN
C
      END
C
C* LANDSIM/CLEAR *************** SUBROUTINE CLEAR ****************
C
      SUBROUTINE CLEAR(LINE)
C
      CHARACTER*1 LINE(100)
C
      DO 10 I=1,100
      LINE(I) = ' '
   10 CONTINUE
C
      RETURN
C
      END
```

```
C
C* STANSIM/PRIME *************** SUBROUTINE PRIME ********************
C
      INTEGER FUNCTION PRIME*2 (NUMSPC)
C
      INTEGER*2 NUMSPC
C
      PRIME = (NUMSPC**2 + NUMSPC) / 2
C
      RETURN
C
      END
C
C* LANDSIM/GETHT ****************** SUBROUTINE SGETHT **********************
C
C     SUBROUTINE SGETHT gets the habitat type characteristics from file
C     HT.DAT.  These data set up a large number of parameters.
C
C*******************************************************************************
C
      SUBROUTINE SGETHT
C
      PARAMETER (MAXSPC = 5)            ! maximum number of species
      PARAMETER (MAXHT = 3)             ! maximum number of habitat types
      PARAMETER (MAXSTS = 15)           ! max. number of states (comm.types)
                                        ! MAXSTS = (MAXSPC**2 + MAXSPC) / 2
      PARAMETER (MAXACL = 50)           ! maximum number of age classes
                                        ! MAXACL = max age / 10
      PARAMETER (MAXREP = 100)          ! maximum number of replicates
      PARAMETER (MAXITR = 100)          ! max. number of iterations (years/10)
                                        ! MAXITR = max years / 10
C
C* STRUCTURE HT
C
      CHARACTER*16 HTNAME(MAXHT)         ! habitat type names
      INTEGER*2    FIRINT(MAXHT)         ! fire return interval
      REAL*4       PRORPO(MAXHT,MAXSPC)  ! probability of repro. by species
      INTEGER*2    FULCRV(MAXHT,5)       ! fuel curve step function
C
C* STRUCTURE PARAMS
C
      INTEGER*2    NUMSPC                ! number of species in run
      INTEGER*2    NUMHT                 ! number of habitat types
      INTEGER*2    NUMSIT                ! number of sites
      INTEGER*2    NUMREP                ! number of replicates
      INTEGER*2    NUMITR                ! number of iterations
      INTEGER*2    REPNUM                ! current replicate number
      INTEGER*2    ITRNUM                ! current iteration number
C
```

```
      COMMON / HT / HTNAME,PRORPO,FIRINT,FULCRV
      COMMON / PARAMS / NUMSPC,NUMHT,NUMREP,NUMITR,REPNUM,YEAR
C
      OPEN (UNIT=1,FILE='HT.DAT',STATUS='OLD',SHARED,
     +      READONLY,ERR=10)
C
      NUMHT = 0
   11 READ(1,100,END=12) HTNAME(NUMHT+1),FIRINT(NUMHT+1)  ! name and fire ret.
      READ(1,101) (PRORPO(NUMHT+1,J),J=1,NUMSPC)          ! prob. of repro.
      READ(1,102) (FULCRV(NUMHT+1,K),K=1,5)               ! fuel curve
      IF (NUMHT .LT. MAXHT) THEN                    ! make sure not to overflow
        NUMHT = NUMHT + 1
        GOTO 11
      ELSE
        WRITE(6,110) HTNAME(NUMHT+1)                ! too many types
        GOTO 12
      ENDIF
C
   10 WRITE(6,120)                                  ! error opening file
      STOP
   13 WRITE(6,130) HTNAME(NUMHT)                    ! error reading file
      STOP
C
   12 CLOSE(1)
C
  100 FORMAT (A16,T20,I4)
  101 FORMAT (10(F5.2))
  102 FORMAT (5(I4))
  110 FORMAT (' TOO MANY HABITAT TYPES, AFTER ',A16,' IGNORED')
  120 FORMAT (' ERROR OPENING HT.DAT ')
  130 FORMAT (' ERROR READING HT.DAT, LAST HT READ = ',A16)
C
      END
C
```

APPENDIX D FORTRAN CODE FOR PROGRAM POLYDRAW

```
C*****************************************************************
C
C  PROGRAM POLYDRAW
C
C*****************************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)     ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)     ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)        ! number of points in buffer
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS         ! number of map ids
      INTEGER*2 NPOLMI(50)     ! number of polygons per id
      INTEGER*2 NUMPOL         ! total number of polygons
      INTEGER*2 MAPNUM         ! current map number
C
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
C* LOCAL
C
      CHARACTER*1 BUTTON     ! button pressed
      CHARACTER*24 DIG,BUF   ! output file spec
      CHARACTER*80 LINE
      CHARACTER*20 TOKEN(10)
      INTEGER*4 XTEM,YTEM
      INTEGER*2 SIZE(10)
      INTEGER*2 COUNT
      LOGICAL*1 OLDFIL
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
      COMMON / MAPS   / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
```

```
C* POLYDRAW ****************** ONE ***************************
C
C
      WRITE(6,100)                        ! prompt for output file
      READ(5,110) LINE                    ! get file spec
      CALL PARSE(LINE,TOKEN,COUNT,SIZE)
      DIG = TOKEN(1)(1:SIZE(1)) // '.DIG'
      BUF = TOKEN(1)(1:SIZE(1)) // '.BUF'
C
      INQUIRE (FILE=DIG,EXIST=OLDFIL)
C
      IF (OLDFIL) THEN
        OPEN (UNIT=1,FILE=DIG,STATUS='OLD',CARRIAGECONTROL='LIST')
        OPEN (UNIT=2,FILE=BUF,STATUS='OLD',CARRIAGECONTROL='LIST')
      ELSE
        OPEN (UNIT=1,FILE=DIG,STATUS='NEW',CARRIAGECONTROL='LIST')
        OPEN (UNIT=2,FILE=BUF,STATUS='NEW',CARRIAGECONTROL='LIST')
      ENDIF
C
  100 FORMAT (' ENTER OUTPUT FILE NAME : ',$)
  110 FORMAT (A80)
C
C* POLYDRAW ******************* TWO ***************************
C
      NUMPOL = 0                     ! initialize number of polygons
      NUMIDS = 0                     ! initialize ids and
      DATA NPOLMI / 50 * 0 /         ! polygons per id
      DATA MAPLST / 50 * ' ' /

      IF (OLDFIL) CALL RESTORE
C
      WRITE(5,200)                                  ! prompt to begin
C
   20 READ(5,210) BUTTON,XTEM,YTEM
      IF (BUTTON .EQ. 'A') THEN                     ! enter map id
        CALL NEWMID
      ELSE IF (BUTTON .EQ. 'B') THEN    ! start new polygon under current
        CALL NEWPOL                     !     map id
      ELSE IF (BUTTON .EQ. 'L') THEN
        CALL LIST                     ! produce list of polygons and buffers
      ELSE IF (BUTTON .EQ. '7') THEN
        CALL SEARCH(XTEM,YTEM)
      ELSE IF (BUTTON .EQ. 'Q') THEN
        GOTO 23
      ELSE IF (BUTTON .EQ. 'F') THEN
        CALL FLUSH                          ! write out polygons and buffers
        GOTO 21
      ENDIF
      GOTO 20
C
```

```
   21 READ(5,210)
      DO 22 I=1,NUMIDS
      WRITE(5,220) MAPLST(I),NPOLMI(I)
   22 CONTINUE
C
      DO 23 I=1,50
      IF (BUFSIZ(I) .NE. 0) THEN
        WRITE(5,230) I,BUFSIZ(I)
      ENDIF
   23 CONTINUE
C
  200 FORMAT ('0',' ENTER ONE OF THE FOLLOWING ',//,
     +        '   A   TO START A NEW MAP ',/,
     +        '   B   TO START A NEW POLYGON ON THE EXISTING MAP ',/,
     +        '   L   TO SEE A LIST OF EXISTING MAPS AND BUFFERS ',/,
     +        '   Q   TO QUIT',/,
     +        '   F   TO FINISH RUNNING POLYDRAW',/)
  210 FORMAT (A1,1X,I6,1X,I6)
  220 FORMAT (' STORING MAP ',A10,' WITH ',I3,' POLYGONS')
  230 FORMAT (' STORING BUFFER ',I3,' WITH ',I4,'  POINTS')
C
      END
C
C*****************************************************************
C
      SUBROUTINE NEWMID
C
C*****************************************************************
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS         ! number of map ids
      INTEGER*2 NPOLMI(50)     ! number of polygons per id
      INTEGER*2 NUMPOL         ! total number of polygons
      INTEGER*2 MAPNUM         ! current map number
C
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
      COMMON / MAPS  / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
```

```
C* POLYDRAW/NEWMID *************** ONE ***************************
C
      WRITE(6,110)                                  ! prompt for mapid
      READ(5,100) MAPID                             ! get current map id
C
      DO 10 I=1,NUMIDS                              ! search list of map ids
      IF (MAPID .EQ. MAPLST(I)) THEN                !   to see if already on
        MAPNUM = I                                  !   list
        GOTO 11
      ENDIF
   10 CONTINUE
C
      NUMIDS = NUMIDS + 1                       ! not on list, increment list
      MAPLST(NUMIDS) = MAPID                    !   counter and add to list
      MAPNUM = NUMIDS                           ! set current map number
C
   11 RETURN
C
  100 FORMAT (A10)
  110 FORMAT (' ENTER NEW MAPID : ',$)
C
      END
C
C*********************************************************************
C
      SUBROUTINE NEWPOL
C
C*********************************************************************
C
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)     ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)     ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)        ! number of points in buffer
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS         ! number of map ids
      INTEGER*2 NPOLMI(50)     ! number of polygons per id
      INTEGER*2 NUMPOL         ! total number of polygons
      INTEGER*2 MAPNUM         ! current map number
C
```

```
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
C* LOCAL
C
      INTEGER*2 FIRST,LAST
      CHARACTER*1 BUTTON
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
      COMMON / MAPS   / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
C* POLYDRAW/NEWPOL ****************** ONE ********************************
C
      NUMPOL = NUMPOL + 1                          ! increment polygon count
      NPOLMI(MAPNUM) = NPOLMI(MAPNUM) + 1          ! incre. polygons per mapid
      NUMPTS  = 0
C
   10 READ(5,100) BUTTON,XIN(NUMPTS +1),YIN(NUMPTS +1)          ! get data
C
      IF (BUTTON .EQ. 'C') THEN
        CALL CLOSE
      ELSE IF (BUTTON .EQ. '4') THEN              ! cut to buffer
        FIRST = 1                                 ! first buffer point
        LAST = NUMPTS                             ! last buffer point
        CALL CUT(FIRST,LAST)
      ELSE IF (BUTTON .EQ. '5') THEN              ! paste from buffer
        CALL PASTE
      ELSE IF (BUTTON .EQ. '6') THEN              ! enter an existing line
        CALL ENTER
      ELSE IF (BUTTON .EQ. 'D') THEN              ! enter a hole
        CALL HOLE
      ELSE IF (BUTTON .EQ. 'E') THEN              ! end of polygon definition
        CALL END
        RETURN
      ELSE
        NUMPTS  = NUMPTS  + 1                     ! increment point counter
      ENDIF
      GOTO 10
C
  100 FORMAT (A1,1X,I6,1X,I6)
C
      END
C
```

```
C*****************************************************************
C
      SUBROUTINE CUT(FIRST,LAST)
C
C*****************************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)    ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)    ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)       ! number of points in buffer
C
C* LOCAL
C
      INTEGER*2 FIRST,LAST
      INTEGER*2 BNUM10,BNUM01
      INTEGER*2 BUFFER
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
C
C* POLYDRAW/CUT ******************** ONE ******************************
C
      READ(5,100) BNUM10                          ! construct buffer number
      READ(5,100) BNUM01
      BUFFER = BNUM10 * 10 + BNUM01
C
      BUFSIZ(BUFFER) = LAST - FIRST + 1           ! set buffer sizes
      BUFSIZ(BUFFER+50) = LAST - FIRST + 1
C
      DO 10 I=FIRST,LAST                          ! cut coords to buffer
      XSTO(BUFFER,I-FIRST+1) = XIN(I)
      YSTO(BUFFER,I-FIRST+1) = YIN(I)
      XSTO(BUFFER+50,I-FIRST+1) = XIN(NUMPTS +FIRST-I)  ! cut in reverse order
      YSTO(BUFFER+50,I-FIRST+1) = YIN(NUMPTS +FIRST-I)
   10 CONTINUE
C
      RETURN
C
  100 FORMAT (I1)
C
      END
C
```

```
C*************************************************************
C
      SUBROUTINE PASTE
C
C*************************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)     ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)     ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)        ! number of points in BUFNUM
C
C* LOCAL
C
      INTEGER*2 BNUM10,BNUM01
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
C
C* POLYDRAW/PASTE *************** ONE ***************************************
C
      READ(5,100) BNUM10                          ! construct buffer number
      READ(5,100) BNUM01
      BUFNUM = BNUM10 * 10 + BNUM01
C
      DO 10 I=1,BUFSIZ(BUFNUM)                    ! paste from buffer to coords
      XIN(NUMPTS +I) = XSTO(BUFNUM,I)
      YIN(NUMPTS +I) = YSTO(BUFNUM,I)
   10 CONTINUE
      NUMPTS  = NUMPTS  + BUFSIZ(BUFNUM)    ! update number of points in polyg
C
      RETURN
C
  100 FORMAT (I1)
C
      END
C
```

```
C*************************************************************
C
      SUBROUTINE CLOSE
C
C*************************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
      COMMON / COORDS / XIN,YIN,NUMPTS
C
C* POLYDRAW/CLOSE ************** ONE ******************************
C
      NUMPTS  = NUMPTS  + 1
      XIN(NUMPTS ) = XIN(1)
      YIN(NUMPTS ) = YIN(1)
C
      RETURN
C
      END
C
C*************************************************************
C
      SUBROUTINE END
C
C*************************************************************
C

C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS         ! number of map ids
      INTEGER*2 NPOLMI(50)     ! number of polygons per id
      INTEGER*2 NUMPOL         ! total number of polygons
      INTEGER*2 MAPNUM         ! current map number
C
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
```

```
C* LOCAL
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / MAPS  / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
C* POLYDRAW/END ***************** ONE ***********************************
C
      WRITE(1,100) MAPID,NPOLMI(MAPNUM),NUMPOL,NUMPTS
      DO 10 I=1,NUMPTS
      WRITE(1,110) FLOAT(XIN(I)),FLOAT(YIN(I))
   10 CONTINUE
C
  100 FORMAT (15X,A10,3(5X,I5),2F10.0)
  110 FORMAT (2F10.0)
C
      END
C
C*****************************************************************
C
      SUBROUTINE HOLE
C
C*****************************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* LOCAL
C
      INTEGER*2 FIRST,LAST
      CHARACTER*1 BUTTON
C
      COMMON / COORDS / XIN,YIN,NUMPTS
C
```

```
C* POLYDRAW/HOLE ****************** ONE **********************************
C
      FIRST = NUMPTS  + 1
C
   10 READ(5,100) BUTTON,XIN(NUMPTS +1),YIN(NUMPTS +1)
C
      IF (BUTTON .EQ. 'B') THEN
        GOTO 10
      ELSE IF (BUTTON .EQ. 'C') THEN
        NUMPTS  = NUMPTS  + 1
        XIN(NUMPTS ) = XIN(FIRST)
        YIN(NUMPTS ) = YIN(FIRST)
      ELSE IF (BUTTON .EQ. '4') THEN
        LAST = NUMPTS
        CALL CUT(FIRST,LAST)
      ELSE IF (BUTTON .EQ. '5') THEN
        CALL PASTE
      ELSE IF (BUTTON .EQ. 'E') THEN
        GOTO 11
      ELSE
        NUMPTS  = NUMPTS  + 1
      ENDIF
C
      GOTO 10
C
   11 XIN(FIRST) = -1 * XIN(FIRST)
C
      RETURN
C
  100 FORMAT (A1,1X,I6,1X,I6)
C
      END
C
```

```
C*********************************************************
C
      SUBROUTINE ENTER
C
C*********************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)    ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)    ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)       ! number of points in buffer
C
C* LOCAL
C
      INTEGER*2 BNUM10,BNUM01
      INTEGER*2 BUFFER
      INTEGER*4 DIST,MINDST
      INTEGER*4 XOUT,YOUT
      REAL*4    XDIFF,YDIFF
      INTEGER*2 FIRST,LAST
      INTEGER*2 INPOS,OUTPOS
      CHARACTER*1 BUTTON
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
C
C* PLOYDRAW/ENTER *********** ONE **********************************
C
      READ(5,100) BNUM10                  ! construct buffer number
      READ(5,100) BNUM01
      BUFFER = BNUM10 * 10 + BNUM01
C
      MINDST = 999999999
      DO 10 I=1,BUFSIZ(BUFFER)
      XDIFF = (XIN(NUMPTS +1)-XSTO(BUFFER,I))**2
      YDIFF = (YIN(NUMPTS +1)-YSTO(BUFFER,I))**2
      DIST = SQRT(XDIFF+YDIFF)
      IF (DIST .LT. MINDST) THEN
        MINDST = DIST
        INPOS = I
      ENDIF
   10 CONTINUE
C
   11 READ(5,110) BUTTON,XOUT,YOUT
C
```

```
      IF (BUTTON .EQ. '4') THEN
        FIRST = 1
        LAST = NUMPTS  + 1
        XIN(NUMPTS +1) = XSTO(BUFFER,INPOS)
        YIN(NUMPTS +1) = YSTO(BUFFER,INPOS)
        CALL CUT(FIRST,LAST)
        GOTO 11
      ENDIF
C
      MINDST = 999999999
      DO 12 I=INPOS,BUFSIZ(BUFFER)
      XDIFF = (XOUT-XSTO(BUFFER,I))**2
      YDIFF = (YOUT-YSTO(BUFFER,I))**2
      DIST = SQRT(XDIFF+YDIFF)
      IF (DIST .LT. MINDST) THEN
        MINDST = DIST
        OUTPOS = I
      ENDIF
   12 CONTINUE
C
      DO 13 I=1,INPOS-1
      XDIFF = (XOUT-XSTO(BUFFER,I))**2
      YDIFF = (YOUT-YSTO(BUFFER,I))**2
      DIST = SQRT(XDIFF+YDIFF)
      IF (DIST .LT. MINDST) THEN
        MINDST = DIST
        OUTPOS = I
      ENDIF
   13 CONTINUE
C
  100 FORMAT (I1)
  110 FORMAT (A1,1X,I6,1X,I6)
C
```

```
C* POLYDRAW/ENTER ************* TWO ************************
C
      NUMPTS  = NUMPTS  + 1
      IF (INPOS .LT. OUTPOS) THEN
        DO 20 I=INPOS,OUTPOS
        XIN(NUMPTS +I-INPOS) = XSTO(BUFFER,I)
        YIN(NUMPTS +I-INPOS) = YSTO(BUFFER,I)
20      CONTINUE
        NUMPTS  = NUMPTS  + OUTPOS - INPOS
      ELSE
        DO 21 I=INPOS,BUFSIZ(BUFFER)
        XIN(NUMPTS +I-INPOS) = XSTO(BUFFER,I)
        YIN(NUMPTS +I-INPOS) = YSTO(BUFFER,I)
21      CONTINUE
        NUMPTS  = NUMPTS  + BUFSIZ(BUFFER) - INPOS
        DO 22 I=1,OUTPOS
        XIN(NUMPTS +I) = XSTO(BUFFER,I)
        YIN(NUMPTS +I) = YSTO(BUFFER,I)
22      CONTINUE
        NUMPTS  = NUMPTS  + OUTPOS
      ENDIF
C
      RETURN
C
      END
C
C*********************************************************************
C
      SUBROUTINE RESTORE
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)    ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)    ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)       ! number of points in buffer
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS          ! number of map ids
      INTEGER*2 NPOLMI(50)      ! number of polygons per id
      INTEGER*2 NUMPOL          ! total number of polygons
      INTEGER*2 MAPNUM          ! current map number
C
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
```

```
C* LOCAL
C
      REAL*4 XTEM,YTEM
      INTEGER*2 NUMPTS
      INTEGER*2 FIRST,LAST
      INTEGER*2 BUFFER
C
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
      COMMON / MAPS  / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
C* POLYDRAW/RESTORE ************ ONE ****************************
C
      WRITE(5,100)
   10 READ(1,110,END=11) MAPID,NUMPTS
      DO 12 I=1,NUMIDS
      IF (MAPID .EQ. MAPLST(I)) THEN
        NPOLMI(I) = NPOLMI(I) + 1
        NUMPOL = NUMPOL + 1
        GOTO 13
      ENDIF
   12 CONTINUE
C
      NUMIDS = NUMIDS + 1
      NPOLMI(NUMIDS) = 1
      MAPLST(NUMIDS) = MAPID
      NUMPOL = NUMPOL + 1
C
   13 DO 14 I=1,NUMPTS
      READ(1,120)
   14 CONTINUE
C
      GOTO 10
C
   11 DO 15 I=1,NUMIDS
      WRITE(5,130) MAPLST(I),NPOLMI(I)
   15 CONTINUE
C
  100 FORMAT (' OLD FILE FOUND, RESTORING ',/)
  110 FORMAT (15X,A10,25X,I5)
  120 FORMAT (A1)
  130 FORMAT (' RESTORING ',A10,' WITH ',I5,' POLYGONS ')
C
```

```
C* POLYDRAW/RESTORE ***************** TWO ************************
C
   20 READ(2,200,END=21) BUFFER,NUMPTS
      WRITE(5,210) BUFFER,NUMPTS
      BUFSIZ(BUFFER) = NUMPTS
      BUFSIZ(BUFFER+50) = NUMPTS
      DO 22 I=1,NUMPTS
      READ(2,220) XTEM,YTEM
      XSTO(BUFFER,I) = IFIX(XTEM)
      YSTO(BUFFER,I) = IFIX(YTEM)
      XSTO(BUFFER+50,NUMPTS -I+1) = IFIX(XTEM)
      YSTO(BUFFER+50,NUMPTS -I+1) = IFIX(YTEM)
   22 CONTINUE
      GOTO 20
   21 CONTINUE
C
      REWIND (2)
C      REWIND (3)
C
      RETURN
C
  200 FORMAT (15X,I10,25X,I5)
  210 FORMAT (' RESTORING BUFFER ',I3,' WITH ',I5,' POINTS')
  220 FORMAT (2F10.0)
C
      END
C
C*****************************************************************
C
      SUBROUTINE FLUSH
C
C*****************************************************************
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)    ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)    ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)       ! number of points in buffer
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS        ! number of map ids
      INTEGER*2 NPOLMI(50)    ! number of polygons per id
      INTEGER*2 NUMPOL        ! total number of polygons
      INTEGER*2 MAPNUM        ! current map number
C
```

```
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
      COMMON / MAPS   / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
C* PLOYDRAW/FLUSH *************** ONE ************************************
C
      DO 10 I=1,50
      IF (BUFSIZ(I) .NE. 0) THEN
        WRITE(2,100) I,BUFSIZ(I)
        DO 11 J=1,BUFSIZ(I)
        WRITE(2,110) FLOAT(XSTO(I,J)),FLOAT(YSTO(I,J))
   11   CONTINUE
      ENDIF
   10 CONTINUE
C
      RETURN
C
  100 FORMAT (15X,I10,25X,I5)
  110 FORMAT (2F10.0)
C
      END
C
C*****************************************************************
C
      SUBROUTINE LIST
C
C*****************************************************************
C
C* STRUCTURE BUFFERS
C
      INTEGER*4 XSTO(100,3000)     ! buffer x coordinates
      INTEGER*4 YSTO(100,3000)     ! buffer y coordinates
      INTEGER*2 BUFSIZ(100)        ! number of points in buffer
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS          ! number of map ids
      INTEGER*2 NPOLMI(50)      ! number of polygons per id
      INTEGER*2 NUMPOL          ! total number of polygons
      INTEGER*2 MAPNUM          ! current map number
C
```

```
C* STRUCTURE NAMES
C
      CHARACTER*10 MAPID          ! current map id
      CHARACTER*10 MAPLST(50)     ! list of map ids
C
      COMMON / BUFFER / XSTO,YSTO,BUFSIZ
      COMMON / MAPS   / NUMIDS,NPOLMI,NUMPOL,MAPNUM
      COMMON / NAMES / MAPID,MAPLST
C
C* POLYDRAW/LIST ***************** ONE ***********************************
C
      WRITE(5,100) NUMIDS,NUMPOL
C
      DO 10 I=1,NUMIDS
      WRITE(5,110) I,MAPLST(I),NPOLMI(I)
   10 CONTINUE
C
      DO 11 I=1,50
      IF (BUFSIZ(I) .GT. 0) THEN
        WRITE(5,120) I,BUFSIZ(I)
      ENDIF
   11 CONTINUE
C
      RETURN
C
  100 FORMAT (' THERE ARE CURRENTLY ',I4,' MAPS WITH ',I4,' POLYGONS',/)
  110 FORMAT (' MAP ',I3,' IS ',A10,' WITH ',I4,' POLYGONS')
  120 FORMAT (' BUFFER ',I2,' HAS ',I4,' POINTS ')
C
      END
C
C*******************************************************************************
C
      SUBROUTINE SEARCH(XS,YS)
C
C*******************************************************************************
C
C* STRUCTURE COORDS
C
      INTEGER*4 XIN(3000)     ! input x coordinates
      INTEGER*4 YIN(3000)     ! input y coordinates
      INTEGER*2 NUMPTS        ! number of points in current polygon
C
C* STRUCTURE MAPS
C
      INTEGER*2 NUMIDS         ! number of map ids
      INTEGER*2 NPOLMI(50)     ! number of polygons per id
      INTEGER*2 NUMPOL         ! total number of polygons
      INTEGER*2 MAPNUM         ! current map number
C
```

```
C* LOCAL
C
      INTEGER*4 XS,YS,DIST
      INTEGER*2 FLAG,FIRST,LAST,POLNUM
      CHARACTER*1 BUTTON
      CHARACTER*10 TEMMAP
C
      COMMON / COORDS / XIN,YIN,NUMPTS
      COMMON / MAPS  / NUMIDS,NPOLMI,NUMPOL,MAPNUM
C
C* POLYDRAW/SEARCH ************* ONE ****************************************
C
      REWIND (1)
C
      FLAG = 0
      DO 10 I=1,NUMPOL
      POLNUM = I
      READ(1,110) TEMMAP,NUMPTS
        DO 11 J=1,NUMPTS
        READ(1,120) XIN(J),YIN(J)
        DIST = ((XS-XIN(J))**2 + (YS-YIN(J))**2)**0.5
        IF (DIST .LE. 2) FLAG = 1
   11   CONTINUE
C
      IF (FLAG .EQ. 1) THEN
        FIRST = 1
        LAST = NUMPTS
        CALL CUT(FIRST,LAST)
        GOTO 12
      ENDIF
   10 CONTINUE
C
   12 DO 13 I=POLNUM+1,NUMPOL
      READ(1,110) TEMMAP,NUMPTS
        DO 14 J=1,NUMPTS
        READ(1,120) XIN(J),YIN(J)
   14   CONTINUE
   13 CONTINUE
C
      RETURN
C
  110 FORMAT (15X,A10,25X,I5)
  120 FORMAT (I9,1X,I9)
C
      END
```

ANALYSIS OF COMMUNITY COMPOSITION AND HABITAT OF PEDIOMELUM PARIENSE (FABACEAE) IN BRYCE CANYON NATIONAL PARK

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ABSTRACT - The distribution of Pediomelum pariense in Bryce Canyon National Park, Utah, and the vegetation and soils associated with it are described. Management suggestions are presented.

Information about the habitat of a plant species proposed for threatened or endangered designation is essential. A detailed habitat description provides guidance for the search for other possible locations to improve knowledge of the species' distribution and abundance, which can affect decisions about its status and identify areas where special protection may be warranted. A habitat description also provides information required for planning and executing recovery programs: selection of possible transplant sites; guidelines for vegetation manipulation to increase or improve habitat.

Paria breadroot, Pediomelum pariense (Welsh & Atwood) Welsh (=Psoralea pariensis Welsh & Atwood), is under consideration for Federal protection as a threatened species (Welsh and Chatterley 1985). The type specimen was collected in Bryce Canyon National Park, and this Utah endemic is known elsewhere only from two locations in Kane County. This paper describes the habitat of the Bryce Canyon population of Paria breadroot.

STUDY AREA

The study area is located in Bryce Canyon National Park on the canyon rim on the east edge of the Paunsaugunt Plateau in southern Utah. Surficial geology consists of Wasatch Formation limestones derived from Tertiary freshwater sediment depositions (Hintze 1973, Lindquist 1977). The soils are fine-

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textured with varying amounts of coarse fragments, and the surface is often covered with a stony pavement. The terrain is flat to slightly undulating with occasional draws. Elevation is about 8000-83000 feet.

The vegetation is open forest, consisting largely of the Pinus ponderosa/Arctostaphylos patula (PIPO/ARPA) habitat type with pockets of the Abies concolor/Arctostaphylos patula (ABCO/ARPA) habitat type, especially in the draws (Youngblood and Mauk 1985).

METHODS

Areas where Paria breadroot is known to occur were searched for the plants and mapped (Fig. 1). Other portions of the Park having similar combinations of forest habitat and soils, based on U.S. Soil Conservation Service soils maps, were also searched.

Eight 0.1 acre macroplots were located subjectively to describe areas where the species occurs. Each macroplot had a 100-foot line-intercept transect, randomly oriented, running through its center. Ten 20 X 50 cm quadrats were placed at 10-foot intervals along the right side of the transect, and perpendicular to it, beginning at the 10-foot mark. Understory cover was estimated from the quadrats (Daubenmire 1959), and frequency and density were estimated from the transect. Trees within the macroplot were measured for breast-height diameter (dbh) to determine basal area.

After vegetation sampling, ten samples of the surface 10 cm of mineral soil were taken at 10-foot intervals, beginning at the 10-foot mark of the transect, air dried, pooled by macroplot, and analyzed for pH, percent organic matter, P (sodium carbonate solution), and Ca, Mg, and K (sodium acetate solution).

Taxonomic nomenclature follows Welsh et al. (1987).

RESULTS

The observed distribution of Paria breadroot is shown in Fig. 1. No other populations were found.

Macroplots 2 and 6 were located in the ABCO/ARPA habitat type, the rest were in the PIPO/ARPA habitat type. Average cover, frequency, and density of understory species by macroplot are shown in Table 1. Tree diameter class and basal area estimates by macroplot are given in Table 2.

Arctostaphylos patula was constant throughout and was the dominant shrub, in terms of cover, frequency, and density, in all macroplots except macroplot 6, which was located in the ABCO/ARPA habitat type. There it had the same density as Mahonia repens, but occurred more frequently. Mahonia repens had a greater estimated coverage but this may be an incorrect assumption since it did not occur in any of the quadrats and its cover was estimated from the line-intercept transect.

Carex rossii was the only graminoid to occur in all macroplots and was generally dominant. In macroplot 1, Elymus elymoides had greater density than C. rossii, but accounted for less cover and frequency. Macroplots 3 and 6 were dominated in all respects by Stipa hymenoides.

No single forb species, other than P. pariense, was universally constant among macroplots. The most common forbs were Arenaria fendleri, Hymenoxys acaulis, and Petradoria pumila. Dominance of the three species varied among the five macroplots in which they were found together such that no one species can be considered to be dominant among forbs for the study area.

Shrubs were the dominant understory morphological class, followed closely by forbs. Graminoids were relatively unimportant. In general, the understory vegetation with which P. pariense is associated is dominated by A. patula and a

mixture of forbs and graminoids, especially A. fendleri, H. acaulis, P. pumila, and C. rossii.

In the overstory, the macroplots in the PIPO/ARPA habitat type were dominated by the signature tree except macroplot 4 where the only measurable tree was Juniperus scopulorum. Pinus ponderosa was incidental in the occurrence of young trees too short for dbh measurement. The distribution of diameter classes of P. ponderosa in the six PIPO/ARPA macroplots indicates that vegetation in this habitat type is at or near climax, and approximates the description of this type given by Youngblood and Mauk (1985).

In the two macroplots in the ABCO/ARPA habitat type, A. concolor is associated with other, less shade-tolerant, trees and is not dominant, indicating that these sites are in an early seral stage. Continued development of A. concolor on these sites will probably lead to additional crown closure and loss of some or all of the associated tree species.

When the macroplots are lumped according to the habitat types, P. ponderosa dominates in terms of basal area in both types: about 70% (25 ft^2/ac) in the PIPO/ARPA type and about 45% (33 ft^2/ac) in the ABCO/ARPA type (Table 3). Pediomelum pariense was found in measurable quantities in all PIPO/ARPA marcoplots except macroplot 7, a harsh site dominated by Pinus longaeva. Of the ABCO/ARPA macroplots, only macroplot 2 had measurable quantities of P. pariense. This species was incidental on macroplot 6 which had the greatest tree basal area of all macroplots.

The results of the soil analysis are presented in Table 4. The most noticeable feature is the wide fluctuation in the Ca:Mg ratio. These fluctuations did not seem to affect the presence of P. pariense, however, as the sites with the highest and lowest ratios were similarly endowed with this species.

CONCLUSIONS

The results of this study indicate that Pendiomelum pariense is an element of open-growth climax PIPO/ARPA type forests on Wasatch Formation limestone soils, with dominant understory species consisting of Arctostaphylos patula, Arenaria fendleri, Hymenoxys acaulis, Petradoria pumila, and Carex rossii. It may also appear in early seral stages of other forest habitat types on these soils, associated with climax PIPO/ARPA, when the crown canopy is still open. Crown closure would probably eliminate the species from these types.

Until the status of Paria breadroot is determined, the sites where it occurs should be protected from disturbance. One small patch of the species is near the trail between the Paria View overlook and a parking lot. Any development there should be pursued very carefully to avoid damaging or destroying the site. Because the species grows quite close to the rim of the canyon to the south of Paria View, any hiking trail or other tourist facility development there should also be planned with care or avoided.

Other sites in the Park, and elsewhere in southern Utah, with similar vegetation and soils characteristics should be carefully searched for other populations of Paria breadroot.

Vegetation manipulation to improve the habitat of the species is an option to be considered. This could consist of the removal of more shade-tolerant tree species from stands where P. pariense occurs and where P. ponderosa dominates, thus reducing tree basal area and maintaining an open canopy. This is probably a relatively short-term aid to the survival of the species and great care must be exercised to avoid damaging breadroot plants and disturbing the understory unduly.

Seeding or transplanting may be possible to increase the distribution and abundance of Paria breadroot. To be safe, only sites closely approximating

those described here should be used for such exercises. Because of the limited number of plants available seeding should be considered first to avoid loss of existing plants. Transplanting from less-than-optimum seral sites should be the next method to be considered. In any case, attempts to introduce the species on other sites should be preceded by studies of its reproductive biology so that existing populations will not be depleted needlessly.

ACKNOWLEDGMENTS

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Table 1. Cover, frequency, and density of plant species.

Macroplot number	1	2	3
Location:			
Quarter quarter	SENW	SENW	NWSW
Section	13	13	13
Township	37S	37S	37S
Range	4W	4W	4W
Topographic position:			
Slope (percent)	5	20	5
Aspect (degrees)	65	145	345
Elevation (feet)	8240	8200	8280
Bearing (degrees)	328	122	164
Cover/Frequency/Density			
Trees			
Abies concolor	-	*	-
Juniperus osteosperma	*	-	-
Juniperus oscpulorum	-	(1.7)/10/2	*
Pinus longaeva	-	-	-
Pinus ponderosa	*	*	*
Pseudotsuga menziesii	-	*	-
Shrubs			
Arctostaphylos patula	3/30/4.1	12.8/100/51	7.9/100/33.7
Ceanothus martinii	-	0.4/40/14.3	(7.4)/20/3.3
Cercocarpus ledifolius	*	-	-
Chrysothamnus depressus	-	-	*
Chrysothamnus parryi	*	*	*
Gutierrezia sarothrae	-	*	0.5/(20)/-
Juniperus communis	-	*	*
Mahonia repens	-	-	-
Ribes cereum	-	-	-
Symphoricarpos oreophilus	*	*	*
Tetradymia canescens	(0.2)/10/1.4	*	(0.7)/10/1.1
Graminoids			
Carex rossii	2/30/5.5	(1.3)/20/6.1	0.3/20/5.4
Elymus elymoides	0.3/20/6.8	-	0.3/10/1.1
Elymus lanceolatus	-	-	-
Elymus salinus	-	-	-
Muhlenbergia montant	-	-	*
Poa fendleri	*	*	-
Stipa comata	-	-	0.8/10/1.1
Stipa hymenoides	-	*	(0.9)/60/7.6
Forbs			
Arbis demissa	0.5/30/5/5	*	-
Arenaria fendleri	(1.2)/30/4.1	-	*
Astragalus sp.	-	-	-
Astragalus convallarius	0.3/20/2.7	*	0.3/20/2.2
Astragalus humistratus	*	-	-
Astragalus kentrophyta	(0.1)/10/1.4	-	-
Astragalus megacarpus	-	-	-
Castilleja linariifolia	(0.1)/10/1.4	-	0.3/(10)/-
Cirsium sp.	-	*	*

Clematis columbiana	-	-	-
Cryptantha sp.	*	-	*
Draba subalpina	-	-	-
Erigeron canus	*	-	-
Eriogonum alatum	*	(0.1)/10/2	*
Eriogonum racemosum	(0.8)/10/1.4	-	*
Euphorbia brachycera	-	(0.4)/10/2	*
Gilia aggregata	*	*	*
Haplopappus armerioides	-	-	-
Hymenoxys acaulis	1/40/20.5	0.5/20/8.2	0.3/10/1.1
Hymenoxys richardsonii	0.3/20/2.7	-	0.5/30/3.3
Linum kingii	-	-	2.3/40/5.4
Linum perenne	-	-	(0.2)/10/1.1
Machaeranthera canescens	-	*	-
Machaeranthera grindelioides	0.3/10/1.4	-	0.5/30/5.4
Oenothera howardii	-	-	0.5/50/6.5
Pediomelum pariense	(0.8)/30/4.1	0.5/30/12.2	0.8/80/17.4
Penstemon sp.	(2.1)/10/2.7	-	-
Penstemon caespitosus	(0.5)/10/1.4	-	-
Petradoria pumila	5/80/32.9	0.3/10/-	*
Phlox sp.	-	-	-
Senecio multilobatus	*	*	(0.5)/10/1.1
Stempanomeria tenuifolia	*	-	-
Streptanthus cordatus	-	*	-
Yucca angustissima	-	-	(1.9)/10/3.3
unknown forb	-	0.3/10/2	-
forb 1	-	-	-
forb 2	-	-	-

Cover was estimated using quadrat frames. Where this figure is presented in parentheses, the species did not occur in a quadrat and cover was estimated from the line-intercept transect.

Frequency and density were estimated using line-intercept transects. Where the frequency figure is presented in parentheses, the species did not occur on the transect and frequency was estimated from quadrats. Where a dash occurs in the density position, the species did not occur on the transect. Density was not recorded in the quadrats so no figure can be given.

* indicates occurrence within the macroplot but not on the transect or in the quadrats.

Taxonomy follows A Utah Flora.

4	5	6	7	8
NWSE	SWSW	NESW	SWSE	SWSW
13	13	13	13	13
37S	37S	37S	37S	37S
4W	4W	4W	4W	4W
10	10	25	10	15
255	315	70	305	325
8220	8240	8160	8220	8290
358	246	62	96	294
-	-	(0.5)/10/3.8	-	-
-	-	-	-	-
*	6.3/(10)/-	-	*	-
-	-	-	*	-
*	(1.7)/10/1.7	*	*	*
-	-	*	-	-
8.5/80/44.1	3.5/50/22	3/40/23.1	5.8/60/4.29	6.5/70/44.4
*	0.3/10/1.7	*	-	0.8/20/5.6
-	*	-	-	-
-	-	-	-	-
*	-	-	-	*
-	-	-	-	-
-	(10)/10/3.4	-	-	*
-	-	(5.4)/30/23.1	-	-
*	-	-	-	-
-	-	(0.8)/10/3.8	-	-
-	*	-	*	*
0.5/70/11.9	0.5/30/10.2	(0.1)/10/3.8	(2.9)/30/9.5	0.5/30/11.1
-	-	-	-	*
-	-	-	-	*
-	-	-	*	(0.1)/10/2.8
-	-	-	-	-
*	-	0.3/10/3.8	-	-
-	-	-	-	-
0.3/(10)/-	-	(0.4)/30/15.4	-	*
-	-	-	-	-
0.5/10/1.7	0.8/40/10.2	*	0.5/40/16.7	0.5/20/5.6
-	(0.2)/10/1.7	*	-	0.3/(10)/-
0.3/10/1.7	-	*	-	0.3/10/2.8
-	-	-	-	-
0.3/20/8.5	-	-	-	-
(0.5)/10/5.1	-	-	-	-
-	0.3/(10)/-	-	-	(0.1)/10/2.8
*	(0.7)/20/3.4	-	*	*

-	-	(1)/10/3.8	0.3/(10)/-	0.5/30/8.3
*	0.3/(10)/-	-	0.3/20/4.8	0.5/20/5.6
-	-	0.3/10/3.8	-	-
-	-	-	-	-
*	*	-	-	-
*	-	-	-	-
(0.4)/20/3.4	0.3/(10)/-	-	*	0.5/(20)/-
-	-	-	-	-
*	-	-	*	-
0.5/30/8.5	0.8/60/11.9	-	(0.3)/20/7.1	0.5/10/2.8
*	(0.4)/10/1.7	-	(0.2)/10/2.4	*
*	0.8/60/18.6	-	*	*
*	-	-	-	-
-	-	-	-	-
*	0.5/10/1.7	-	*	0.3/(10)/-
-	0.3/20/3.4	*	(0.3)/10/4.8	0.3/(10)/-
0.8/30/8.5	0.3/20/3.4	*	*	(0.3)/10/2.8
-	-	-	-	-
(2.3)/20/3.4	-	-	-	-
1.8/20/3.4	0.8/10/5.1	-	0.3/20/4.8	0.3/20/5.6
-	-	-	*	-
*	-	*	-	*
-	-	-	-	-
-	-	-	-	-
*	*	(3.6)/10/3.8	*	*
-	-	(1.6)/10/7.7	-	-
-	-	-	(0.5)/20/4.8	-
-	-	-	(0.3)/10/2.4	-

Table 2. Diameter classes and basal areas of trees.

Species	Basal Area (ft^2/ac)	Diameter (dbh) Class in Inches 0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
Macroplot 1													
Pinus ponderosa	42.3					1		2			1		
Total	42.3												
Macroplot 2													
Abies concolor	0.07	1											
Juniperus scopulorum	0.03	1											
Pseudotsuga menziesii	0.5		1										
Total	0.6												
Macroplot 3													
Juniperus scopulorum	7.6						1						
Pinus ponderosa	19.3	1									1		
Total	26.9												
Macroplot 4													
Juniperus scopulorum	0.1	2											
Total	0.1												
Macroplot 5													
Juniperus scopulorum	0.3	4											
Pinus ponderosa	29.2	1		1									1
Total	29.5												
Macroplot 6													
Abies concolor	12.9				2		1						
Juniperus scopulorum	10.8	3				1	1						
Pinus ponderosa	67.3	1	1						1	1	2		
Pseudotsuga menziesii	52.6	2	1						1	1		1	
Total	143.6												
Macroplot 7													
Juniperus scopulorum	14.5									1			
Pinus longaeva	38.3					1	1		1	1			
Pinus ponderosa	19.5										1		
Total	72.3												
Macroplot 8													
Pinus ponderosa	40.6		1	3	1	2	1	2					
Total	40.6												

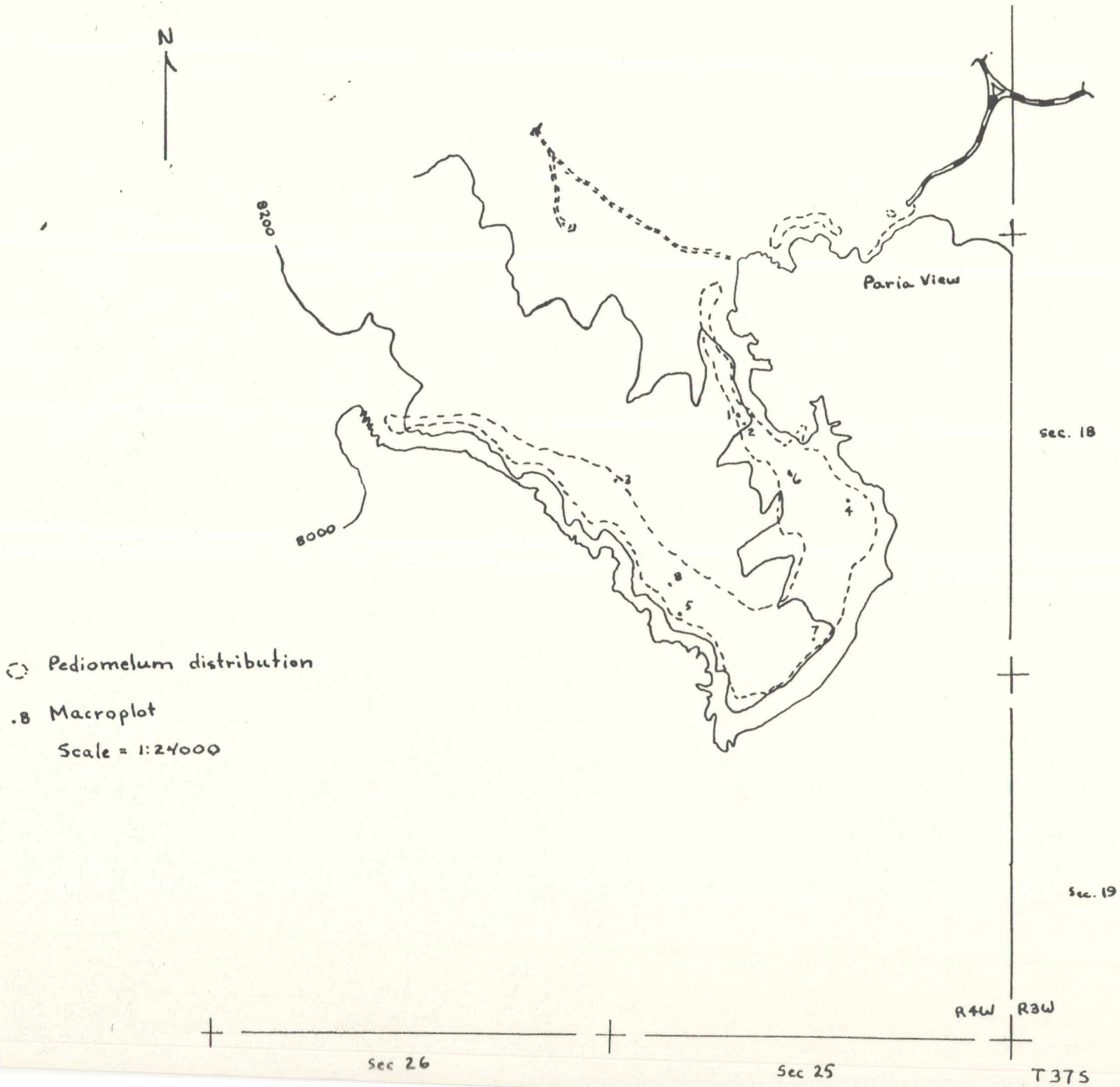
Table 3. Basal area by habitat type.

Species	Habitat Type PIPO/ARPA (n=6) Total	$\bar{x}$	% of Total	ABCO/ARPA (n=2) Total	$\bar{x}$	% of Total
Abies concolor				12.97	6.49	8.99
Juniperus scopulorum	22.5	3.8	10.6	10.83	5.42	7.51
Pinus longaeva	38.3	6.4	18.1			
Pinus ponderosa	150.9	25.2	71.3	67.30	33.65	46.67
Pseudotsuga menziesii				53.10	26.55	36.82
Total	211.7	35.4		144.20	72.11	

Table 4. Soil analysis.

Macroplot	pH	Organic Matter (%)	P (mg/kg)	K (meq/100g)	Ca (meq/100g)	Mg (meq/100g)	Ca:Mg
1	7.7	8.7	5.0	1.97	101.6	14.21	7.2
2	7.7	13.0	7.8	1.93	158.7	9.88	16.1
3	7.9	6.3	3.3	1.41	75.1	7.01	10.7
4	7.6	12.0	7.1	1.31	125.6	7.26	17.3
5	7.8	13.5	4.8	1.54	148.8	17.61	8.5
6	7.8	14.1	6.1	1.78	126.4	9.12	13.9
7	7.9	17.6	5.3	1.03	126.1	13.50	9.3
8	7.8	15.3	5.6	1.34	135.1	18.30	7.4
$\bar{x}$	7.8	12.6	5.6	1.54	124.7	12.11	11.3
SE	0.1	3.6	1.4	0.33	26.3	4.45	4.0

Fig. 1. Study area.



APPENDIX F FILE NAMES FOR DIGITAL MAPS

1) Habitat Type Maps

1.1) Full Park ..... PARKHT.DIG
1.2) North End of Park ..... NORTHHT.DIG
1.3) Middle of Park ..... MIDDLEHT.DIG
1.4) South End of Park ..... SOUTHHT.DIG

2) Community Type Maps

2.1) Full Park ..... PARKCT.DIG
2.2) North End of Park ..... NORTHCT.DIG
2.3) Middle of Park ..... MIDDLECT.DIG
2.4) South End of Park ..... SOUTHCT.DIG

3) Soil Maps

3.1) Full Park ..... PARKST.DIG
3.2) North End of Park ..... NORTHST.DIG
3.3) Middle of Park ..... MIDDLEST.DIG
3.4) South End of Park ..... SOUTHST.DIG

4) Combined Habitat Type and Community Type

4.1) Full Park ..... PARKHTCT.DIG