

**A RESURVEY OF THE VEGETATION AND SOILS OF
FISHTAIL MESA, GRAND CANYON NATIONAL PARK,
ARIZONA**

By

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INTRODUCTION

Fishtail Mesa is an isolated and waterless relict area. The 439 ha (1,084 ac) mesa is located immediately east of the confluence of Kanab Creek and the Colorado River in Grand Canyon National Park, Arizona (Figure 1). A narrow ridge separates the 1,829 m (6,000 ft) high mesa top from the "mainland" of the Kaibab Plateau, located 1 mile to the northeast. The two predominant vegetation communities on the mesa are a pinyon-juniper woodland and a sagebrush-mutton grass steppe. Lightning-caused fires are allowed to burn (Duhnkrack 1992). The mesa has never been grazed by livestock due to the steep 610 m (2,000 ft) cliffs that encircle it. However, its relative isolation is compromised when mule deer scale the northern edge of the mesa and utilize the forage during winter months. The mainland has similar elevation, geology, and vegetation, but differs in land management practices. Grazing by domestic livestock, logging, hunting, recreation, and fire suppression have been carried out on the mainland since the late 1800s.

The vegetation and soils of Fishtail Mesa were originally studied in May 1958 (Jameson et al. 1962). At that time, the objective was to provide management information and a comparison site for similar areas on the mainland, also administered by the U. S. Forest Service, which were grazed by domestic livestock. Our study was conducted to compare changes in the vegetation since 1958 and to evaluate Fishtail Mesa as a relict site for long-term surveillance of ecological change in the pinyon-juniper and sagebrush-mutton grass communities.

After Jameson et al. (1962) surveyed Fishtail Mesa, it was often compared with other relict studies in the pinyon-juniper ecosystem (among them Mason et al. 1967, Thatcher and Hart 1974, Schmutz et al. 1976, Turner 1982, Moir and Carleton 1986). Hikers, Arizona Game and Fish Department personnel, and university researchers (Butchart 1962, McCulloch 1976, Klopatek pers. comm. 1996, and Beymer 1984) have also visited Fishtail Mesa.

Description of the Study Site

Jameson et al. (1962) described two vegetation types on Fishtail Mesa: a pinyon/Utah juniper woodland¹ and a sagebrush shrubland² or steppe, henceforth called the tree type and the shrub type respectively. In 1958, the tree type comprised 74% of the area, while the shrub type comprised 26%. Pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) had no measurable cover in the shrub type, but constituted 59% in the tree type. Big sagebrush (*Artemisia tridentata*) had a relative total cover of 88% in the shrub type and 69% of the understory plant cover in the tree type (or 29% of the total absolute plant cover in the tree type). Shrubs, other than big sagebrush, comprised 12% relative cover and herbaceous plants comprised 0.5% relative cover in both the tree and shrub types. The low relative cover composition of understory species is typical of relatively undisturbed "old growth" pinyon-juniper stands (Erdman 1970, Barney and Frischknecht 1974, Tausch and West 1995). Jameson et al. (1962) noted two other minor plant communities: a patch of desert needlegrass (*Stipa speciosa*) grassland occupied a bowl-shaped depression, or swale, in the approximate center of the mesa and a small patch along the rim was dominated by snakeweed (*Gutierrezia sarothrae*).

The pinyon-juniper woodland of Grand Canyon National Park and adjacent lands has received some study (Rasmussen 1941, Merkle 1952, Darling 1966, Despain 1987, Klopatek 1987). Little study has been made of the grasslands or shrub steppe. However, the presence of grama grasses, galleta, and desert needlegrass mark Fishtail Mesa and nearby Boysag Point, semi-relictual area, as a southern fasciation of the Great

¹A woodland is defined as shrubs and/or small trees usually 0.5 to 5.0 m in height with crowns not usually touching, with between 25-60% cover with shrubs, herbs, and nonvascular plants present at any cover value (The Nature Conservancy 1994).

²A shrubland is defined as shrubs and/or small trees usually 0.5 to 5.0 m in height with individuals or clumps not touching to interlocking, generally forming over 25% canopy cover. Trees may be present, but with cover 10% or less and herbs and nonvascular plants present at any cover value (The Nature Conservancy 1994).

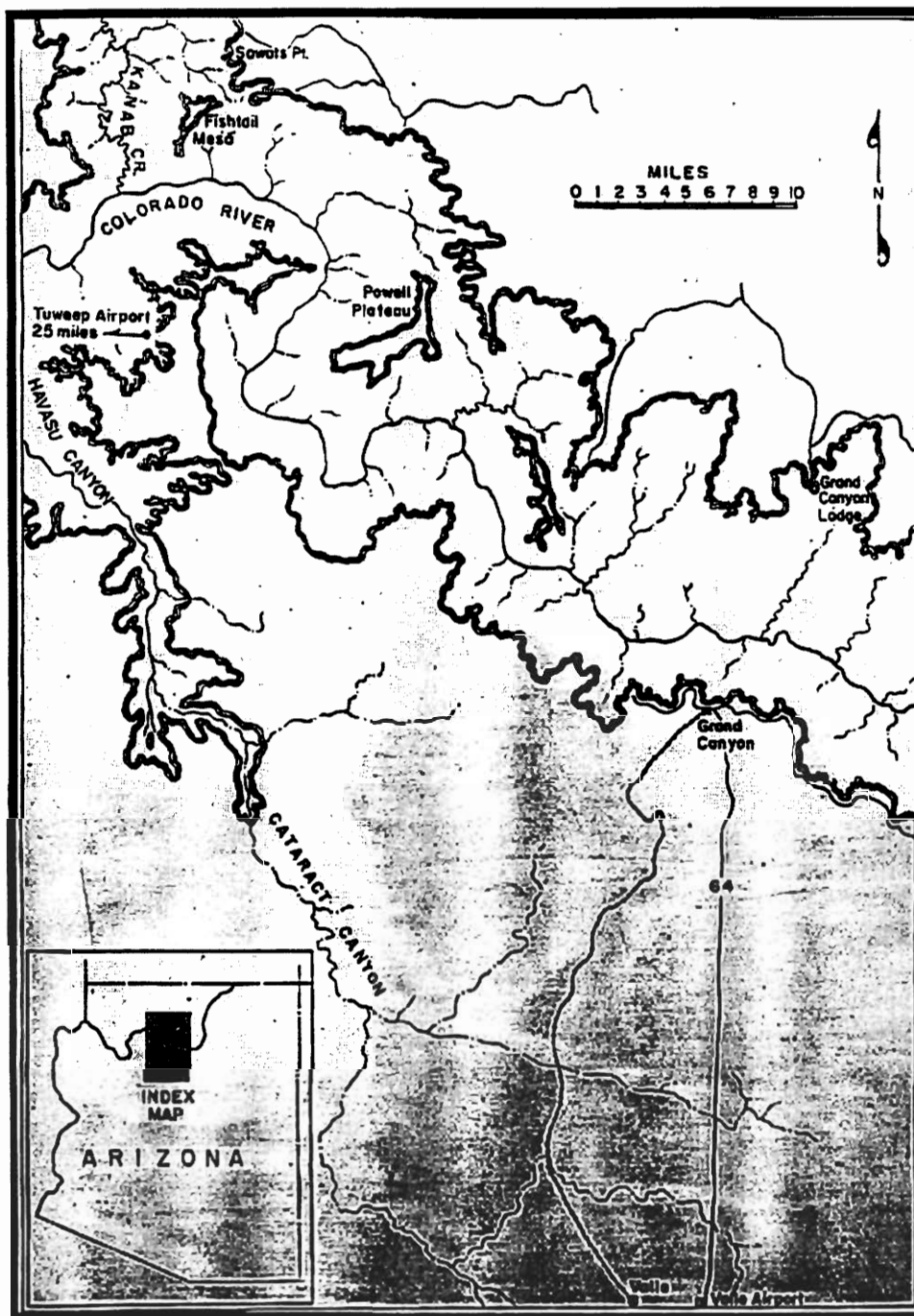


Figure 1. Location map of Fishtail Mesa (scanned from a photo of the original map drawn by Don Jameson in 1958).

Basin desertscrub (Young et al. 1977). The biotic community of Fishtail Mesa has been classified as the Great Basin Desertscrub Formation (Warren et al. 1982). Fishtail Mesa has been compared with Boysag Point (Schmutz et al. 1967, Turner 1982).

Precipitation records for Grand Canyon National Park and Tuweep (Green and Sellers 1964, Sellers and Hill 1974) indicate that annual rainfall on Fishtail Mesa is probably about 356 mm (14 in), with 45% occurring during winter and spring (December through April) and 34% occurring during the summer monsoon season (July through September) (Jameson et al. 1962). The mesa is waterless, but summer thundershowers can be sudden and locally heavy. About 95% of the precipitation is lost through evapotranspiration (Hunt 1967) or by percolation through the soil and sinkholes (Jameson et al. 1962). During the summer, the airflow is generally from the southwest. The average growing season is 141 days. The average January temperature is -1.7°C (28.9°F). The average temperature for July is 20.4°C (68.8°F). Extreme daily high temperatures can reach 37.8°C (100°F). The area is classified as semiarid, microthermal, and precipitation deficient at all seasons using the Thornthwaite (1931) climatic classification.

Fishtail Mesa has a gently rolling topography and the elevation of its surface varies from 1,769 m to 1,867 m (5,800 ft to 6,125 ft). The alpha member of the Permian-aged Kaibab Formation makes up the entire surface. Two types of limestone are exposed, both of which are "thin-bedded," and about 30 cm to 90 cm (1 ft to 3 ft) thick. One is a chemically precipitated normal marine limestone that weathers to a smooth surface of small blocks of fine, uniform-textured gray limestone. The other is a fine grained, gray, magnesium rich limestone that weathers with a rough pitted surface (McKee 1938). These two layers alternate with beds of sand and chert and thin layers of gypsum. Together they form a sloping rim above the massive, cliff-forming, beta member of the Kaibab Formation.

Thin, small areas of Quaternary alluvial deposits are generally found in the central portion of the mesa, along small, ephemeral drainages and at the foot of slopes. There are no significant aeolian deposits, with the exception of very minor reworked sands trapped near vegetation. Overall, the soils are shallow and poorly developed. The small, ephemeral drainages are stable with no serious cutting or rilling of the surface layers. Jameson et al. (1962) recognized five soil types and estimated their relative areal extent on the mesa: an upland soil developed from normal marine limestone (57%), an upland soil developed from sandy limestone (25%), cherty ridges and uplands (9%), alluvial soil (6%), and steep rocky slopes (3%).

History of Fishtail Mesa and the Adjacent Kaibab Plateau

In spite of its remote and inaccessible location, the vegetation of Fishtail Mesa has probably been grazed for millennia by native ungulates, primarily mule deer. The relictual or natural condition of the mesa is assumed to reflect the pre-settlement condition, i.e., that which existed when the Kaibab Plateau was utilized by Native American tribes as a summer home and hunting grounds. With the western expansion of Anglo settlement in the 1850s, Mormon pioneers first used the North Rim of the Grand Canyon for livestock pasturage. Extensive grazing of the Kaibab Plateau began in 1885 when over 2,000 cattle were introduced. By 1889, the plateau was grazed by about 200,000 sheep, 20,000 cattle, and an unknown number of horses (Mann and Locke 1931, Rasmussen 1941, Kimball and Watkins 1951, Merkle 1952, Caughley 1970).

The Kaibab Plateau remained in the public domain until 1893 when President Benjamin Harrison created the Grand Canyon Forest Preserve, administered by the Forest Service. In 1906, President Theodore Roosevelt created the Grand Canyon National Game Reserve. In 1919, Grand Canyon National Park was established by an Act of Congress. However, the range continued to deteriorate due to a series of events. From 1893-1920, the plateau continued to be overstocked by ranchers, first by an early period of heavy sheep use, followed and overlapped by heavy cattle use between 1908-1921 (Kimball and Watkins 1951). Overgrazing since the 1880s also served to exclude naturally occurring fires on the North Rim through removal of the grasses and herbs which carried the wildfires. During 1906-1931, game management by the Reserve warden and private hunting parties aimed to protect deer and other "game animals." This was accomplished by exterminating predators, among them an estimated 781 mountain lions, 30 timber wolves,

4,889 coyotes, 554 bobcats (Botkin 1990) and an unknown number of owls, hawks, and eagles. In 1923, active fire suppression began to protect the forest from lightning-caused wildfires. Prior to this time, the North Rim pre-settlement mixed conifer forest was maintained by frequent, low-intensity, fires which occurred every 15.8 to 19.0 years (White and Vankat 1987). At the higher elevations to the interior of the plateau, large stand replacement fires in the boreal spruce-fir forest had a return interval of 70 to 250 years (White and Vankat 1987).

Many text books cite the story of the Kaibab Plateau deer herd as a classic case example of the depressant effects predation has on regulating ungulate populations. After predators were eliminated, the predator-prey relationship was altered. The 1906 population estimate of 4,000 mule deer increased exponentially, creating a "deer problem." In 1918, the situation became critical. By 1924, the browse conditions were reported as deplorable when deer numbers were estimated to peak at almost 100,000 (Rasmussen 1941, Leopold 1943). Most ecologists of the time attributed the overpopulation of mule deer to predator control (Leopold 1943, Allee et al. 1949, Lack 1954, Davis and Golley 1963). Caughley (1970) ascertains that this interpretation is an overstatement of evidence, making conclusions speculative (Botkin 1990). Widely different 1924 population estimates are quoted by Rasmussen from forest supervisor estimates, "reports of men visiting the Kaibab Plateau to make observations on the deer," and Rasmussen's own trend estimates. The estimates vary from 30,000, to 40,000, 60,000, 70,000 and 100,000. In contrast, the forest supervisor's estimates for the 1907 to 1939 period were much lower, never above 35,000 (Caughley 1970). The supervisor also estimated the population to be stable at 30,000 over the period of the postulated decline.

Caughley (1970) concludes that ungulate population irruptions are initiated by a change in food or habitat and are terminated by overgrazing, a pattern exhibited by the Kaibab deer herd. The population increase was concomitant with the reduction of predators, but the later was only a minor influence (Caughley 1970; Botkin 1990). More importantly, the irruption coincided with a reduction of sheep and cattle (Caughley 1970). Whereas the overgrazing of the Kaibab Plateau by 200,000 sheep began in 1885, it had decreased to about 5,000 by 1908 (Russo 1964). The newly available browse allowed the population explosion of the deer herd. Ten years later in 1918, the first warning was given when damaged was seen. About 1920, fawns were reported to have starved. Seven successive warnings were given between 1922 and 1924. By 1924, Forest Ranger B. Swapp estimated that 60% of the deer herd (i.e., a drop from 50,000 to 20,000) had died of malnutrition or starvation, during the succeeding two winters (Caughley 1970). Subsequently, the first regulated deer hunt was conducted in 1924.

Browse productivity improved somewhat between 1936-1941, but there was an overall downward trend for the entire plateau (Service and Watkins 1946 as reported in Kimball and Watkins 1951). In 1955, officials estimated the North Kaibab mule deer population at 30,000 (Russo 1964). In 1987, it was estimated at 17,000, but by 1995, it had declined to about 14,000, (Randy Smith, Arizona Game and Fish Department, pers. comm. 1996).

During the winter months, a portion of the herd uses the western edge of the Kaibab Plateau and a small group accesses Fishtail Mesa. The means of access is probably via the Esplanade and up through small "breaks" on the northern edge of the Mesa (Figure 1). In 1975, Fishtail Mesa and adjacent lands were added to Grand Canyon National Park by the Grand Canyon Enlargement Act. Since that time, the National Park Service has administered the area.

Historical Accounts of Fishtail Mesa

Vegetation Composition

Range conservationists made brief surveys of Fishtail Mesa between 1934 and 1954 (Julander et al. 1934, 1948; Bostick 1949, Cravens and Pase 1954). They recognized Fishtail Mesa as a relict site because it was uninfluenced by settlement and post-settlement activities, such as domestic stock grazing, chaining, fire suppression, or predator control.

The first documented visit to Fishtail Mesa was by Julander in 1934, as part of a grazing reconnaissance. His report has apparently been lost but is cited by subsequent visitors. Julander concluded that four times as much forage per acre was produced on Fishtail Mesa when compared to similar areas on the mainland (Julander 1934 as cited in Bostick 1949). He also reported that substantially more grass, predominantly mutton grass (*Poa fendleriana*) and Indian ricegrass (*Oryzopsis hymenoides*), was produced on Fishtail Mesa than on the mainland. In contrast, the mainland, which comprises most of the winter mule deer pasturage, had undesirable weeds and low-value perennials (Julander 1934 as cited in Ellison 1947).

Relying on range ecology and management theories, which were in vogue at the time, Ellison (1947) reported that no part of Fishtail Mesa was in excellent condition. He concluded that the range condition of most of Fishtail Mesa was poor with a downward trend, while some areas were in fair condition with an upward trend. The latter conclusion was due to the establishment of grass seedlings of needle-and-thread and Indian ricegrass. Of course, these conclusions, as well as those cited below, are largely based on assumptions about the Mesa's "potential" vegetation and the palatability (i.e., "desirability") of the existing vegetation to domestic and native ungulates. They have little to do with documentation of actual, natural vegetation dynamics.

Cravens and Pase (1954) visited Fishtail Mesa on April 27-28, 1954. They described two distinct vegetation types: pinyon-juniper and sagebrush-grass. A third area totaling 1.2 – 2 ha (3-5 ac) and comprised of almost pure needle-and-thread grassland with no sagebrush invasion was also mentioned. They believed that the grassland stand was the result of old sagebrush or other woody shrubs dying out. Very little reproduction of either pinyon or Utah juniper was found and the considerable age of the junipers was noted. Little reproduction was also observed for sagebrush, round leaf buffalo berry (*Shepherdia rotundifolia*), Fremont barberry (*Berberis fremontii*), Utah serviceberry (*Amelanchier utahensis*), and cliff-rose (*Cowania mexicana* var. *stansburiana*). They found snakeweed as uncommon, scattered plants on shallow, rocky, unstable soils on the southern edge of the mesa. One woodland pace-transect suggested that "desirable" range plants constituted 89%, including 3% sagebrush, and "undesirable" plants comprised the remainder. They found the sagebrush-grass type "only in very old burns in the larger woodland formation, suggesting the fact that it is disclimax to the woodland, at least under the current edaphic and climatic conditions." A majority of the grass plants (71.4%) were found growing within the protection of older sagebrush plants, as opposed to out in the open (28.6%). Mutton grass was found to be the dominant grass in the woodland type along with Indian ricegrass and smaller amounts of needle-and-thread (*Stipa comata*) and squirrel-tail (*Sitanion hystrix*) grasses. They found long tongue mutton grass (*Poa longiligula*) throughout the mesa. It was especially common in the sagebrush-grass type³. Annuals were virtually absent and no plants of six-weeks fescue (*Festuca octaflorea*), filaree (*Erodium cicutarium*), or rabbitbrush (*Chrysothamnus nauseosus*) were noted on the mesa top. Desert needlegrass (*Stipa speciosa*) was only found on the dry, rocky, southern edge of the mesa. Snowberry (*Symphoricarpos oreophilus*) and mock orange (*Philadelphus microphyllus*) were found below the mesa rim and were fairly common on the north slopes of the ridge line joining Fishtail Mesa to the mainland.

Fire

Ellison (1947) reported that the,

"...sagebrush type dominates a large area which was burned many years ago, possibly as much as a century ago." However, he qualified this by noting, "In the present sagebrush type the evidence of standing snags [probably Utah juniper] indicates that a burn did occur. I think the burn is as old as I have indicated because no sign of charcoal can now be seen. Furthermore, some of the trees that have invaded the burn appear to be fairly old, although none of them could be called ancient. The succession from sagebrush to pinyon-juniper is obvious, both in the sagebrush type and in the woodland where dead sagebrush is found where the trees are growing thick."

³Long tongue mutton grass has since been combined into mutton grass (*Poa fendleriana*) by Cronquist et al. (1977) and Lehr (1978).

Cravens and Pase (1954) estimated that fires on Fishtail Mesa had occurred 75-100 years ago. Like Ellison (1947), they also noted that sagebrush preceded pinyon-juniper woodlands, as evidenced by dead sagebrush under the tree canopy.

Jameson et al. (1962) estimated that 20% of the original tree type had been converted to a shrub type by fires and that these areas made up about 60% of the shrub type. They estimated that if fires had not occurred, 90% of the shrub type would have remained under the dominance of trees. The age of the burns was not estimated. They concluded that fires must have occurred long ago since pinyon and Utah juniper snags were left standing. They noted that only the heartwood of Utah juniper remained. Dead pinyon wood is far less resistant to decomposition than Utah juniper. Jameson and his colleagues reasoned that the presence of both pinyon snags and weathered remains of much older juniper heartwood obviated any recent fires. Since this material would have been removed, Little reinvasion of the burns by pinyon and juniper trees was also noted. Utah juniper trees were found to be mature and even-aged. Pinyon comprised about 50% of the tree cover. They presumed that pinyon cover could further increase due to observations of many seedling and young-to-immature trees. In comparison, Schmutz et al. (1967) found 192 burned juniper and three burned pinyon snags on a mainland site near Boysag Point, ca. 11 mi (17.6 km) southwest of Fishtail Mesa. Tree-ring analysis of burned stumps and the oldest stumps of sagebrush indicated that no extensive fires had swept Boysag Point since 1889 (Schmutz et al. 1967).

McCulloch (pers. comm. 1996) explored Fishtail Mesa on May 27, 1973 and May 7-8, 1974. He photographed what he considered a burned pinyon-juniper stand on Fishtail Mesa, but couldn't recall if he had seen charcoal or assumed that a fire had occurred based upon the appearance of the vegetation. He did recall observing other stands of juniper on the mainland which had died due to a drought in the 1950s and were untouched by fire.

Mule Deer Population Estimate

Julander (1934 as cited in Ellison 1947) noted hedging of juniper, pinyon, cliff-rose, and Fremont barberry shrubs, which he ascribed to the high numbers of mule deer during the 1920-30s. Joint-fir or Mormon tea (*Ephedra* spp.) and four-wing salt-bush shrubs (*Atriplex canescens*) were not hedged.

Bostick (1949) reported that the mesa was "well-stocked, but not overstocked," by deer. He described that the deer browsed small and large twigs of cliff-rose and that range conditions were extremely variable, due primarily to the amount of gypsum in the soil and the severity and time since the last fire. He did not think that any part of Fishtail Mesa was in excellent condition, and in places it was poor with severe erosion. He noted that "all blue grama [*Bouteloua gracilis*] grass was in very low vigor....and numerous dead grass clumps of the better bunchgrasses were observed. This death was not due to overuse, as no evidence of any use of the grasses was observed." Care should be taken in interpreting this statement. "Low vigor" may be the result of selection of low growth forms due to a number of edaphic conditions, the effect of recurrent drought on herbaceous species, or inter- and intraspecific plant competition.

Cravens and Pase (1954) noted moderate to heavy use of cliff-rose (even though it was not abundant), four-wing salt-bush, Mormon-tea (*Ephedra viridis*), and Utah serviceberry. Sagebrush use, however, was light. They describe that an old "high-line" or grazing line was readily evident on older shrubs, especially juniper, while a distinct current high line was evident on all cliff-rose and smaller junipers. Cravens and Pase also counted deer pellet groups on twelve, randomly established 6.6 ft radius circular plots. They reported that an average of 1.085 pellet groups per plot, or 26.8 deer-days use per acre per year, and an estimate of 210 deer or one deer per 5.71 acres. These densities are similar to the one deer per 7.6 acres reported for "Jump-up Pasture," a 5,000 acre area studied in 1931 on a broad point north of Fishtail Mesa on the mainland and extending toward Kanab Creek (Rasmussen 1941).

McCulloch (per. comm. 1996) noted in the early 1970s that cliff rose was generally scarce, in poor vigor, and not noticeably browsed. He found that deer droppings (i.e., pellet groups) were infrequent, but a few fecal pellets were compacted as if the animals were on a rich, herbaceous diet.

METHODS

General Study Design – The Elb

We resurveyed the vegetation and soils of Fishtail Mesa during May 10-15, 1996, approximately 38 years after Jameson et al. (1962) studied the mesa during May 6-11, 1958. Donald Jameson, the principal author of the previous study, participated in the present study. Like Jameson et al. (1962), we used an adaptation of a method originated by Woodin and Lindsey (1954) called an "elb" (Figure 2). The term "elb," a shortened form of elbow, refers to the sampling unit, whereby two 400 ft base-lines, which serve as line intercepts (Canfield 1941, Parker and Savage 1944), are oriented at right angles to produce an L-shaped plot with two orthogonal "arms." Elbs are noted by left (L) and right (R) when observed from the origin.

Woodin and Lindsey (1954) believed that this orientation avoids the linear influence of topography. They reasoned that a random straight line might fall largely within or parallel to a gully, ridge, slope base, or geological stratum, thereby obscuring the sampling results. They never defended their assumptions with rigorous statistical analysis. Some aspects of this experimental design bothered us. For example:

- A small area (100 ft²) where the strip transects, which form the elb arms, overlap at the origin. This overlap potentially effects only the pinyon and juniper observations. Luckily, no trees were double-sampled on any of the seven complete elbs (Elbs 1 – 7) since they were always absent from this small area. Elb 8, consisted only of one arm.
- The four, three foot square frequency plots are too few in number to give accurate spatial assessments of plant frequency as well as assessment of temporal change in frequency with acceptable statistical reliability. A more reliable plant frequency estimate could be obtained directly from the baseline line intercepts by breaking down each 400 ft line intercept into smaller subsamples (e.g., 20 x 20 ft subsections). A frequency estimate could be assessed according to the number of subsections in which a species occurs divided by the number of subsections times 100. The accuracy of the frequency estimate thus gained could be improved by weighting it according to the inverse of the mean size of each species (Cox 1972).
- No observation of any kind for trees under three feet tall were taken in 1958. Thus, we have no idea of the density of small seedling juniper and pinyon (stems < 1 cm in diameter) which had become established at that time.
- In 1958, the only substrate composition observations (rock, litter, bare ground) were taken using the Parker loop. These observations would also be more reliable if they were assessed using the line intercept as a sampling unit or by employing replicate Daubenmire frames (20 x 50 cm).
- The 1958 methodology employs no random sampling procedures other than location of the elbs proper.
- According to Woodin and Lindsey (1954), seven elbs gave an acceptable degree of error when used to typify an area of from 80 to 100 ac. Fishtail Mesa is just over 1,000 ac and was sampled using only eight (actually 7½) elbs.
- Jameson et al. (1962) claim that species cover along line intercepts was estimated to an accuracy of 0.01 ft (≈ 3 mm). There are inherent difficulties in identifying the extents of plant canopies and graminoid bases along an intercept. Among the difficulties are wind-caused displacement of the line from its proper position, accidental movement due to human error, parallax (Mueller-Dombois and Ellenberg 1974), expansion and contraction of the tape due to temperature changes, differences in canopy density and shape of crown outline among species (Mueller-Dombois and Ellenberg 1974) and other factors. Furthermore, differences in cover of perennial grasses as estimated using line intercepts can be attributed to differences among observers (Bonham 1989). We considered that an accuracy of 0.03 in (≈ 1cm) was more reasonable.
- Finally, the use of U.S. Customary units makes assessments, calculations, and analyses unnecessarily cumbersome.

We employed the same methods and units as Jameson et al. (1962), as taken from Woodin and Lindsey (1954), for the sake of consistency. Readers wanting more information regarding the elb method should consult Woodin and Lindsey (1954) and Jameson et al. (1962).

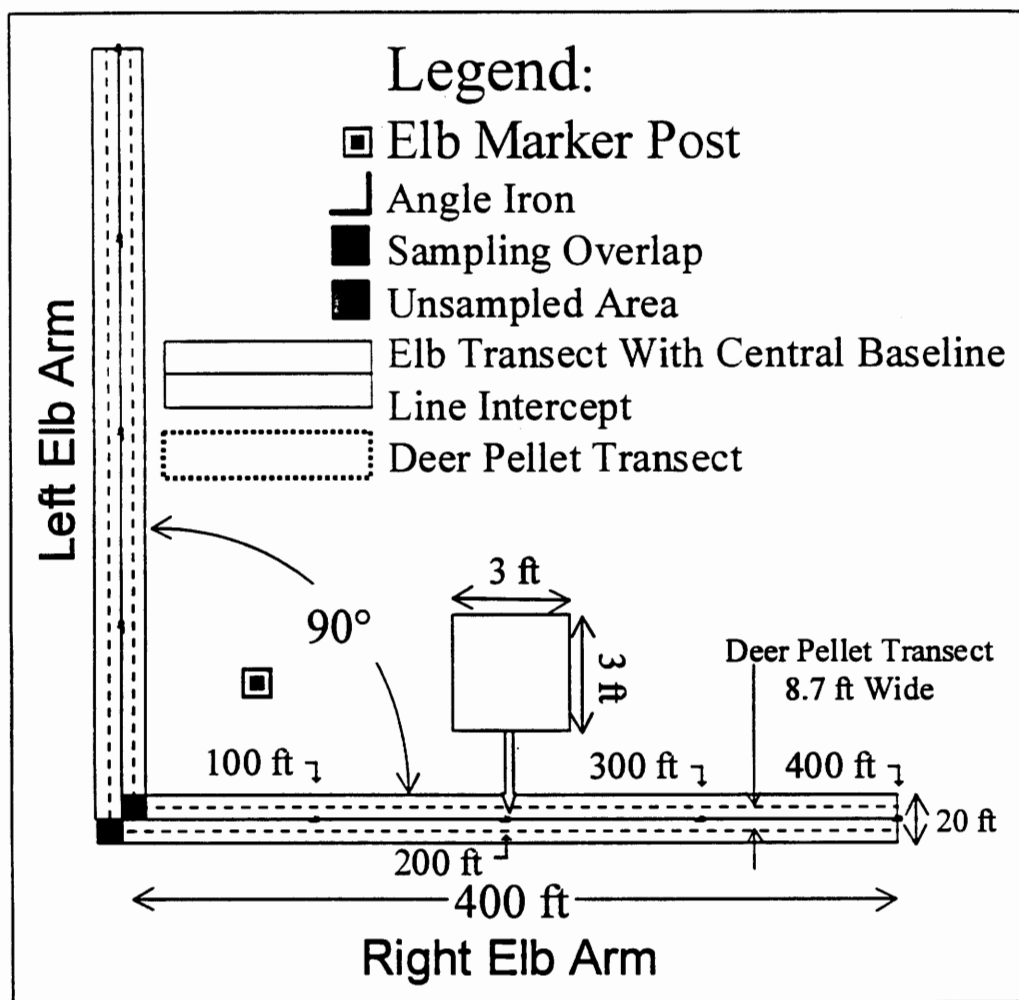


Figure 2. Diagram of the left and right arms of an elb showing elb transect with central baseline line intercept, deer pellet transect and frequency plot.

Jameson et al. (1962) randomly located eight permanent elbs on Fishtail Mesa. Four elbs were located in the shrub type and three and a half elbs were located in the tree type (Figure 3, Table 1). The sampling of one tree type elb (Elb 8), in the 1958 survey, was incomplete and restricted to one arm. This was due to time constraints created by the availability of a military helicopter used for access. The location of each elb was permanently marked with a six-foot metal "T" post erected near the elb origin. Nine buried angle-irons demarcated the two elb baselines. One angle iron marked the origin, with four each located at 100 ft intervals along each elb baseline (Figure 2).

Table 1. Description of the eight permanent elbs on Fishtail Mesa as originally installed by Jameson et al. (1962) in 1958.

Elb No.	Vegetation Type	Line intercept length (ft) and number of Parker loops	No. of 3-foot square (9 ft ²) frequency quadrats
1	Shrub	2 x 400	8
2	Shrub	2 x 400	8
3	Tree	2 x 400	8
4	Shrub	2 x 400	8
5	Shrub	2 x 400	8
6	Tree	2 x 400	8
7	Tree	2 x 400	8
8	Tree	1 x 400	4
Total Shrub Elbs		3,200	32
Total Tree Elbs		2,800	28

Specific methods for vegetation, soil, and additional analyses are outlined below.

Vegetation

Field Measurements and Inventory

Line intercept data for all vascular plant species were recorded along the entire length of each elb. Accuracy in 1996 was to the nearest 0.5 in. When plant cover was less than this, it was recorded as a "trace," equal to 0.012 in or 1/1,000 ft. A 20 ft wide strip or quadrat centered over the elb line was used to measure tree species. Jameson et al. (1962) only measured live trees greater than 3 ft in height. We measured trees of all heights and ages, as well as standing dead trees. The seedling tree diameters were measured at ground level, while pole-sized, mature trees, and snags were measured at 1 ft above the ground, not at breast height, due to the low branching characteristic of pinyon and juniper. In addition, the Cartesian *x* and *y* coordinates (relative to the elb baselines), canopy diameter, and height for all trees were recorded. When the cross-section of the canopy was eccentric or irregular, as opposed to nearly circular, the maximum and minimum canopy spread was averaged. Canopy cover was calculated simply as the area of a circle expressed as $\pi(D/2)^2$, where $D/2$ equals the radius. Trees with more than half of the base located inside the strip perimeter were counted, while those outside were omitted.

Understory vegetation cover is recorded along the two orthogonal line intercepts, i.e., elb arms. Density, abundance, and frequency of trees are derived from a two-dimensional "strip-plot" 20 ft wide and 400 ft long, centered over each of the two line-intercepts. For each elb, the sum of absolute vegetation cover derived from the line-intercepts,

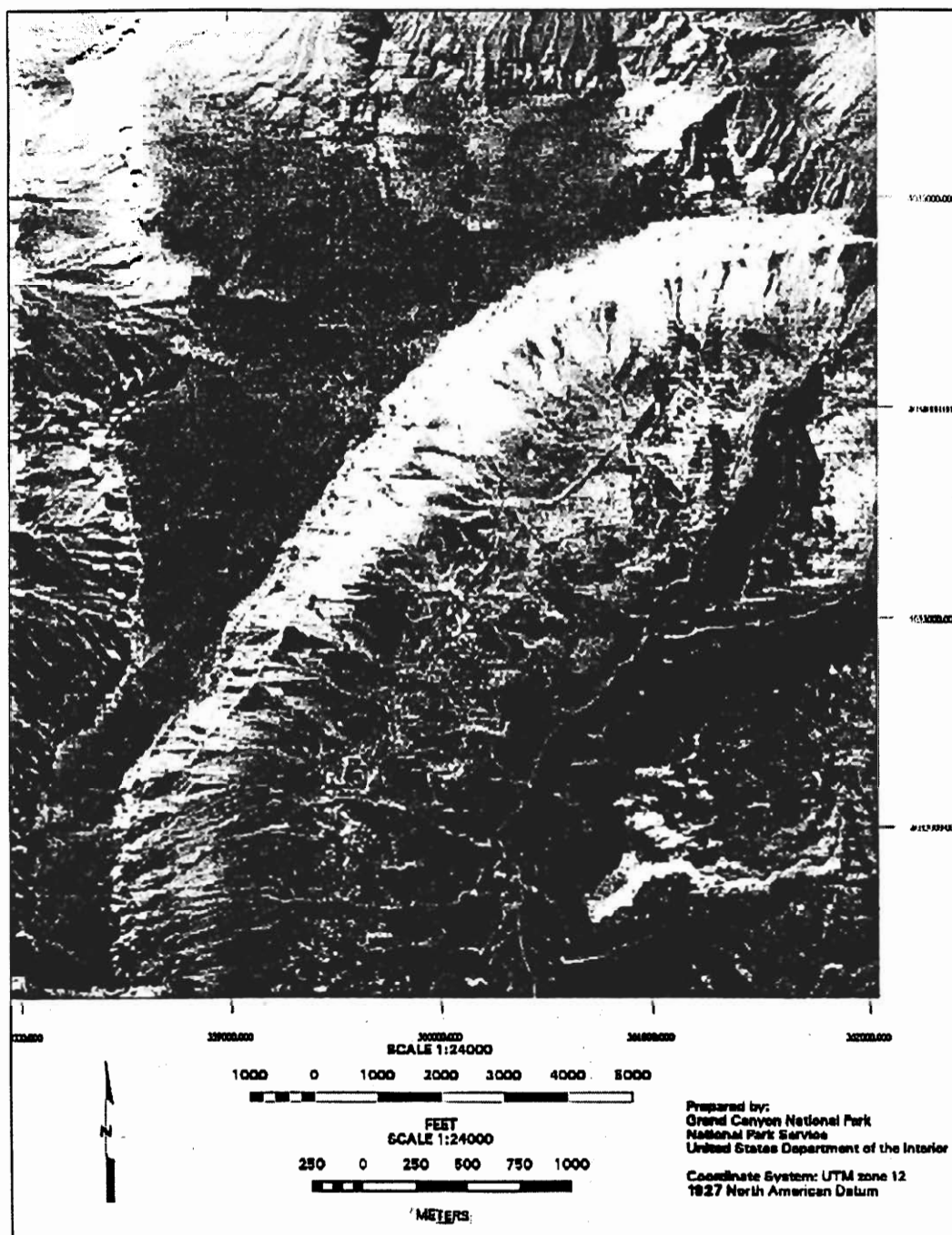


Figure 3. Fishtail Mesa and elb locations.

was subtracted from the total length of the intercepts (800 ft) to yield an approximation of non-vegetation cover, which would include bare ground, rock, and litter. The true non-vegetation cover is actually somewhat more, as many of the plants had overlapping cover. Percent relative cover was calculated as the sum of a species cover divided by the sum of intercepts for all species on the elb or transect line, times 100. It is also called relative dominance (Mueller-Dombois and Ellenberg 1974).

A stand "map" was easily prepared using the x- and y-coordinates by entering the data into a SigmaPlot graph file (which we call a "bubble map") and creating a scatter plot. Dead Utah junipers and pinyons, as well as unidentifiable dead, standing trees which we labeled "snags," were given a nominal "cover" so that they would be mapped by the program. These snags and dead stems were labeled as such on the final scatter plot map. The results of one of the elb halves "bubble map" is presented in this report as an example (see Results) but no interpretation is presented.

Three-foot square quadrats (i.e., nine ft²) were centered over the baseline at 100 – 103 ft, 200 – 203 ft, 300 – 303 ft and 400 – 403 ft adjacent to the permanent angle irons (Figure 2). These quadrats or plots totaled eight for each elb, except Elb 8, which only had four. Each quadrat, which was first photographed in 1958, was rephotographed in 1996. The 1958 photographs were located at, then obtained from, the U.S. Forest Service Rocky Mountain Station's Fort Valley Experiment Station, Flagstaff, Arizona. Species frequency was determined for each elb. Percent frequency was calculated as the number of three foot square plots occupied by a species divided by the total number of plots examined, times 100. Percent frequency was tabulated for each elb (i.e., eight for Elbs 1-7, and four for Elb 8). We repeated these observations and the plots were rephotographed using 35 mm black and white film with a sign board indicating elb number, the plot number, orientation (i.e., left or right), and date.

Basal and cover presence data for tree, shrub, and cactus species were taken at each foot interval for each elb using a 0.75 in Parker loop fixed at the end of a metal rod (Parker 1951, Driscoll 1958, Parker and Harris 1959). Only basal cover was recorded for forbs and grasses. Double hits were noted if there was a crown hit for a tree and a basal hit for a grass, shrub, or cactus species. If no vegetation was encountered, the presence of bare ground, litter, or rock was noted.

Tree Cores

Tree cores taken from one foot (30 cm) above the ground or cross sectional slabs were collected from four to six living pinyon trees located outside of the elb strips to ascertain tree age. The height and basal diameter measurements were also recorded. One large cliff-rose was measured and cored. Utah junipers were not cored as this long-lived species is subject to highly irregular diametric growth and generally does not yield easily datable cores. The cores were glued to wooden mounts, sanded, and polished until the rings were visible (Stokes and Smiley 1968). Rings were counted using a 10-30 power zoom microscope. In cases where the core missed the pith, an estimate of the missing rings was made using a pith locator (concentric circles matched to the curvature and density of the inner rings). No cross-dating or ring width measurements were made, nor were slabs or cores taken from standing snags.

We chose the date of 1850 as the pre-settlement date for tree ring analyses. The date 1848, the year of the Mexican-American War and the beginning of the Territorial Period, has been cited as a turning point in changes in ecological processes and forest ecosystem health for ponderosa pine (*Pinus ponderosa*) in the Southwest (Dahms and Geils 1997). It is generally considered that European or Anglo settlement of northern Arizona began in the 1870s (Rapport and Yazvenko 1996). By 1880, cattle herds in Arizona and New Mexico were estimated at 172,000 head (Baker et al. 1988).

Age-size relations of the dominant and codominant trees were established by fitting observed basal diameters (height could also be used) to corresponding age data, as estimated by tree-ring counts, to the Chapman-Richards equation (Clutter et al. 1983, Tausch and Tueller 1990). The Chapman-Richards model is derived from basic biological considerations and has proven to be very flexible in modeling growth of both individuals and populations (Clutter et al. 1983). In this paper, the equation takes the three parameter form:

$$diameter = A(1 - e^{-BAge})^C \quad (1)$$

and was fitted using SigmaPlot for Windows version 4.01 (SPSS 1997) using the Levenburg-Marquardt non-linear fitting algorithm. Three constants are defined: A , B , and C which are the parameters of the Chapman-Richards equation.

In order to increase the number of samples, we made a conscious decision to analyze the 1996 data according to separate elb arms. That is the right and left arms of each elb were considered to be independent sampling units. Due to the great length of each elb arm and their orientation at right angles to one another, the elb is not really a contiguous sampling unit; we believe that this decision is not unreasonable. Thus, the shrub type is represented by eight sampling units and the tree type by seven sampling units (remember, Elb 8 consisted of one arm only). The decision affects only the 1996 data that we collected. The original 1958 data have been lost, so temporal comparisons are based on the 1958 data summaries given in Jameson et al. (1962).

Qualitative Vegetation Analysis

The Shannon diversity index, H' , (Kent and Coker 1992) was calculated from the relative cover percentages for the 1958 and 1996 data sets. Relative cover for each side, i.e., left and right of the tree and shrub type elbs, were analyzed separately for 1996. The Shannon index is defined as:

$$H' = -\sum_{i=1}^s p_i \ln p_i \quad (2)$$

where H' is the Shannon Index, s is the number of species, and $\ln$ is the natural logarithm. The term, p_i , is the relative abundance of the i^{th} species expressed as:

$$p_i = \frac{A_i}{\sum A} \quad (3)$$

where A_i is the abundance (cover, biomass, density) of the i^{th} species and $\sum A$ is the total abundance of all species in the sample.

Species and elb arm (samples) vegetation data were analyzed using Two-way Indicator Species Analysis or TWINSpan (Hill 1979b, Kent and Coker 1992). This method is a so-called polythetic, divisive method of classification. The algorithm first constructs a classification of the samples. It then uses this classification to obtain a second classification of species based on their ecological preferences. The result is a two-way table that expresses the species' synecological relations succinctly (Kent and Coker 1992). Hill 1979b describes this terminology as "unfortunate and confusing." He suggested that a better name would have been *dichotomized ordination analysis*, since the method is based on progressive, iterative refinement of a single axis reciprocal averaging ordination (i.e., correspondence analysis). Eventually, these progressive ordinations lead to the delineation of one or more differential species according to their scores (+ or -) on the single ordination axis, or, positive and negative differential species. As many as 15 differential, or *indicator* species, in the program's terminology, can be chosen. If the program default options are accepted, as in this analysis, five indicator species are employed. The concept of differential species is based on presence and absence, but Hill (1979b) introduced the concept of pseudospecies as a way of adapting abundance data to a qualitative equivalent which can then be used in the construction of a classification dichotomy (Kent and Coker 1992). One to five pseudospecies are generated if the default options of the computer program are accepted. The number of these pseudospecies is a transformation of the original quantitative vegetation data according to a scale defined by Hill (1979b):

- 0-2 = 1 pseudospecies
- 2-5 = 2 pseudospecies

5-10 = 3 pseudospecies
 10 -20 = 4 pseudospecies
 >20 = 5 pseudospecies

In this study, relative percent vegetation cover data were used to redefine nine pseudospecies based on an octal scale conversion. The primary reason that Hill (1979b) recommended smaller numbers of pseudospecies (i.e., five) were the constraints of computing time and memory limitations. We did not feel so constrained since computing power has increased considerably since Hill first derived his method. Furthermore, we wanted our pseudospecies transformation scale to reflect as closely as possible the quantitative species information in the original data matrix. Thus our scale was constructed as follows:

0-0.5% = 1 pseudospecies
 0.5-1% = 2 pseudospecies
 1-2% = 3 pseudospecies
 2-4% = 4 pseudospecies
 4-8% = 5 pseudospecies
 8-16% = 6 pseudospecies
 16-32% = 7 pseudospecies
 32-64% = 8 pseudospecies
 >64-100% = 9 pseudospecies

These classes are non-exclusive and cumulative, that is if a particular plant species exhibited a relative cover of 2% in one quadrat, it would be assigned a pseudospecies level of 3, but if it occurred in another quadrat with 65% relative cover, all nine pseudospecies would be present.

The line intercept data were analyzed using detrended correspondence analysis (DCA), an eigenvector-based ordination procedure related to reciprocal averaging and based upon an occurrence of a set of species in a set of samples (i.e., elbs) (Hill 1979a). Detrended correspondence analysis corrects the two most severe faults of reciprocal averaging: scale contraction and the "arch effect." Scale contraction is an artifact of the reciprocal averaging algorithm. Eigenvector components (i.e., species scores) associated with the first eigenvalue extracted from the $s \times s$ transition matrix tend to be relatively closer to one another at extreme values (i.e., axis ends) than at intermediate values. The arch effect is the tendency of several eigenanalysis-based ordination methods such as reciprocal averaging and principal components analysis to produce an arch or horseshoe-shaped ordination due to nonlinear structure in the original ecological data. Rather than being independent, the first and second DCA axes are related to each other by some nonlinear function. The arch effect leads to misrepresentation of species or stand distances (similarities) relative to one another in ordination space. DCA corrects scale contraction by subdividing the first DCA axis into a number of segments and rescaling (expanding or contracting) those which require it. The fundamental reason for rescaling is to ensure that species turn-over along DCA axis 1 occurs at a uniform rate throughout so that equal distances in the ordination correspond to equal differences in species composition. The arch effect is corrected by mathematically dividing the ordination into several short segments (usually 26) with dividing lines perpendicular to the first DCA axis. Each segment is "slid" up and down with respect to each other until the within-stand mean and stand standard deviations of the species scores on DCA axis 2 are equal over all segments, thus removing the arch effect. This detrends the relation between axes 1 and 2 (Gauch 1982, Pielou 1984).

Since, in DCA, within-sample standard deviations are constant, they can be set to one to achieve a standard scaling. This, in turn, causes the average species abundance profile to have a standard deviation of one. This means that the unit of ordination length in DCA can be referred to as an average standard deviation of species turnover or S.D. A species appears, rises to its maximum abundance and declines to zero over a span of four S.D.'s and a 50% change in sample species composition requires about one S.D. (Gauch 1982). Most DCA computer programs, including Hill's (1979a) original DECORANA program, and the MVSP V2.2 DECORANA program used in this study (Kovach 1995) multiply the DCA Axis S.D. values by 100.

Efficacy of the DCA was assess by relating ecological distances for $n(n-1)/2 = 105$ sample (i.e., elb arm) pairs calculated for the original species by samples matrix with the similarly calculated distances derived from the final

two dimensional stand ordination. The distance metric employed was the Czekanowski coefficient or “percent similarity.” This similarity coefficient, often mistakenly referred to as Sorensen’s or Jaccard’s coefficient (Kent and Coker 1992) is expressed as:

$$Sc_{j,k} = \frac{2 \cdot \sum_{i=1}^m \min(X_i, Y_i)}{\sum_{i=1}^m X_i + \sum_{i=1}^m Y_i} \quad (4)$$

where $Sc_{j,k}$ is the Czekanowski similarity coefficient quantifying the similarity between samples (i.e., elb arms, quadrats, etc.), j and k X_i and Y_i are the abundances of species i , m is the number of species and the numerator is twice the sum of the lesser abundances of species i where it occurs in both samples. The number of possible similarity coefficients between all possible sample pairs in a data base is an upper (or lower) triangular matrix with $n(n-1)/2$ elements where n equals the number of samples. In our study, we employed 15 elb arm samples, thus 105 similarity coefficients are possible. Multiplication of Sc by 100 gives percent similarity or PS .

The Multivariate Statistical Package (MVSP V.2.2) (Kovach 1995) was used to perform DCA, whereas PC-ORD (McCune and Mefford 1995) was used to generate the TWINSpan two-way ordered table. The interested reader should consult Hill (1979a, 1979b), Gouch (1982), Pielou (1984), Kent and Coker (1992), and Kovach (1995) for more detailed descriptions of DCA and Two-way Indicator Species Analysis.

Rephotography, Maps, and Other Documentation

A series of black and white, scenic or landscape photographs were taken with a Speed Graphic 4 by 5 camera, in order to replicate the photographs taken in 1958. Existing aerial photography of Fishtail Mesa archived at the Forest Supervisor’s Office in Williams, Arizona was also examined to determine if changes in vegetation could be observed over time. Vegetation maps were prepared using rectified 1978 color aerial photography with a scale of 1:12,000. Data from 1996 Global Positional System (GPS) coordinate data collected from the mesa perimeter and elbs was used in the map preparation. All maps produced by our study conform to U. S. National Mapping standards. Field notes were taken on general observations, plant species adjacent to the elbs, and archeological sites. A vascular plant species list was made for the entire mesa and vascular plant specimens collected to confirm plant identification. Plant names follow that of Lehr (1978) and Lehr and Pinkava (1980, 1982). Faunal lists were compiled and mammalian scat was collected for species verification.

Mule Deer Population Estimates

Mule deer pellet groups were counted to determine deer use (Neff 1968). An 8.7 ft wide strip (Figure 2) was centered over the elb. Each 100 ft elb-arm section equaled 0.019 acres, totaling about 0.16 acres for each elb. It is generally assumed that during the winter a deer deposits 13 pellet groups per day when feeding on depleted ranges (Rogers et al. 1958). Jameson et al. (1962) used the time frame of 150 days. The estimated number of deer present is theoretically a function of the density of pellet groups per unit area divided by the estimated production of pellet groups per deer, per unit time, the whole divided by the total number of days over which the observations were made. More simply put:

$$Deer\ No. = \frac{[(pg \cdot ac^{-1} \times ac) / (pg \cdot deer^{-1} \cdot d^{-1})]}{\sum d} \quad (5)$$

where pellet groups are *pg*, unit area is expressed in acres (*ac*) and time is expressed in days (*d*).

Because deer range over a large area, the intensity of use, or "deer-days," is the preferred metric rather than the number of deer per section of land. The deer-days figure provides a means of comparing use levels or population between years or areas. To obtain the number of deer-days, division by the total number of days (Σd) over which the observations were made is omitted.

A deer pellet group is defined as 30 or more, dark brown pellets in a pile (Neff 1968). Adjacent pellet groups of very similar appearance were counted separately unless scattered pellets connected the groups. If a pellet group were located on the outside edge of the strip, only groups with more than half of the group within the strip were counted. Grey or white pellet groups were considered to be from previous years. Although we counted them, the numbers were not considered in the analysis. Ideally, the method requires that all deer pellet groups be cleared from the area several months prior to field work (Neff 1968). This was infeasible due to the remote nature of the site, therefore allowing only crude estimates to be made. However, Jameson et al. (1962) were also unable to clear the area prior to field work, so our results should be comparable to theirs.

Soils

A 1958 soil map was recreated using a photo-enlargement of a black and white halftone figure in the Jameson et al. (1962) report. Portions of the soil unit boundaries, especially in the north central part of the mesa, were difficult to discern and were estimated. A 1996 soils map was prepared using a combination of field notes and aerial photographic interpretation. The 1996 soils units were mapped on a 1978, 1:24,000 scale, color aerial photograph which was enlarged to a scale of 1:12,000. A 7.5 minute Fishtail Mesa topographic map was superimposed upon the image. Boundaries of the mapping units were determined using discernible color and elevational parameters. Reddish hues within the sagebrush and pinyon-juniper vegetation and below 6,000 ft were presumed to represent sandy limestone. The normal and cherty limestone beds were lighter colored, usually supported an open pinyon-juniper woodland, and occurred above 6,000 ft. The gypsum beds noted in the field survey were easily identifiable on the aerial photography due to their light color and lack of vegetation. Photographs of four soil test pits were taken and the soil samples collected, but not analyzed due to budget constraints. For additional comparisons, extrapolations were made to four mapping units from the Terrestrial Ecosystem Survey (TES) for the Kaibab Plateau (U. S. Department of Agriculture 1991).

Data Archiving

Original data sheets, 1958 and 1996 photography, field notes, and electronic data are archived at Grand Canyon National Park's Museum Collections for future research use. After a thorough search of U. S. Forest Service archives, the 1958 original data sheets were not located. They are presumed lost. All 1996 plant vouchers have been deposited in the park herbarium. Duplicate plant specimens have been deposited at the Desert Botanical Garden Herbarium.

RESULTS

General Observations

Each elb (Table 1, Figures 1 and 2) was approximately a 15 minute walk from the closest, nearby elb. A majority of the steel fence posts were found standing within 30 ft (10 m) of the elb origin, between the two arms (Figure 2). Angle irons indicating the 100 ft (30 m) increments along the elb were also found. We repositioned fallen fence posts and angle irons that had been displaced by frost heaving. We observed patches of standing juniper snags. We were predisposed to assume that the standing snags were the remnants of a wildland fire, 80-100 years ago, mainly because of the accounts of previous researchers cited above. However, many of the snags appeared to us as if they had simply been weathered. No evidence of recent burns, dead shrubs, or charcoal was observed. Any fire would have had to have been a very old one, certainly predating the earliest published articles dealing with the biota of Fishtail Mesa (Julander 1934 as cited in both Ellison 1947 and Bostick 1949). Unfortunately we did not collect stem cross-sections from any of the standing snags to confirm either the presence or age of burns. Transect notes and associated plant species lists are presented in Appendix 1.

A more accurate assessment of the mesa's top was derived using rectified aerial photography and GPS data. We found that the top of Fishtail Mesa is approximately 4,337,469 m² (433.7 ha or 1,084 ac). Jameson et al. (1962) had previously estimated the area of Fishtail Mesa to be 1,430 ac, whereas Cravens and Pase (1954) estimated it to be 1,200 ac.

Vegetation and Flora

Floristic Survey

Ninety-one plant species were observed or recorded on Fishtail Mesa (Appendix 2) and 70 voucher plant specimens collected. No voucher specimens were collected in 1958. Therefore, some effort was expended in matching a few species cited by Jameson et al. (1962) with the floristic list obtained from our 1996 resurvey. For example, we equated 'pinque' (*Hymenoxys richardsonii* var. *floribunda*), with Cooper's hymenoxys (*H. cooperi*). Four species collected on Fishtail Mesa in 1996 and not previously listed for the park (Phillips et al. 1987) are considered new: *Astragalus argophyllus* var. *panguicensis*, *A. pinionis* var. *atwoodii*, *Echinocereus engelmannii* var. *chrysocentrus*, and *Oenothera caespitosa* var. *crinita*. Three other species, *Coryphantha vivipara* var. *desertii*, *E. triglochidiatus* aff. var. *toroweapensis*, and *Phacelia* aff. *constancei* may prove to be new records for the park, but additional material is needed to confirm the identifications.

We did not encounter any of the following seven plant species observed by Jameson et al. (1962): black grama (*Bouteloua eriopoda*), yellow tansy mustard (*Descurania pinnata*), whitlow grass (*Draba cuneifolia*), wild rye (*Elymus salinus*), gilia (*Gilia* sp.), stickseed (*Lappula redowskii*), or sand dropseed (*Sporobolus cryptandrus*). Neither did we observe buck brush (*Ceanothus fendleri*), filaree, deer vetch (*Lotus* spp.), mock orange, squaw bush (*Rhus trilobata*), or snowberry; as was reported by earlier visitors (Ellison 1947, Cravens and Pase 1954, McCulloch, pers. comm.). We were the first to observe species previously reported for Grand Canyon National Park, but not for Fishtail Mesa, such as sand verbena (*Abronia nana*), brownfoot (*Acourtia wrightii*), pinyon dwarf mistletoe (*Arceuthobium divaricatum*), mariposa lily (*Calochortus nuttallii*), many-headed barrel cactus (*Echinocactus polycephalus* var. *xeranthemoides*), inflated wild buckwheat (*Eriogonum inflatum*), two Fendler bush species (*Fendlera rupicola* and *Fendlerella utahensis*), Colorado four o'clock (*Mirabilis multiflora*), beargrass (*Nolina microcarpa*), pancake pear (*Opuntia chlorotica*), porcupine prickly pear (*O. erinacea* var. *hystricina*), beard tongues (*Penstemon bridgesii*, *P. pachyphyllus* var. *congestus*, *P. utahensis*), rock daisy (*Perityle congesta*), milk wort (*Polygala rusbyi*), hop tree (*Ptelea trifoliata* ssp. *pallida*), townsendia (*Townsendia exscapa*), and Grand Canyon rose (*Rosa stellata* ssp. *abyssa*). The Grand Canyon rose collection is significant as this is a former Category 2 plant (Arizona Game and Fish Department 1996), which the U. S. Fish & Wildlife Service now calls a "species of special concern." This rare plant is found near breccia pipes and rough broken limestone slopes. We also observed two moss species (*Bryum* sp. and *Tortula* sp.). Future visits to Fishtail Mesa, especially after years of

above average precipitation will undoubtedly result in the discovery of new species and will further refine our preliminary species list.

Species Richness and Diversity

The shrub type, exhibited greater species richness, with 31 species, as opposed to the tree type with 26 species. However, the tree type was sampled by 3.5 elbs as opposed to the shrub type, which was sampled by 4. A weighted species richness gives a crude estimate for the tree type of 30. A more sophisticated technique for estimating species richness with 95% confidence intervals from replicate samples has been developed by Heltshe and Forrester (1983) using the statistical device known as the "jackknife." Application of this technique to the Fishtail Mesa observations gives a first order, jackknifed species richness estimate for the shrub type of 42 ± 6 plant species. The first order jackknifed estimate for the tree type was 36 ± 9 species. Obviously, there is considerable overlap in the two species richness estimates. Therefore, at this point in time, we believe species richness to be essentially the same for both vegetation types.

Plant Cover

The 1996 relative percent cover figures, based on the line-intercepts, were used to derive the species abundance curves (Whittaker 1975) for the tree type (Figure 4A) and the shrub type (Figure 4B), for each side of the elbs (i.e., left and right). Each alphacode representing each elb half and the associated Shannon diversity (H') index is shown below each species abundance curve. For each curve in the figure, species abundance, as shown on the y-axis by its logarithm (base 10), declines in rank order from left to right on the x-axis. The shrub type indices range from 0.50 to 1.14, while the tree types range from 1.24 to 1.79. Elb 4 left, exhibited the lowest species diversity, whereas Elb 6 left was the highest. These figures suggest that the tree type elbs have a relatively higher species diversity (i.e., heterogeneity) than the shrub type even though the reverse was true for species richness (see above). This was confirmed by a Student's t-test (Table 2).

Table 2. T-test results which determine whether or not there is a significant difference in the mean of H' between shrub and tree vegetation types on Fishtail Mesa. Homogeneity of variance is confirmed by both Levene's Median test ($p = 0.408$) and F-test ($p = 0.257$). The Shannon index is known to have a normal distribution in repeated sampling (McGurran 1988). The results show a highly significant difference between the two means of H' .

Summary of H' statistics for each vegetation type based on elb halves as sampling units						
Group	N	Sum	Mean	Variance	Standard Error	95% Conf. Lim.
Tree type	7	10.14	1.448	0.058	± 0.091	± 0.223
Shrub type	8	6.08	0.760	0.036	± 0.068	± 0.160

T-test Results						
Pooled Var.	t	df	p(one-tail)	t-critical (1-tail)	P(two-tail)	t-critical (2-tail)
0.046	6.174	13	1.68e-5	1.771	3.36e-05	2.160

A comparison between 1958 and 1996 relative percent cover data (species abundance) curves is shown in Figure 5. The shrub Shannon diversity index in 1958 was $H' = 0.62$, while that for the 1996 data was $H' = 0.90$, similarly, the diversity was lower for the 1958 tree-data with $H' = 1.59$, while the 1996 data was $H' = 1.73$. The differences between the two years may reflect better growing and establishment conditions in the years leading up to 1996, subtle differences in data collection between 1958 and 1996 field staff, or a combination of other factors. We cannot claim any degree of significance. Unfortunately, we could not perform statistical analyses because the original field data from 1958 had been lost and the above comparisons are based only on the data summaries in the original journal article (Jameson et al. 1962).

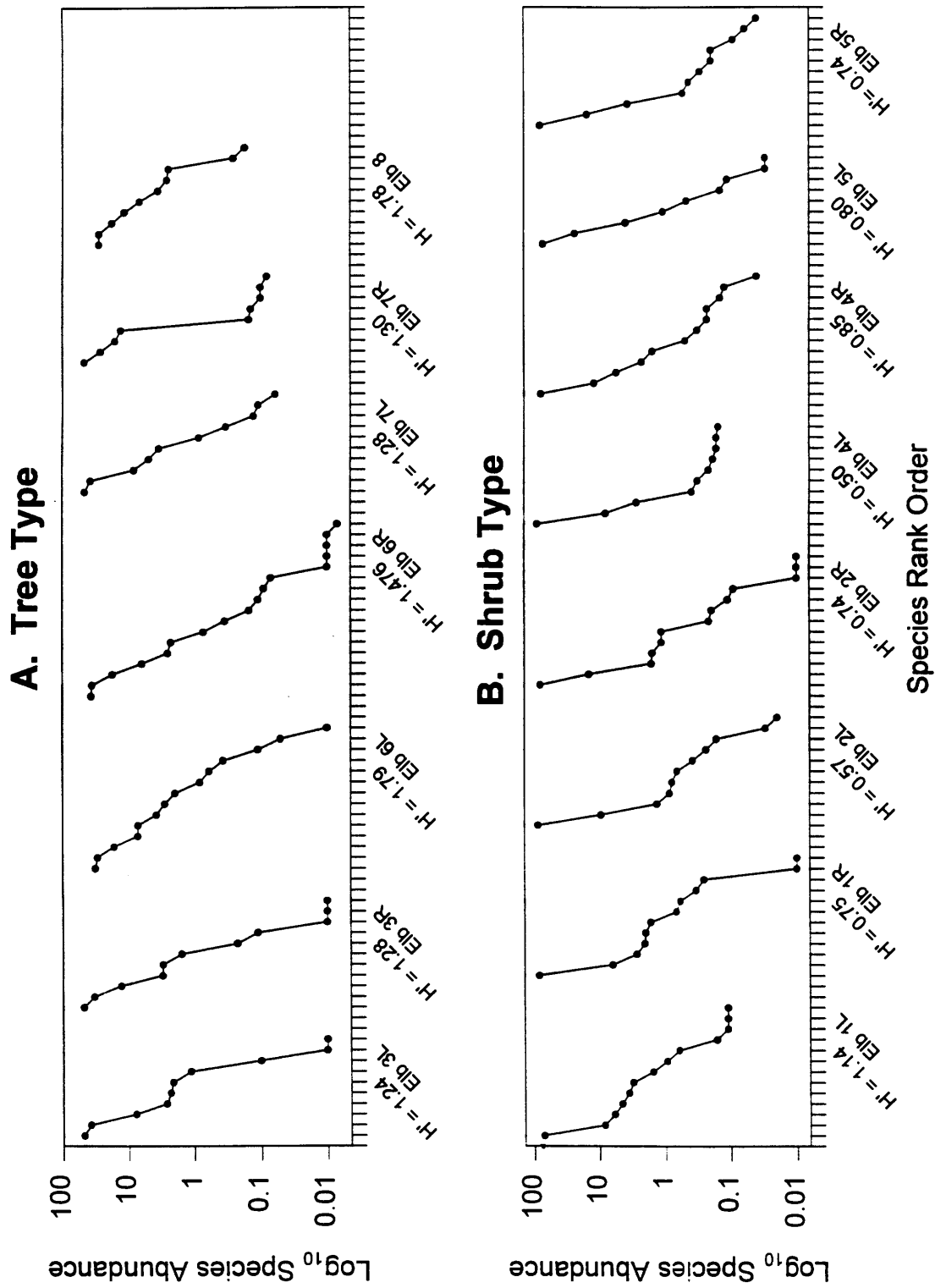


Figure 4. Species abundance curves for (A) tree type elbs and (B) shrub type elbs in 1996.

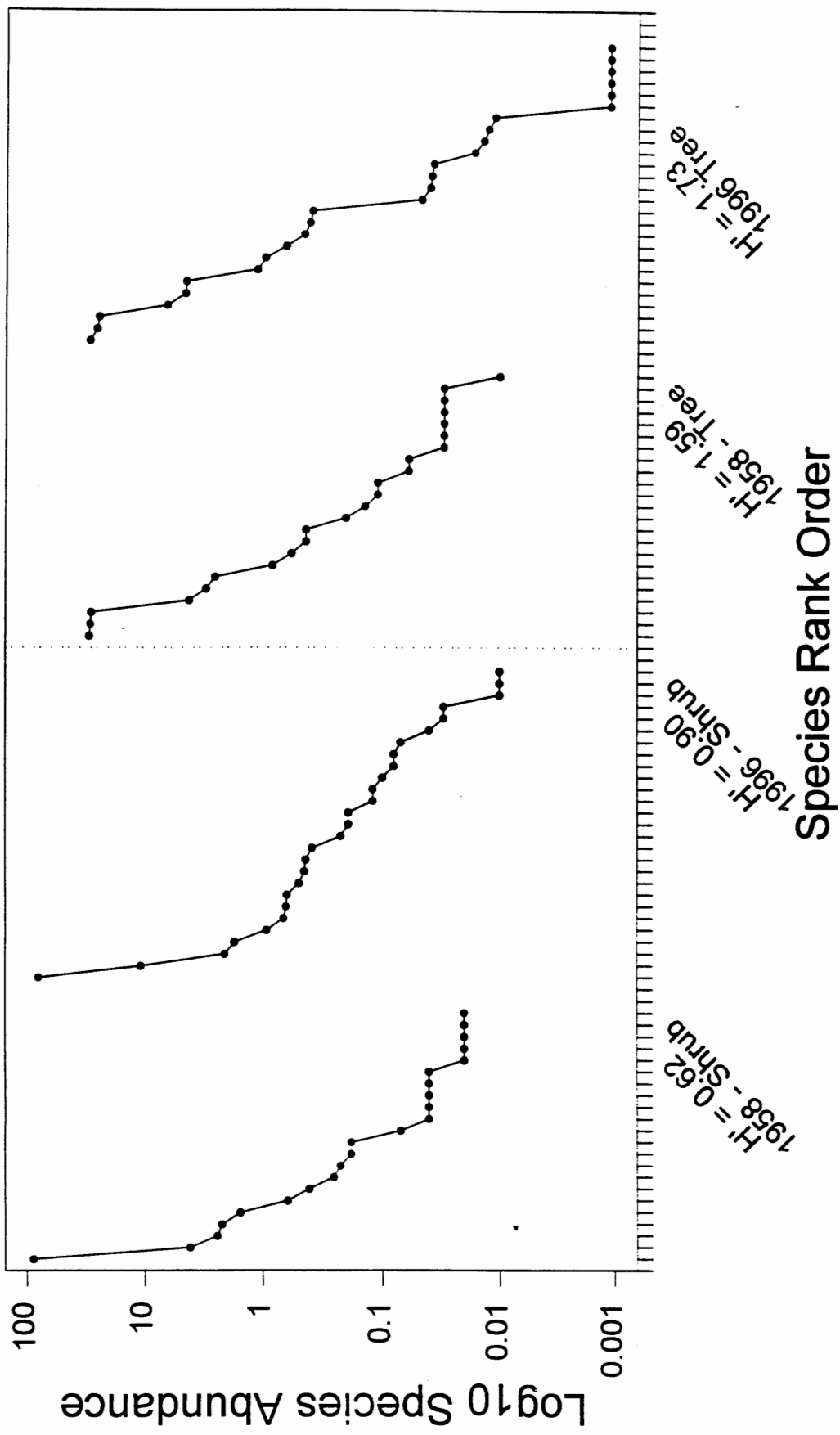


Figure 5. Rank-abundance curves for Fishtail Mesa shrub and tree vegetation types: 1958 vs. 1996.

Vegetation Types

Current Species Composition. Forty plant species were recorded along the eight elb strips (Appendix 2). Jameson et al. (1962) found two sagebrush species: big sagebrush and Bigelow's sagebrush (*Artemisia bigelovii*), which were not measured separately due to lack of inflorescences for identification. This also happened in 1996. Thus, "sagebrush" is used throughout this report to refer to both of these species.

The relative percent cover (RC) figures derived from the line intercept method (Appendix 3) showed that sagebrush was the primary plant species on Fishtail Mesa with 48% of the total vegetation cover, followed by pinyon, 18%, and Utah juniper, 15%, or a combined tree cover of 33%. Mutton grass had the fourth highest cover with 8.3%, followed by blue grama and banana yucca (*Yucca baccata*) with 3% each, and Torrey joint-fir (*Ephedra torreyana*) with 1%¹. Similar results were found when the elb data were separated into shrub and tree types. In the shrub type, the RC of sagebrush was 80%, followed by mutton grass, 11%, and Torrey joint-fir and pinyon at 2% each. Each of the remaining 24 species had less than 1% cover and thus contribute relatively little to the cover composition of the shrub type. In the tree type, the RC of sagebrush was 26%, pinyon, 30%, Utah juniper, 25%, and mutton grass, 7%. Blue grama, banana yucca, and Greens rabbit brush had less than 5% cover each, whereas Torrey joint-fir and round leaf buffalo berry accounted for 1% cover each. Each of the remaining eleven species comprising the tree type contributed less than 1% cover to the vegetation composition (Appendix 3).

Interpretation of plant species dominance and cover composition based on absolute cover (AC) is similar to that based on relative percent cover. Specifically, sagebrush had the highest absolute percent cover of 15%, followed by pinyon (5.5%) and Utah juniper (4.5%). Mutton grass ranked fourth, with 2.6% AC. Sagebrush was present on most of the elbs, especially those in the shrub type, ranging in AC from 75% to 83 (Appendix 3).

Results from Parker loop surveys of all eight elbs showed that bare ground accounted for 63% of the loop hits (Appendix 4). Vegetation cover accounted for 32% of the hits, litter 5% and rock, a trace (< 0.5%). Overall, the most important species was sagebrush with 16% cover, followed by Utah juniper, 5%, pinyon, 6% and mutton grass, 3%. Basal and crown hits, by species, for the shrub and tree types are also shown in Appendix 4. When separated into the shrub and tree types, bare ground is 67% and 58% respectively, whereas vegetation cover is 28% and 37% respectively. These results are very similar to those derived from line-intercept data. Litter comprises about 5% of the surface in the shrub type and 4% in the tree type. Rocks constituted a trace in both the shrub and tree types. Twenty plant species were detected by the Parker loop method, about half as many as were recorded by the line intercept method. In terms of crown canopy hits, sagebrush was the dominant species in the shrub type with 22% of the total hits on vegetation. In terms of basal hits, mutton grass was the dominant in both the shrub and tree types, even though it was recorded on less than 3% of the basal hits. Pinyon was the most important species in the tree type with 12% cover, followed by sagebrush and Utah juniper, each with 10% cover. As a comparison, Cravens and Pase (1954) reported an average of 31% litter (with a range of 27-35%) and 53% total plant cover from four transects in the sagebrush-grass type.

The three foot square frequency plots detected twenty-six species (Appendix 5a and 5b). Results indicate that for both vegetation types, mutton grass was the most frequently encountered species (86 to 94% for the shrub and tree types respectively, or about 90% for both), followed by sagebrush (78 and 39% respectively, or about 59% for both), and milk-vetch species (69 and 21% respectively, or about 45%). However, it should be noted that none of the 1996 photographs of the three foot square plots matched those taken in 1958.

The community types, percent cover, and elb locations are shown in Table 3 for three vegetation studies completed for Fishtail Mesa: Jameson et al. (1962), a park-wide vegetation study (Warren et al. 1982), and this study. Our revised 1996 vegetation map (Figure 6) delineated three plant communities: a pinyon-juniper-sagebrush woodland with 25-60% tree cover (768.3 ac, or 70.9% of the mesa top), a sagebrush steppe with less than 10-24% tree cover (315.3 ac, or 29.1%), and a needle-and-thread grassland (0.6 ac, or 0.1%). In comparison, Cravens and Pase (1954) estimated this grassland to be 3-5 ac with no sagebrush.

¹ Jameson et al. (1962) as well as Ellison (1947) reported only mountain joint-fir (*Ephedra viridis*), but we did not observe, nor collect, this similar species.

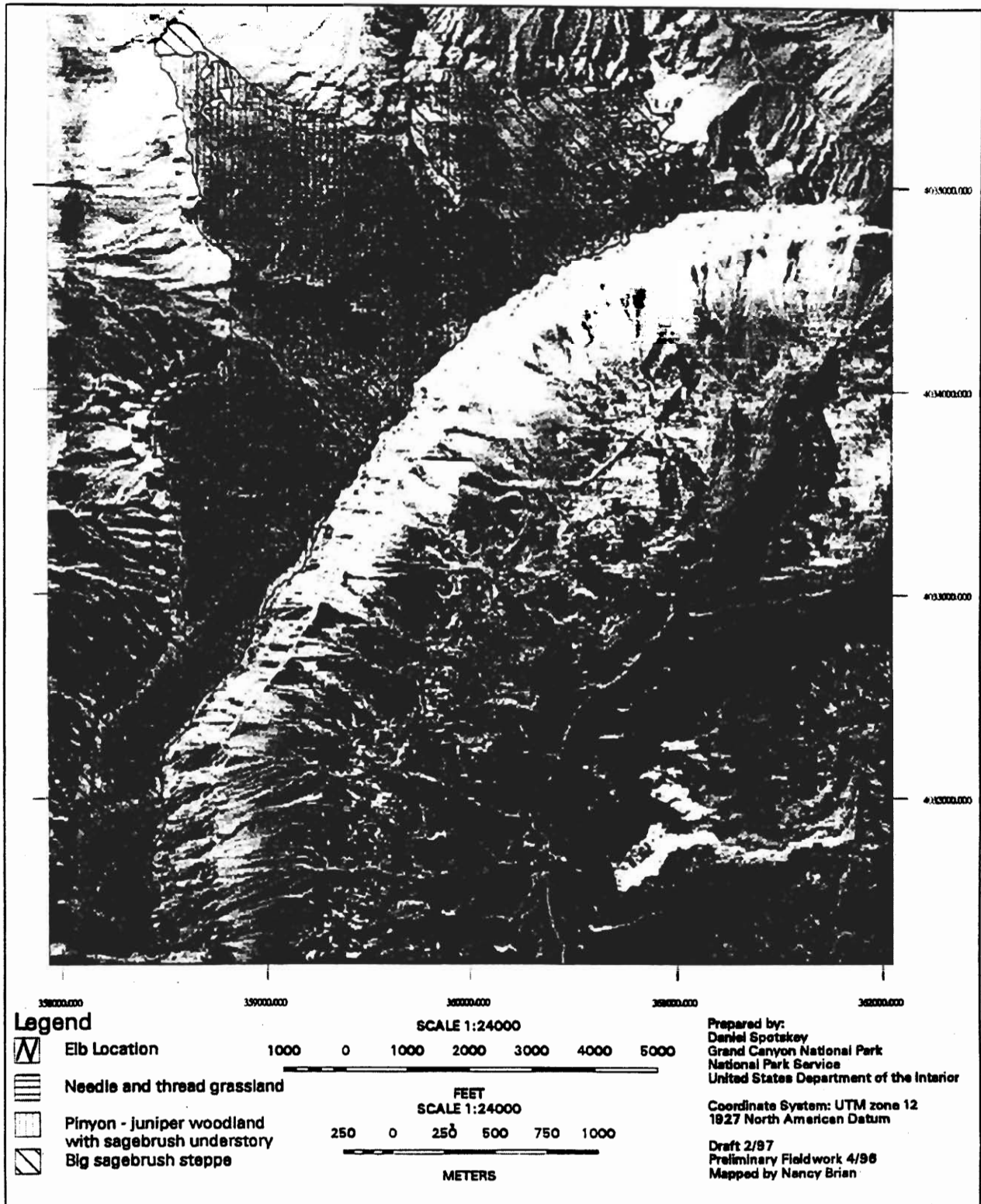


Figure 6. Fishtail Mesa vegetation map.

Table 3. Comparison of community types described for Fishtail Mesa by author with percentage of area, community type name, and elb location.

Jameson et al. (1962)	Warren et al. (1982)	This Report
74%	9%	70.9%
Tree type (Elbs 3, 6, 7, 8)	Pinyon-Utah juniper-big sagebrush- cliff rose (Elbs 6, 7)	Pinyon-juniper woodland with sagebrush understory (Elbs 3, 6, 7, 8)
Not Recognized	67% Utah juniper-big sagebrush-pinyon (Elbs 3, 8)	Not Recognized
26%	24%	29.1%
Shrub type (Elbs 1, 2, 4, 5)	Big sagebrush-Utah juniper-pinyon (Elbs 1, 2, 4, 5)	Big sagebrush steppe (Elbs 1, 2, 4, 5)
Trace, Needle-and-thread grassland	Not Recognized	0.1% Needle-and-thread grassland

Community Classification and Ordination

TWINSPAN Classification. Since TWINSPAN is based on progressive, refined reciprocal averaging, the species and stand orderings in the two-way ordered table (Table 4) reflect, to an extent, an ecological gradient. In general, the two-way ordered table classifies stands and species according to a complex moisture (aridity) gradient with less xeric adapted species and plant associations in the upper left quadrant of Table 4 replaced by more xeric species and plant associations in the lower right quadrant.

Stand order from left to right across the top of the table reflects one component of this moisture gradient. Less xeric pinyon – juniper woodland stands (elb arm sampling units), in the Mesa interior are replaced by more xeric shrub – steppe stands along the Mesa Rim and in interior areas cleared by historical fires. Elb 4R was unique in that the transect ran across a small valley with deep, fine alluvial fill and was adjacent to a small stand of desert needlegrass. Elbs 1L, 1R and 2R were located on the southern, most exposed tip of the Mesa, subject to warm, dry air rising from the canyon below. Halvorson (1972) originally documented the phenomenon on the North Rim of the Grand Canyon in the vicinity of Cape Final. The canyon produces strong convective air movement resulting in hot, dry winds rising from the warmer canyon bottom. These hot, dry winds have the immediate effect of drying and heating upland areas adjacent to the rim. In addition, storms brought by the prevailing southwest winds are forced away from the rim by the warm updrafts. This so-called “rim effect,” creates a zone of increased aridity for some distance, up to 400 m or more, away from the rim (Halvorson 1972). On an isolated mesa in the Grand Canyon, the most noticeable rim effects should be on the windward side. In the case of Fishtail Mesa, this is the southwest portion. The extreme southern tip of the Mesa is very narrow, without an “interior,” for the most part arid, and devoid of woodland. In general, throughout the length of Fishtail Mesa, woodland is noticeably denser away from the southeast-facing rim (Figure 6). The rim effect is strongly implicated.

The species order also reflects a gradient from less xeric to more xeric (i.e., top to bottom). Woodland species such as round leaf buffalo berry, cliff rose, banana yucca, pinyon, juniper and blue grama give way to species such as wild buckwheat, blackbrush, desert needlegrass, four-wing salt-bush, snakeweed and squirrel tail (Table 4).

Differential (Indicator) Species. Several of the more commonly observed species, though important overall, are not useful as differential or association defining species. These **ubiquits** include mutton grass, prickly pear, sagebrush and Torrey joint-fir. The first two species are present in every elb arm sample, regardless of whether the elbs are

labeled as tree type or shrub type. Torrey joint-fir is present in all elb arm samples except Elb 7R and prickly pear is absent only from Elb arms 2R and 4L (Table 4). These common and, in the case of sagebrush, dominant species do not define the shrub type or shrub-steppe vegetation on Fishtail Mesa since they also form the understory of the pinyon-juniper woodland. In general, mutton grass, sagebrush and Torrey joint-fir tend to increase in relative importance from the tree type to the shrub type elb arms and were therefore classified by TWINSpan with the shrub type species group after the first (primary) TWINSpan division. Prickly pear shows no apparent trend in abundance values, but has relatively high importance in tree type Elbs 3L, 3R, 6L and 7R (Table 4). Therefore it was classified into the tree type species group.

Differential species for the tree type include primarily pinyon, Utah juniper and blue grama (Table 4). However, pinyon and Utah juniper are not completely faithful to the tree type. Pinyon is present in at least one shrub type elb arm (Elb 4R) in moderate abundance (13 % AC, 12% RC). Utah juniper is present in shrub type Elb 4L ($\leq 0.5\%$ RC) and 5R ($\leq 8\%$ RC). Blue grama is absent from both arms of tree type Elb 3 and also occurs in shrub type Elb 2L. Otherwise, it is faithful to the tree type. Since there is reason to believe that both tree species are in the process of "invading" (reoccupying?) the shrub type on the Mesa (see below), then this "infidelity" is really just an artifact of natural vegetation dynamics.

With the possible exception of wild buckwheat, no plant species in the shrub type group could be interpreted as a differential species. The only abundant species in this group were the ubiquitous discussed above which tend to reach their greatest levels of abundance here. Wild buckwheat, though never abundant (>0 to 4% RC) is present in all of the elb arm samples except Elb 4L and occurs outside the shrub type only in tree type Elb 7R; and then, only sparsely ($<0.5\%$ RC). Besides wild buckwheat, the other plant species classified into the shrub type group, occur in less than 50% of the elb arm samples and generally in low abundance (Table 3, light gray shaded area). Only needle-and-thread and snakeweed exhibit RC values in the 8-16% category (i.e., class 5 in Table 4). In other words, these species are rare in the statistical sense. The shrub type therefore is defined more on the basis of the absence of pinyon and juniper rather than any special associations of differential species with a high preference for this vegetation type.

Plant Associations. The TWINSpan results presented in Table 4 and the species abundance and constancy patterns discussed above show that there is a clear demarcation at the primary division level between woodland (tree type) species and samples and shrub-steppe (shrubby type) species and stands. Not surprisingly, pinyon, Utah juniper, and banana yucca form a distinct association within the tree type.

In brief, we can define two associations within the tree type. Elb 8 is unique in that round leaf buffalo berry, bladder pod, dwarf mistletoe, cliff rose, hedgehog cactus and true mistletoe are absent while pincushion cactus, and Apache plume are present. It is differentiated from Elbs 3L and 3R by the presence of banana yucca. Elbs 6L, 6R, 7L, 7R, 3L, and 3R constitute the components of the second association with Elbs 3L and 3R forming a sub-association. Interestingly, Elb 8 is located along the top of a ridgeline where the substrate consists of heavy, cherty soils not present in any of the other tree type sampling sites.

Table 4. Two-way ordered table produced by TWINSpan (Hill 1979b) in PC-ORD (McCune and Mefford 1995). The two heavy lines mark primary stand and species divisions. Heavy, dashed lines mark secondary divisions, dashed lines mark tertiary divisions and the fine, dotted line marks a quaternary division.

Analysis was done, using as input data an initial species by stands matrix of species cover values relativized within each stand (i.e., converted to a 0-100% scale). All defaults were accepted except for species cut-levels which were defined on an octave scale: as 0-0.5% (1), 0.5-1.0% (2), 1.0-2.0% (3), 2.0-4.0% (4), 4.0-8.0% (5), 8.0-16.0% (6), 16-32% (7), 32-64% (8) and >64% (9). Thus the values within the two-way ordered table are the octal scale transforms of the original relative cover data. The shrub type species-stands block in the lower right is highlighted by light gray shading whereas the tree type species / samples block in the upper left is highlighted using darker gray shading.

Plant Species' Common Name	Stand Sampling Units on Fishtail Mesa																Species Division Level
	Tree Type Elbs								Shrub Type Elbs								
	Elb 8	Elb 6L	Elb 6R	Elb 7L	Elb 7R	Elb 3L	Elb 3R	Elb 2L	Elb 4L	Elb 5L	Elb 5R	Elb 4R	Elb 1L	Elb 1R	Elb 2R		
Round leaf buffalo berry	-	4	-	-	-	4	4	-	-	-	-	-	-	-	-	11111	
Bladder pod	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	11111	
Pinyon dwarf mistletoe	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	11110	
Cliff rose	-	4	1	1	-	-	-	-	-	-	-	-	-	-	-	11110	
Hedgehog cactus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	11110	
Mistletoe	-	2	4	-	-	-	-	-	-	-	-	-	-	-	-	11110	
Banana yucca	7	5	4	4	-	-	-	-	-	-	-	-	-	-	-	11101	
Utah juniper	6	7	8	8	7	5	6	-	1	-	4	-	-	-	-	11101	
Pinyon	4	6	8	8	8	8	8	-	-	-	-	6	-	-	-	11101	
Pincushion cactus	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11100	
Apache plume	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11100	
Blue grama	7	2	2	1	1	-	-	3	-	-	-	-	-	-	-	110	
Indian paintbrush	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	10	
Prickly pear	1	3	1	1	1	3	3	2	-	1	1	1	3	4	-	10	
Phlox	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	01	
Gray locoweed	-	1	1	-	1	1	1	1	1	1	1	1	1	-	1	01	
Mutton grass	5	5	5	6	6	4	4	6	5	7	6	5	6	5	6	01	
Sagebrush	7	7	7	5	6	8	8	9	9	9	9	9	9	9	9	01	
Spurge	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	0011	
Beard tongue	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	0011	
Indian ricegrass	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	0011	
Globe mallow	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	0011	
Wild parsley	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	0011	
White aster	-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	0010	
Pinyon milkvetch	-	-	1	1	1	-	1	-	1	3	1	4	-	-	-	0010	
Pinque	-	-	1	-	-	-	-	-	1	-	1	-	-	1	1	0010	
Torrey joint-fir	4	1	1	2	-	4	1	2	4	4	3	3	4	4	1	0010	
Winterfat	-	-	-	-	-	-	-	2	1	-	-	-	-	2	-	00011	
Wild buckwheat	-	-	-	-	1	-	-	1	-	1	1	1	2	3	1	000101	
Tidy fleabane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	000100	
Rock cress	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	000100	
Black brush	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	000100	
Desert needlegrass	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	000100	
Milk-vetch	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	000100	
Four-wing salt-bush	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	000100	
Needle-and-thread	-	-	-	-	-	-	-	-	-	-	-	-	5	1	-	000100	
Snakeweed	-	-	-	-	-	-	-	-	-	-	-	1	5	-	3	000100	
Rabbit brush	-	-	1	-	-	-	-	-	-	-	-	-	-	4	-	0000	
Twist flower	-	-	-	-	-	-	1	-	-	-	-	1	1	-	3	0000	
Squirrel tail	-	1	-	-	-	-	1	-	1	-	-	-	4	1	3	0000	
Stands Division Level	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1		
	0	1	1	1	1	1	1	0	0	0	0	0	1	1	1		
		0	0	0	0	1	1	0	0	0	0	1					

In the shrub type, there are no really distinct species subgroups due to the influence of the ubiquitous. A possible exception is the species-samples block in the lower right of Table 4 which consists of a "mixed bag" of secondary

shrub type plant species including, among others, winter fat, wild buckwheat, and snakeweed. Nevertheless, three "loose" associations can be defined within the shrub type samples. Elb 4R uniquely possesses a pinyon component. Elbs 2L, 4L, 5L, and 5R lack snakeweed, four-wing salt-bush, needle-and-thread, desert needlegrass, milk vetch, black brush, rock cress, and flea bane. Elbs 1L, 1R, and 2R possess these species components.

DCA Ordination. Since no quantitative observations on physical factors such as soil structure, moisture and chemistry, or microclimatology were made, the DCA results from this study are intended as an adjunct to TWINSpan. The first two axes produced by DCA accounted for 70.3% of the variation within the original species – samples matrix (Table 5). Although this value is not as important as it would be in a principal components analysis (Kent and Coker 1992), it does indicate a successful ordination in the first two dimensions. Only 4.5% more was accounted for by the addition of a third axis. The efficacy of the ordination in representing the original species by samples matrix in only two dimensions is corroborated by the R^2 values resulting from comparisons of ecological distance between the original data matrix and ordination distances (Table 5). Cumulative R^2 increases from 0.870 with only the first ordination axis is considered to 0.970 when both ordination axes are used to calculate ordination distances. The addition of a third axis serves only to reduce the cumulative R^2 . A three-dimensional ordination was therefore eschewed.

Table 5. Summary statistics for the eigen-analysis component of the Fishtail Mesa DCA. Coefficients of determination (R^2) relate ordination distances to the distance metric if the original data matrix. The distance metric employed was percent similarity otherwise known as Czekanowski's coefficient (sometimes mistakenly referred to as Sørensen's coefficient or Jaccard's coefficient [Kent and Coker 1992]) as defined in the Methods section. Distance comparisons between the original and ordination matrices were based on the $n(n-1)/2$ possible comparisons for 15 samples.

Eigenanalysis Statistics	DECORANA Axis No.			
	1	2	3	4
Eigenvalue	0.496	0.106	0.0390	0.019
Percent of Total	57.904	12.409	4.540	2.223
Cumulative Percent	57.904	70.313	74.854	77.077
Coefficients of Determination (R^2) – Incremental	0.870	0.100	-.008	—
Coefficients of Determination (R^2) – Cumulative	0.870	0.970	0.962	—

Species Ordination. The species ordination is generally less important than the stand ordination in synecological analyses (Kent and Coker 1992). Nevertheless, an examination of the species ordination can often yield some valuable insights into the problem of community compositional patterns.

Both TWINSpan and DCA are based on the multivariate technique of reciprocal averaging (equivalent to correspondence analysis). DCA, in fact, is just a modified (i.e., detrended) form of reciprocal averaging. It is not surprising to observe a very close correspondence between the species order (bottom to top) in Table 4 and the species scores (left to right) along DCA axis 1 in the species ordination (Figure 7). We interpret the species sequence along DCA Axis 1 as a reflection of a complex moisture gradient. Species typical of the more xeric shrub type vegetation (group A, Figure 7) are gradually supplanted from left to right along axis 1 by plant species more typical of the tree type vegetation (groups C, D, and E, Figure 7). Ubiquitous and occasional species with little or no faithfulness to either vegetation type are aggregated in group B.

Species typical of the shrub type and ubiquitous/occasional species show little dispersal along DCA axis 2 (Figure 7) whereas tree type species (C-E) are well dispersed along the axis. We interpret DCA axis 2 as possibly reflecting a gradient of soil textures. The agglomeration of species in group C (i.e., banana yucca, blue grama, pincushion cactus, and apache plume) are more typical of sample sites with heavier, rockier soils, often with bedrock close to the surface. Species comprising group E (i.e., prickly pear, Indian paintbrush, round leaf buffalo berry, pinyon, and bladderpods) were observed to be more typical of fine to moderately fine textured soils.

Stand Ordination. The stand ordination (Figure 8) reflects the same inferred ecological gradients as the stand ordination. All of the shrub type elbs are clustered on the left of the ordination (xeric) whereas tree type elb arms are aggregated, though more loosely, on the right (less xeric). Elb 4R group II (Figure 8) is somewhat disjunct from

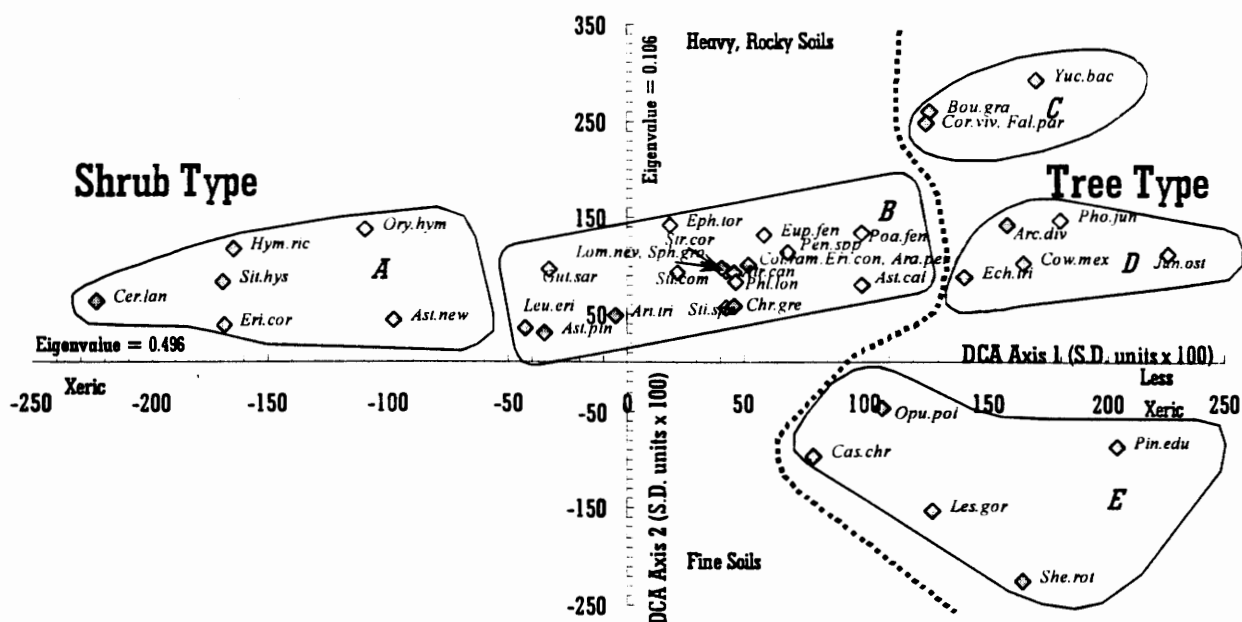


Figure 7. Detrended correspondence analysis—species plot—of the current vegetation on Fishtail Mesa.

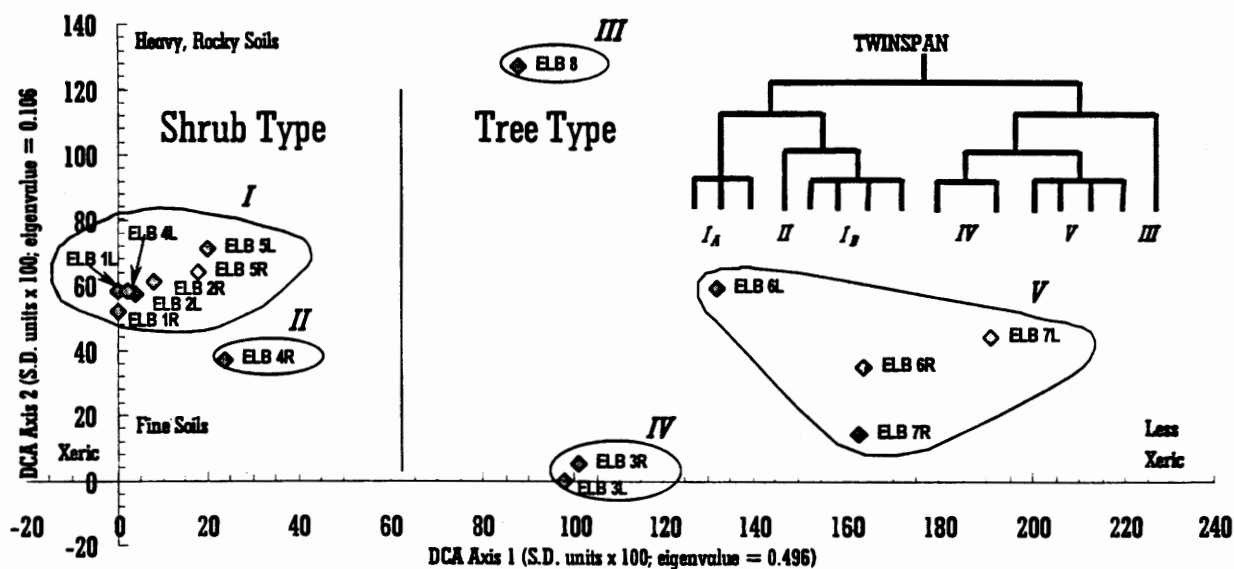


Figure 8. Detrended correspondence analysis—elb plot—of the current vegetation on Fishtail Mesa.

the main group of shrub type elbs (group I) just as it was in the TWINSPAN results (Table 4). Elb 4R was the only shrub type elb which had a substantial amount of pinyon cover and may be undergoing invasion. Utah juniper was present in both Elb 5R ($\approx 6\%$ RC) and 4L ($< 0.5\%$ RC), however these relatively small amounts of tree cover do not appear to have influenced either TWINSPAN classification (Table 4) or DCA ordination (Figure 8). Both elb arms are firmly aggregated with the shrub type samples.

Group III (Figure 8) consists only of Elb 8 (with only one arm). This sample was located on a ridge with heavy, rocky calcareous soils on cherty parent material thus establishing the possibility of a soil texture gradient reflected in DCA axis 2. Group IV consisted of two elb arms from Elb 3R and 3L. They are located in an area of sandy limestone with a high proportion of fine particle soils. Group V consists of a group of elb arms which can be described as well-established, mature, pinyon-juniper woodland. Relative cover of both pinyon and juniper is high throughout this sample group and soil textures vary in composition. The elb arm sample groups formed by DCA (Figure 8) coincide nicely with those defined by TWINSPAN (Table 4, Figure 8, inset TWINSPAN elb dendrogram). One minor deviation of the TWINSPAN classification from DCA was the clear separation of Elbs 1R, 1L, and 2R into a separate subgroup (Figure 8, insert). The DCA ordination was not as clear in this regard. Note that a TWINSPAN dendrogram is like a hanging mobile in that clusters are allowed free rotation around their separate stems. It is the clusters themselves which are important, not their precise order of occurrence.

Woodland Tree Demographics

The frequency of pinyon and Utah juniper can be inferred from the presence or absence of a number of trees for each elb from the 2,000 ft² plots shown in Table 6. Pinyon exhibited an average frequency of about 57%, while Utah juniper averaged about 52%. The density of all pinyon and Utah junipers recorded along the elb strips is shown in Table 6. In 1996, the average per elb arm was 4.2 pinyons and 2.4 Utah junipers. If only the tree type elbs are considered, an average of 8.6 and 4.7, respectively, were found. The highest tree density (n=98) was observed on Elb 7R.

Table 6. Pinyon and Utah juniper density within 100 foot sections of 8 sampling elbs on Fishtail Mesa. Note that Elb 8 is only half an elb with just one 400 foot component. Eight of the 18 pinyon in the 100-200 ft section of Elb 7R were seedlings ($< 1\text{cm}$ in diameter).

Elb	0-100 ft		100-200 ft		200-300 ft		300-400 ft		Sub Total
	Pinyon	Juniper	Pinyon	Juniper	Pinyon	Juniper	Pinyon	Juniper	Both
1-L	0	0	0	0	0	0	0	0	0
1-R	0	0	0	0	0	0	0	1	1
2-L	0	0	0	0	0	0	0	0	0
2-R	0	0	0	0	0	1	0	1	2
3-L	6	0	10	3	2	1	6	6	34
3-R	5	3	6	3	9	4	9	5	44
4-L	0	0	1	0	0	0	0	0	1
4-R	0	0	0	0	0	0	3	1	4
5-L	1	0	0	0	1	0	0	0	2
5-R	1	3	2	1	1	1	0	1	10
6-L	9	0	10	6	9	5	5	2	58
6-R	13	12	9	6	9	5	19	4	71
7-L	14	6	8	9	6	8	11	4	66
7-R	12	6	18	6	22	12	14	11	98
8-L	2	3	1	0	0	0	1	0	4
Subtotal	63	33	65	34	59	37	68	36	395
Total	96		99		96		104		395

There were substantially more pinyon trees ($n=100$) in the <1 cm stem diameter class in the tree type than Utah juniper in any stem diameter class (Table 6, Figure 9). In fact, establishment of seedling Utah juniper was sparse to nonexistent. After thorough sampling, only three Utah juniper seedlings were discovered throughout the elbs in the tree type vegetation and none were discovered in the shrub type elbs. In general, numbers of both trees in the shrub type were low for all classes and age-size relations could not be ascertained.

The size-frequency distribution curve for pinyon, calculated from observations gained from all the tree type elb strip plots, exhibits a classic inverse J-shaped distribution curve. This type of curve originally called type 1 by Pearl (1928), is indicative of plants with high reproduction where the probability of death decreases exponentially as plants age (Figure 9) (Begon et al. 1996).

When tree density is $\log_{10}$ transformed, the pinyon size-density relationship approximates a "rotated sigmoid curve" (Goff and West 1975, West et al. 1981) typical of an all-age stand with differential recruitment from one size-class to the next. Mortality is high and growth rates are slow in the smaller size classes, resulting in a very steep curve. Recruitment to the canopy, however, increases the growth rate and reduces mortality. As a result, the slope of the curve decreases. As size classes increase, the slope of the curve again increases due to a decrease in growth rate and an increase in mortality with senescence (Goff and West 1975). Theoretically, the shape of this curve changes from a first order polynomial to a third or fourth order polynomial with stand maturity. That is, as stands increase in age, the plateau in the middle size classes becomes more pronounced from nonexistent to almost flat (Goff and West 1975, West et al. 1981, Tress and Klopatek 1987). High germination and seedling establishment followed by space

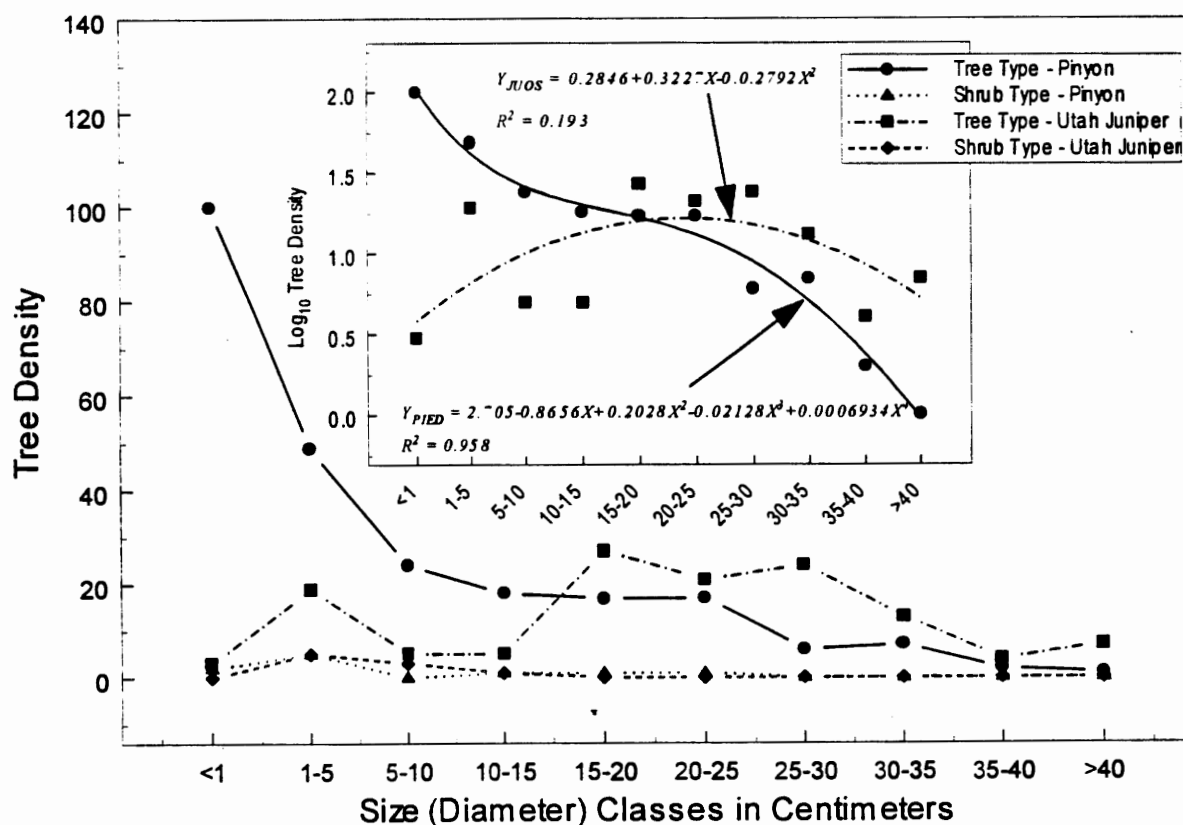


Figure 9. Tree density and size (diameter) classes in centimeters for tree and shrub type elbs for pinyon and Utah Juniper

and light competition results in rapid mortality and reduced growth of young stems in older stands (West et al. 1981). On Fishtail Mesa, the decrease in density of pinyon beginning with the seedling class (<1 cm) declines smoothly and a well defined plateau region at the intermediate size classes never manifests (Figure 9). This suggests only a moderate decline in mortality between intermediate size classes. In other words, the pinyon population at Fishtail Mesa may be approaching an all-aged condition, but is not there yet. Assuming that no catastrophic changes occur in the future, such as a stand replacing fire, the pinyon population in the tree type vegetation of this relict area may eventually become fully mature and all-aged.

In terms of simple equations, the density-size relation for Utah juniper is best fitted by a second-degree polynomial, but the regression is not significant ($R^2=0.193$; $F_{[\alpha=0.05;3,7]}=2.075$; $p=0.196$) and quite anomalous in terms of the "rotated sigmoid-curve" ideal (Figure 9 inset). The relation is actually somewhat bimodal, with a peak at the 1-5 cm and again at the 15 - 20 cm, 20-25 cm, and 25-30 cm classes. Density depressions occur in the 5-10 and 10-15 cm diameter classes and, not surprisingly at the largest diameter classes, i.e., > 30 cm (Figure 9 and inset). This pattern suggests that recruitment to the Utah juniper population on Fishtail Mesa is low and perhaps pulse-like.

The age-size (basal diameter) relationship for the 40 pinyons, for which age was directly determined, is presented in Figure 10 (Appendix 6). Pinyon cores, taken adjacent to tree type elbs are shown as open graph markers whereas cores taken from trees near shrub type elbs are represented by filled, black markers. These data were fitted to the Chapman-Richards function (see Methods). Both upper and lower 95% confidence are shown to assess the possible error in the diameter estimate. The age-size relation as predicted by the Chapman Richards function is significant (Figure 10b) but there is a rather high degree of scatter around the regression line. Different trees of similar age within the study area may exhibit basal diameters which differ by as much as 20 cm. This is no doubt due to differences in microsite characteristics and competition suppression from adjacent dominant pinyons.

Almost all the tree cores taken from tree type vegetation fall below the regression line in Figure 10 and therefore show some degree of growth suppression. This indicates that intraspecific competition is an active factor within the pinyon population of the tree type. Not surprisingly, the majority of pinyon cores collected from the shrub type lie above the regression line showing increased growth rates over their woodland congeners. An exception occurs for pinyon collected near Elb 2. Four out of the five cores give evidence for growth suppression, which, in this instance, is probably due to stressful site characteristics. Elb 2 is located in the narrowest portion of the Mesa and is subject to the full brunt of the rim-effect.

According to Tausch and Tueller (1990) size-age patterns of pinyon populations are more accurately reflected when suppressed trees are removed from analysis. In our research, we felt that the pattern of growth suppression in relation to location and vegetation type was an important issue, thus the entire data set was retained. However, we did separate pinyon cores taken from the tree type from those taken from the shrub type and removed the five Elb 4 samples from the latter. Both data subsets were fitted to the Chapman - Richards function individually and the results are presented in Figure 10. First note the great improvement in the R^2 values for the curve fits. Second, pinyons growing within the woodland communities on Fishtail Mesa are generally growth-suppressed, but only in comparison to trees located within the shrub type. Growth suppression of pinyon on Fishtail Mesa, a relict area, is relative to site location and community type. These results are a further indication that our hypothesis that pinyon are actively occupying most of the shrub type on Fishtail Mesa is correct. Exceptions, like Elb 2 are explained on the basis of site characteristics involving the rim-effect and under the current climatic regime it is unlikely that pinyon would ever establish there. There will always be some shrub type areas on Fishtail Mesa, regardless of the comings and goings of pinyon.

Based on the evidence given in Figure 10b, and if 1850 is taken as a pre-settlement date, then five, pinyon core samples taken from the tree type and only one from the shrub type, represent pre-settlement pinyons within the sample analyzed. Since 1850 is 146 years prior to our field research completed in 1996, then the basal diameter estimate at 146 years $\pm$ the 95% confidence limits is a reasonable value for attribution of pre-settlement, post-settlement and indeterminate status. In the tree type the basal diameter (BD) estimate for a pinyon 146 years old ($BD_{est[146]}$) is 22.4 ± 4.7 cm. Pinyon with a BD greater than 27.1 cm are probably pre-settlement trees. Pinyon with a BD smaller than 17.4 cm are probably post-settlement trees. Trees with BDs in between are indeterminate. Likewise, for pinyon growing in the shrub type, ($BD_{est[146]}$) is 30.9 ± 7.4 cm. Pinyon growing in the shrub type with

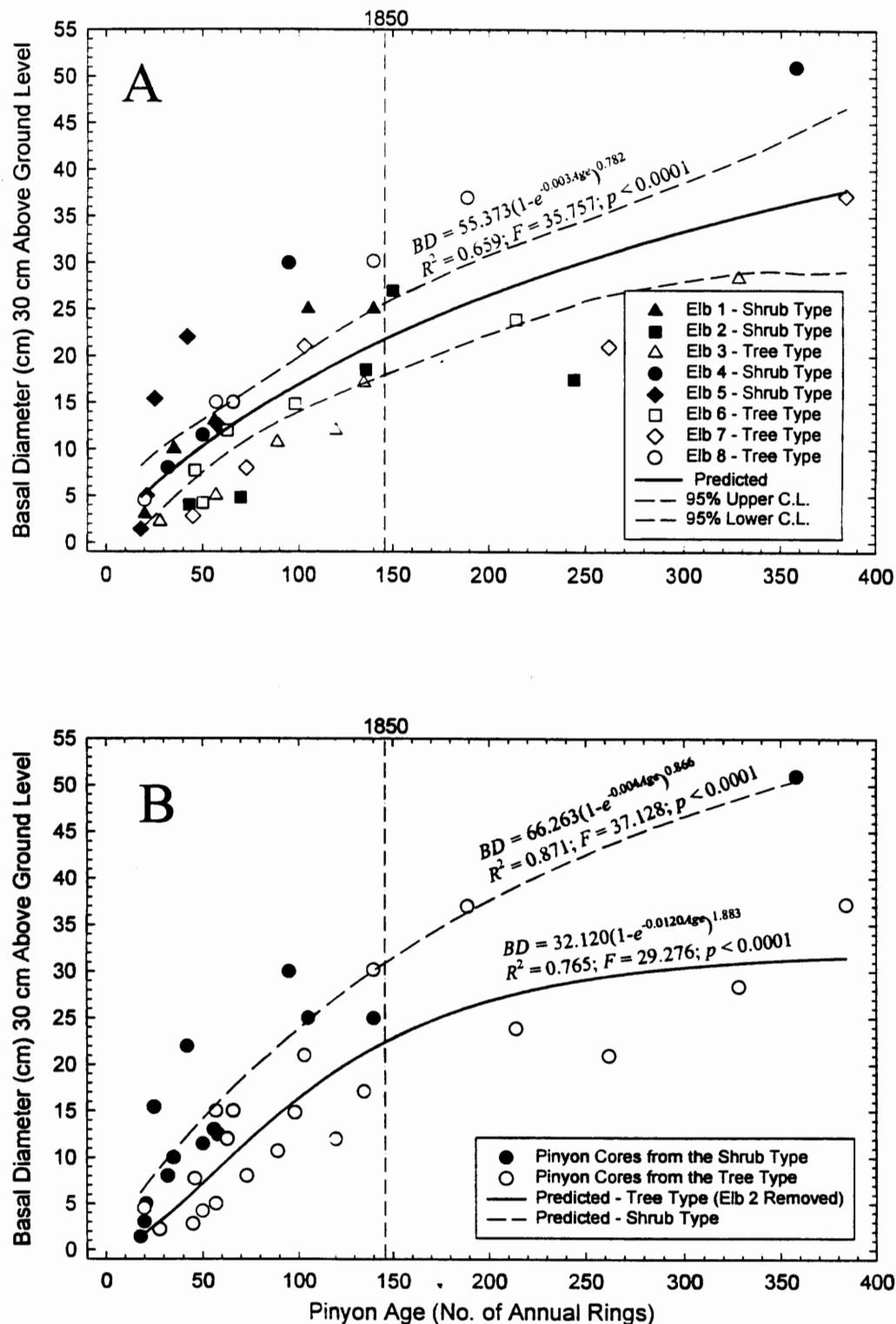


Figure 10. Pinyon age – size relation using (A) basal diameter and annual ring counts collected from trees adjacent to and outside all eight elb arms and (B) according to shrub type and tree type. Note that observations collected from the Elb 2 area have been eliminated from the analysis (see text).

a BD greater than 38.3 cm are probably pre-settlement trees. Pinyon smaller than 23.5 cm are probably post-settlement trees. Trees with BDs in between are indeterminate.

An example of the stem mapping, or "bubble diagram" of the pinyon and Utah junipers is shown in Figure 11. Data from Elb 3L (Appendix 7) was entered into a "bubble diagram" whereby the Cartesian x and y coordinates and the canopy cover are plotted. The diagram is not to scale. The figure illustrates the approximate location and size of both tree species as well as standing snags. This figure is included here as an example of how the data can be visualized to show the placement and growth of the two tree species. Future resurveys may find this stem mapping technique valuable in relocation of live trees and snags.

Changes in Species Distribution and Cover Composition Since 1958

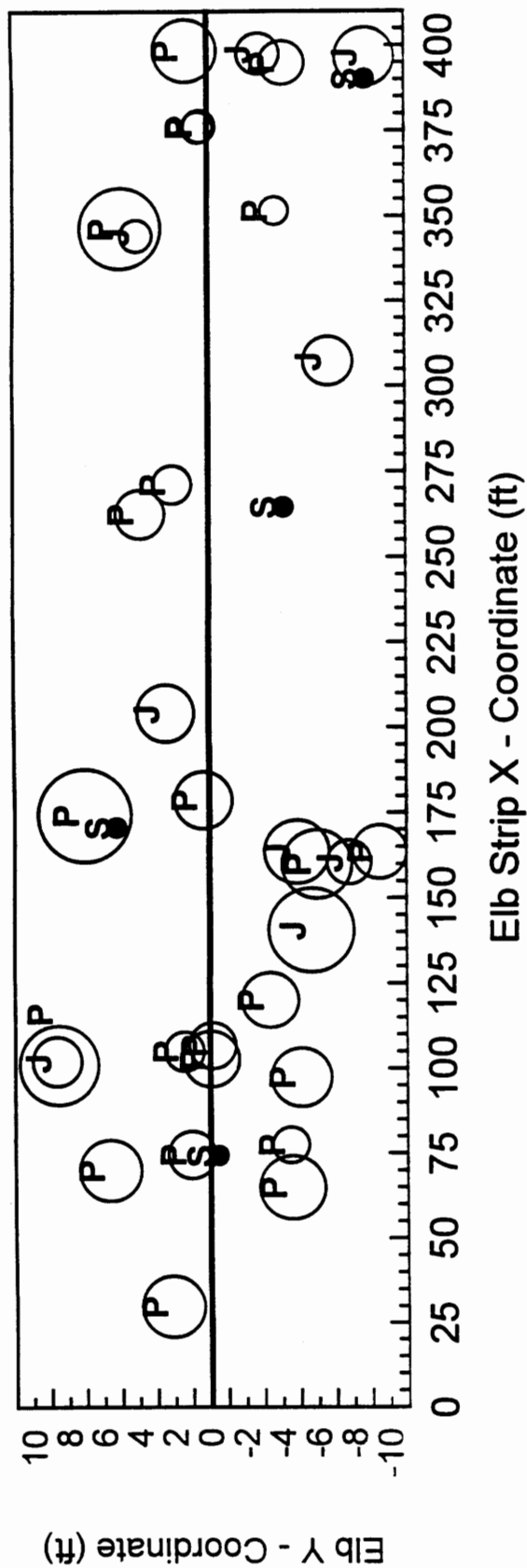
Apparently, our placement of the plot frames in 1996 was not consistent with the precise locations of the 1958 plots. Distinctive large rocks in the foreground of our photographs did not match those in the original photographs and vice-versa. Nor could we find matches given the assumption that Jameson et al. (1962) might have placed the first of the 1958 plots at the elb origin instead of at the 100 ft marker angle iron. A possible explanation is that the three-foot square plots, which were sampled in 1958, did not conform to our information on how they were installed. One of the 1958 plot photographs (Elb 1R, fourth plot) shows an angle iron on the ground ready to be planted. None of the rest of the 1958 photographs showed any evidence of an angle iron marker. Obviously, the angle iron markers were put in after the plots were photographed and sampled, not before. Moreover, our notes indicate that the angle irons were not put in precisely. Consequently, we have almost no data on vegetation change based on these small, frequency plots.

Panoramic rephotography of shrub type, Elb 5R (Figure 12), for example, shows little change in the standing dead juniper snags and growth of the surrounding shrub vegetation. Only the finger sized tips of the snags' branches have been removed in the past 38 years. It is clear, however, from the increase in pinyon tree density in both the foreground and background of the 1996 photograph as compared with the 1958 photograph, that pinyon trees are invading, or more correctly reoccupying, this shrub type site. Other ground-based rephotography sets not shown also give visual evidence of pinyon invasion into shrub type vegetation on Fishtail Mesa. Aerial photographs taken in 1940 and 1996, discussed below, give corroboration of these observations.

Photographic evidence supports the observation that tree cover has been increasing on Fishtail Mesa in the last 50 to 60 years. Figure 13 shows details of a 1940 and a 1994 aerial photograph of the south end of Fishtail Mesa. The locations of individual tree canopies can be seen in both photographs. A small circular patch of vegetation, lacking tree cover, is apparent in the upper right-hand corner of the earlier aerial photograph. This suggests that the area inside the circle supported a patch of shrub-steppe vegetation. Since 1940 (at least), pinyon and Utah juniper have colonized the patch.

Fire and Other Landscape Features

No recent burns were noted, nor was burn evidence such as scorched shrubs, charred tree stumps, or charcoal. However, our field notes (Appendix 1) record that the last 100-ft of Elb 6L and the area near Elbs 1 and 4 had standing snags which suggested "old burns." We assumed that the standing snags were Utah junipers. Pinyons generally rot quickly at the root collar and subsequently topple. Also, our records of standing snags showed a Utah juniper:pinyon ratio of 19:1. We assumed that the snags were remnants of an 80-100 year old burn, because Jameson et al. (1962) and Ellison (1947) described such a burn on Fishtail Mesa. Similarly, Schmutz et al. (1967) described a burn at nearby Boysag Point. However, the snags may be dead remnants from drought, mistletoe infestation, and/or insect attack since charcoal remnants were not observed on the ground surface.



Legend:

The size of the circle in the above graph is proportional to the area of the tree's canopy cover. Note that the elb arm is not drawn to scale. Negative distances on the Y - coordinate are to the right of the baseline when viewed from the elb origin (Figure 2).

P = Pinyon

J = Utah juniper

S = Standing snags

Figure 11. Example of a stand map, in the form of a bubble diagram, of pinyon, Utah juniper and standing snag locations and areal extent within the left arm of Elb 3.

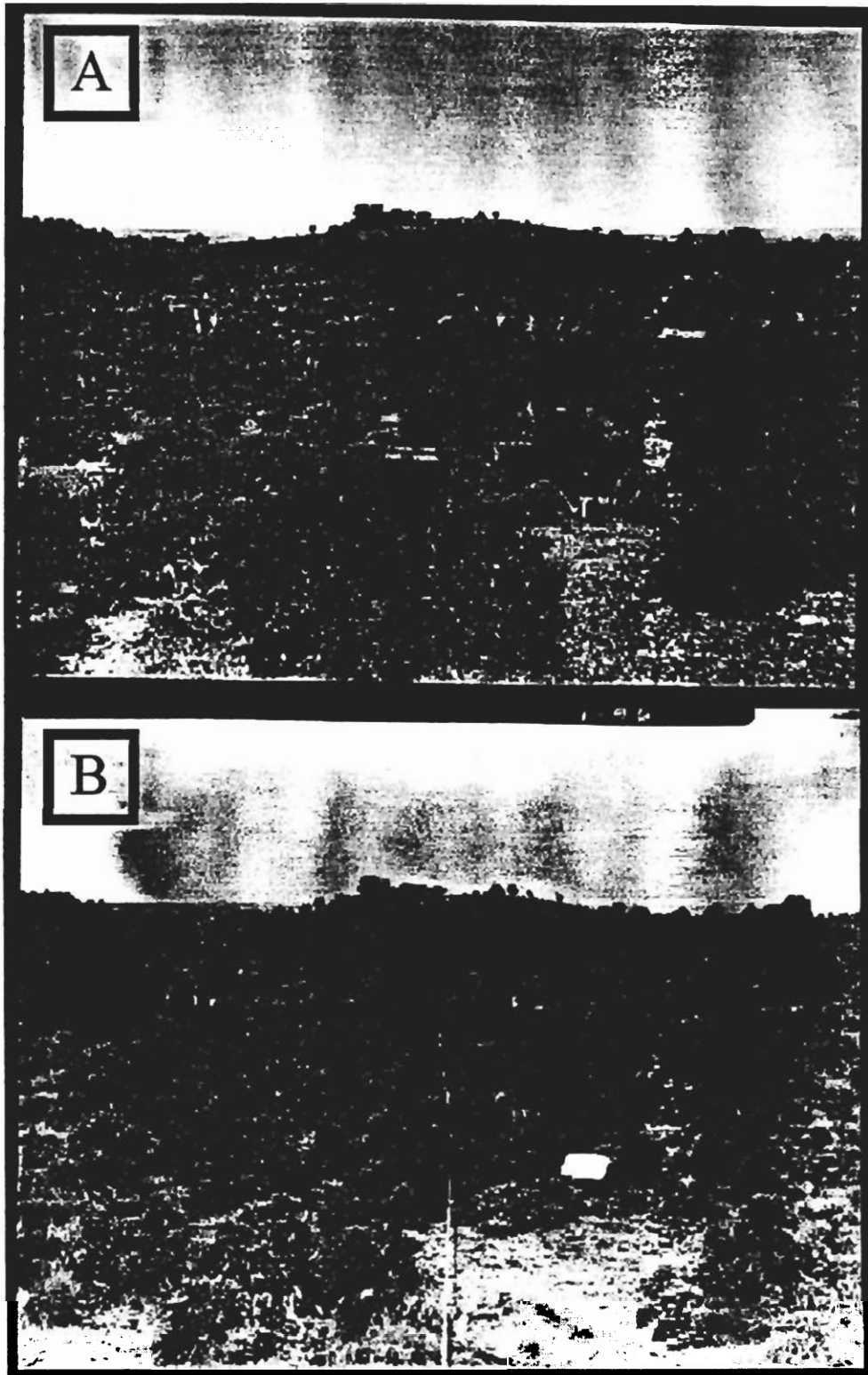


Figure 12. Landscape photographs of shrub type Elb 5, right arm, in (A) 1958 and (B) 1996. Note that pinyon density and size of individuals have increased throughout the depicted scene. Standing weathering snags in the mid-ground are still present.

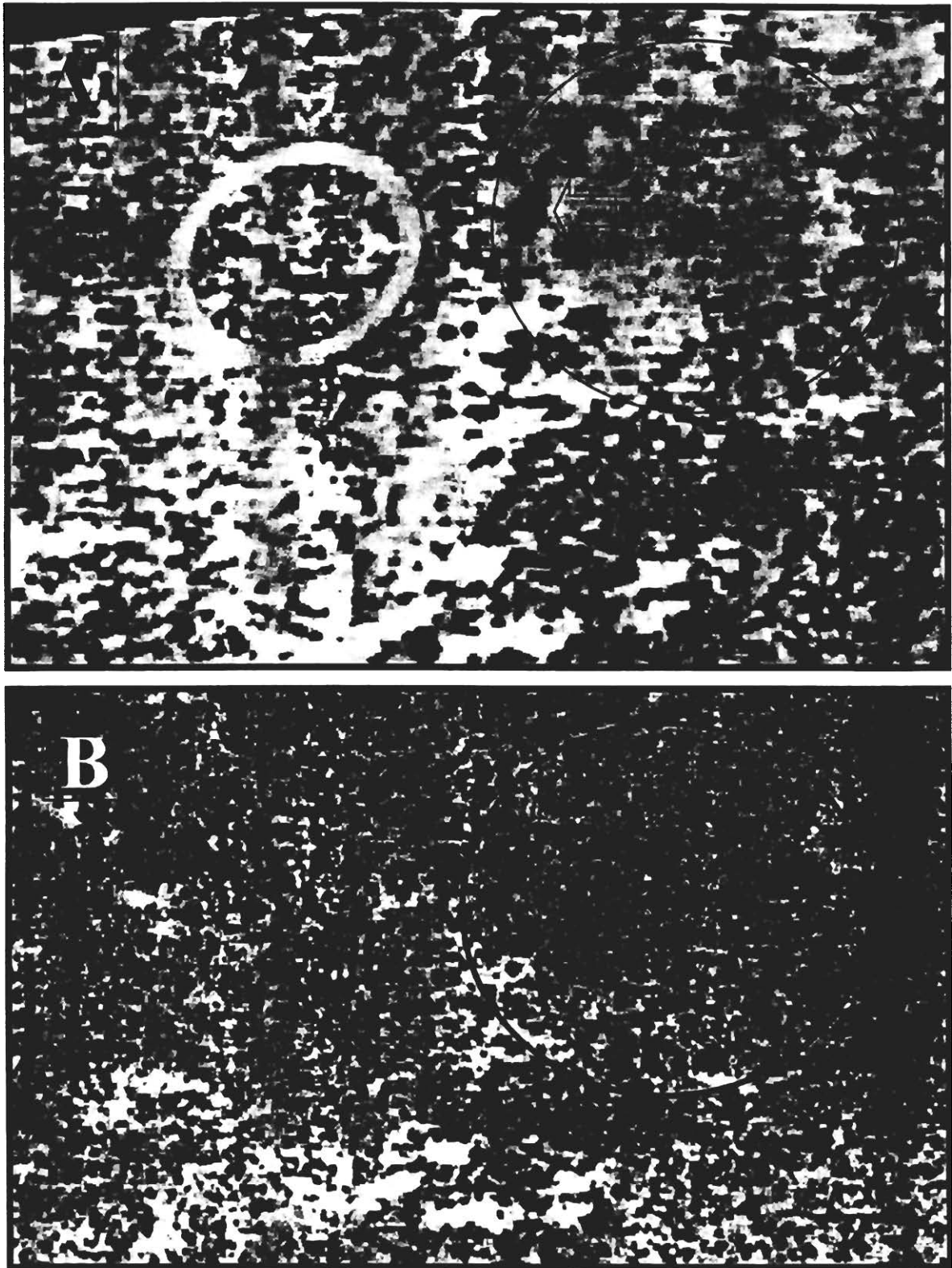


Figure 13. Detail of aerial photographs of the southern end of Fishtail Mesa taken in (A) 1940 and (B) 1994. The scale is approximately 1:7,000. The circle delineates a woodland opening in 1940 which was recolonized by pinyon during the intervening time.

Unique Plant Community Components

Many large and presumably old pinyon and Utah juniper trees grow on Fishtail Mesa. To compare these trees with "champion" trees of the species, the criteria used by the Arizona Register of Big Trees (1996) was used.¹ The largest pinyon, located on Elb 7 had 87 combined points (52.8 in + 29.7 ft + 4.6 ft), significantly less than the National champion with 295 points. The largest Utah juniper, located on Elb 8, had 88 combined points (69.7 in + 14.85 ft + 3.6 ft), also significantly less than the National champion with 310 points. Many large cliff-rose were also observed. One of the largest, located south of Elb 8 had a diameter of 42 cm at ground level and had four branches with diameters measuring 21, 22, 10.5, and 10 cm at one ft above ground level. The age of the largest branch was estimated at 72 years, making the plant's age 80 years or older (Appendix 6).

Faunal Survey

General Observations

A preliminary list of 39 species of birds, seven species of reptiles, and seven mammals (Appendix 8) was prepared based upon visual observations and scat collection from our week of field study. The scat of bobcat, coyote, mule deer, gray fox, mountain lion, and juvenile elk were collected and identified by the park's wildlife technician (Elaine Leslie, pers. com. 1996) and confirmed by Dr. Jim Mead, Northern Arizona University (pers. com. 1996). Beymer (1984, and pers. comm. 1996) reported that large ungulate scat on Fishtail Mesa collected in 1984 was identified as that of elk by Arizona State University faculty. The presence of elk is significant since elk are not native to Grand Canyon National Park. Isolated individuals and groups of elk have been reported on the Kaibab Plateau and elsewhere within the northern portion of the park beginning in 1983 (Britt 1983, Jeffrey Klopatek, pers. comm. 1997). These animals have apparently moved south of their normal winter range in the Paunsaugunt Plateau of southern Utah (Britt 1983).

Mule Deer Population Estimate

We did not observe any mule deer or recent tracks during our field study. Two carcasses were discovered, one in a sinkhole near the southeastern edge and one adjacent to the needle and thread grassland in the center of the mesa. A high number of deer antlers were observed throughout Fishtail Mesa, some of which had been piled under a pinyon tree by a visitor. The abundance of deer antlers is to be expected as deer shed their antlers from late February through March (Hoffmeister 1971), the season that mule deer utilize the mesa.

In 1996, the highest number of deer pellet groups (pg, Table 7) were found on the shrub type Elbs 5 and 1, located on the most northern and southern edges of the mesa respectively. The lowest number was found on the tree type Elbs 6, 7, and 8 located in the interior of the mesa. An average of 35 pg were found on the shrub type elbs and 20 pg in the tree type elbs. The pellet groups averaged 187 pellet groups per acre (pg/ac) for the entire mesa, or 221 pg/ac for the shrub type and 153 pg/ac for the tree type.

Following the Jameson et al. (1962) methodology, we weighted pg values, by vegetation type. In 1958 pg densities averaged 57 pg/ac for the shrub type (26% cover) and 113 pg/ac for the tree type (76% cover) for a sum of 170 pg/ac for the entire mesa. Inserting these values into the aforementioned pellet group formula², yields an estimate of 95 deer visiting Fishtail Mesa during the 1995-96 winter months.

¹Total points are obtained by adding the trunk circumference at a point below 4.5 feet where the circumference is smallest (in inches), plus the height (in feet), plus one quarter of the average crown spread in feet.

² $[(170 \text{ pg/ac})(1,084 \text{ ac})/13 \text{ pg/deer/day}]/150 \text{ days} = 95 \text{ deer}$

Table 7. Actual and estimated pellet groups (pg) per elb and per acre in 1996 and 1958.

	Shrub Type Elbs				Tree Type Elbs				Mean $\pm$ 95% C.L.
	1	2	4	5	3	6	7	8	
pg per Elb - 1996	36	27	29	49	27	15	30	18	29 $\pm$ 9
Estimated pg-ac ⁻¹ -1996	225	170	182	307	169	94	125	225	187 $\pm$ 55
Estimated pg-ac ⁻¹ -1958	153		78	78	38				87 $\pm$ 76

The 95 deer estimate for 1996 (Table 8) is equal to 14,175 deer-days or 11.4 acres per deer. These numbers support the field observation by Jameson et al. (1962) that the range on Fishtail Mesa was improving in 1958, based upon the decrease in numbers of deer using the mesa since 1954 as reported by Cravens and Pase (1954). They also corroborate Jameson's (pers. comm. 1996) observation that deer use in 1996 was greater than that observed in 1958. Of course, errors can be generated around these population estimates. However, since there is substantial overlap of the individual 95% confidence intervals around the means of the 1958 and 1996 data, no definitive statements about differences in estimated deer populations can be drawn.

Table 8. A comparison of estimated pellet groups, deer-days, number of deer, and acres/deer on Fishtail Mesa for 1954, 1958, and 1996.

Year	Investigators	Pellet Groups Per Acre	Deer-days	Estimated Deer Numbers	Estimated Acres Per Deer
1954	Cravens and Pase (1954) ¹	346	28,531	190	5.6
1958	Jameson et al. (1962)	58	4,783	31	33.6
1996	This Report	170	14,175	95	11.4

¹Figures were revised using 1,084 acres as the actual area of Fishtail Mesa (see above)

Soils

A reconstructed 1958 soil map (Figure 14) shows the five soil units originally described by Jameson et al. (1962). A 1996 soil map (Figure 15) was prepared and included gypsum as a sixth unit. Five of the units are derived from Permian-aged Kaibab Formation (Pk) and one is of Quaternary age (Q). These include: normal limestone (Pk1, 26.9%), sandy limestone (Pk2, 46.7%), cherty limestone (Pk3, 17.5%), steep rocky slopes (Pkx, 4.3%), gypsum (Pkg, 0.4%), and alluvium (Qal, 4.2%). Our extrapolation of the TES Unit 250 corresponds to the normal and sandy limestone soil unit, unit 272 corresponds to the recent alluvium soil unit, and units 251 and 252 correspond somewhat with the steep rocky slope soil unit (Table 9).

Table 9. Terrestrial Ecosystem Survey (TES) units.

TES Unit	Descriptive Name	Percent slope	Soil Texture
250.00	Lithic Ustochrepts	0-15	Gravely fine sandy loam
251.00	Lithic Ustochrepts	15-40	Gravely fine sandy loam and rock outcrop
252.00	Lithic Ustochrepts	40-80	Fine sandy loam
272.00	Typic Haplustalfs	0-15	Clayey-skeletal to fine gravely loam

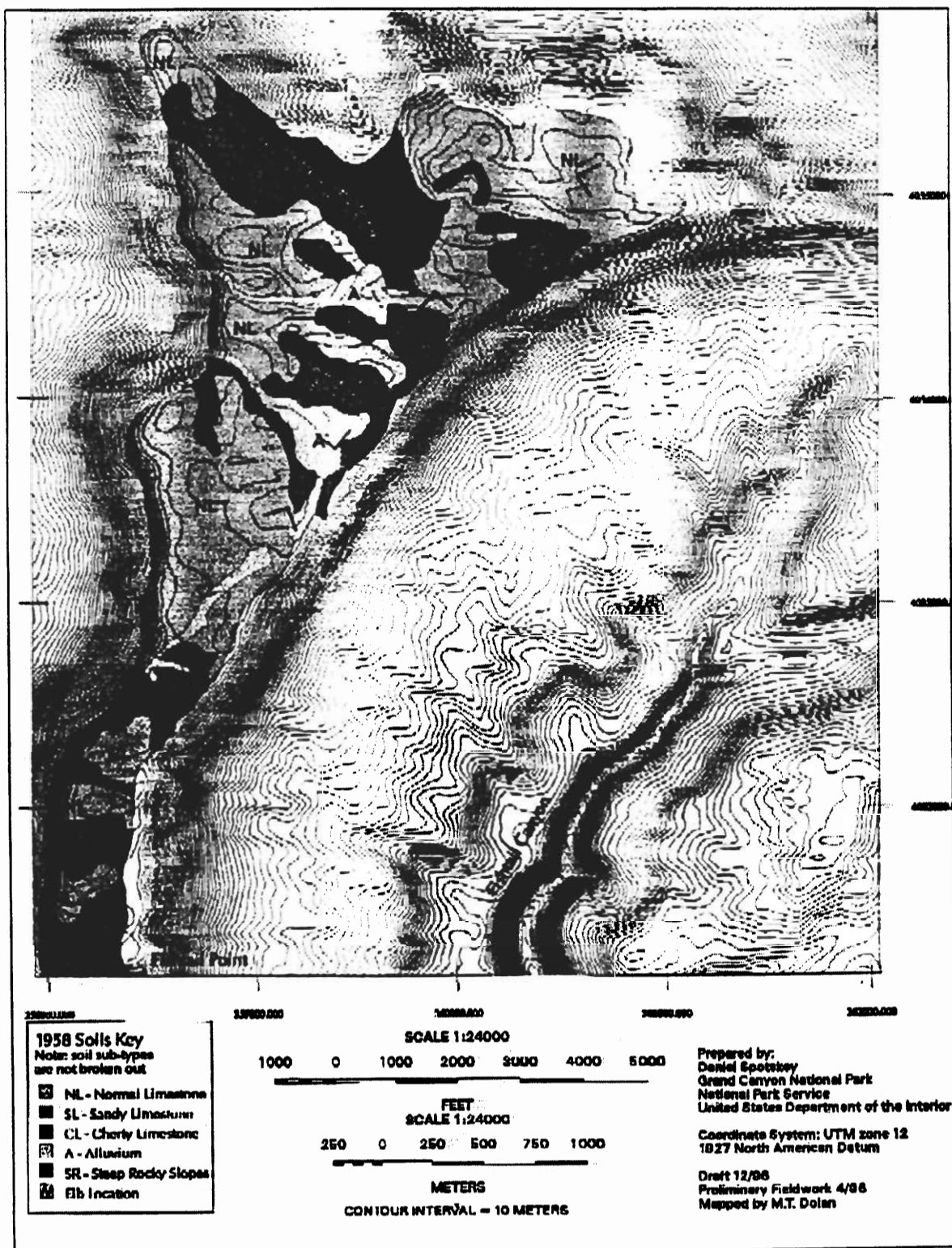


Figure 14. 1958 Soils map (as reconstructed from the original [Jameson et al. 1962]).

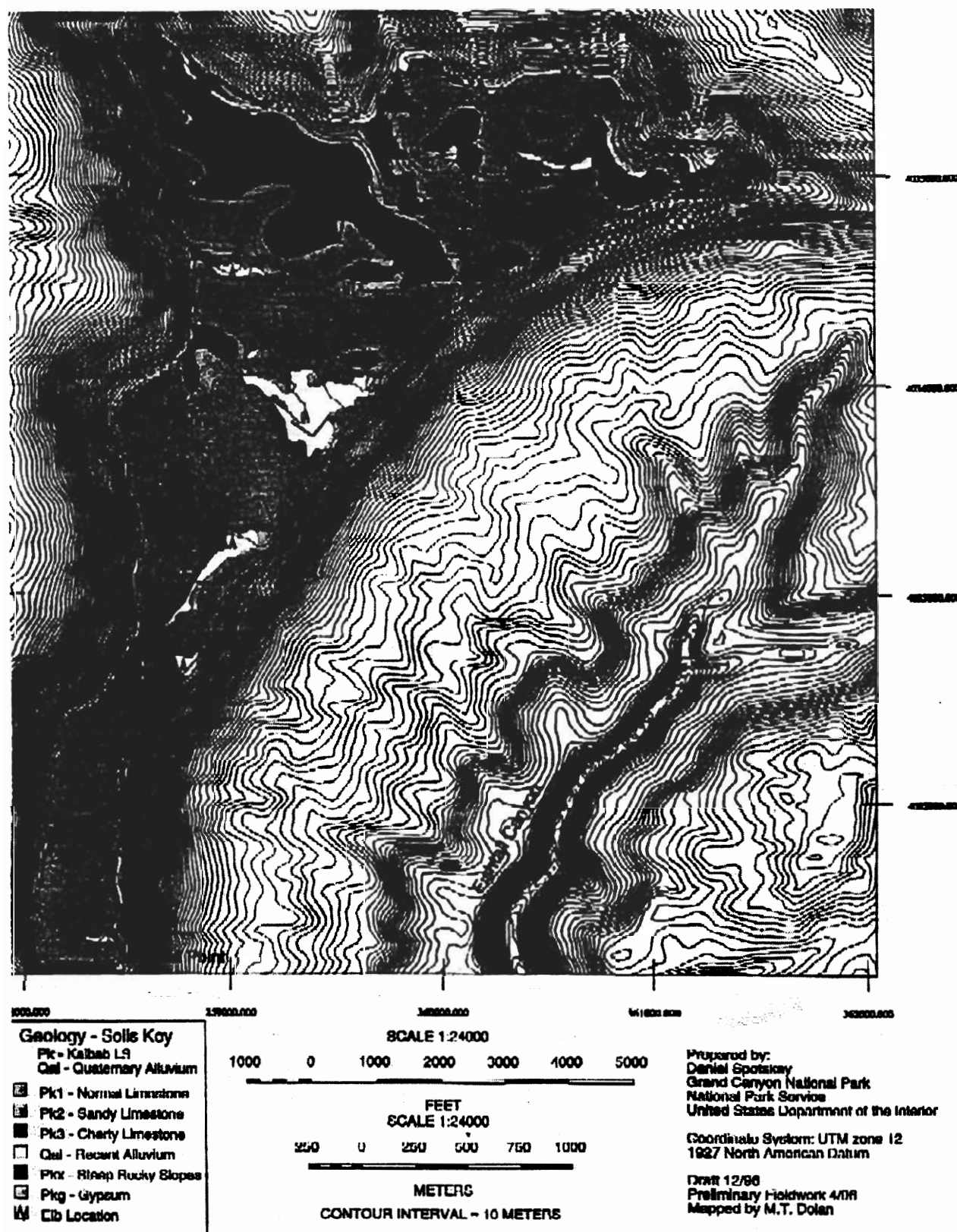


Figure 15. Fishtail Mesa soil map (1996 version).

DISCUSSION

The Great Basin desert is thought to have evolved comparatively recently, perhaps only 5,000 to 12,000 years ago (Butler 1976, Stutz 1978). Woody sagebrush species (*Artemisia tridentata* var. *tridentata*, *A. arbuscula* ssp. *nova* and *A. bigelovii*) are regarded as subdominants in Great Basin Conifer Woodland and Great Basin Grassland (Turner 1982). The range of big sagebrush is more northerly and westerly than that of Bigelow sagebrush, which is the most widespread of the sagebrush species in the Southwest. The occurrence of a significant graminoid component in the sagebrush vegetation type may cause the communities to be regarded as a steppe, shrub steppe (Turner 1982), or sagebrush savanna (Clements 1930). Such is the case for the vegetation on Fishtail Mesa at this point in time.

Vegetation

Are the eight permanently established elbs on Fishtail Mesa adequate to fully characterize the vegetation of the area? Woodin and Lindsey (1954) determined that seven elbs were sufficient to yield acceptably low standard errors for the dominant species within a 80 to 100 acre study area using the line-strip method. One way to examine their conclusion is to approach the problem from the standpoint of the "homogenous stand of vegetation" concept. The number of necessary and sufficient elbs to characterize a stand is very much a function of the innate homogeneity of such a stand. Stand homogeneity can be defined two ways. One point of view is from the standpoint of randomness, whether or not the probability of observing a individual of a plant species within a sampling unit is the same in all parts of the area. The second is from the standpoint of homogeneity of community composition, whether or not the characteristic plant species are homogeneously distributed (Shimwell 1971). In either case, determining the optimum number of sampling units required to characterize a particular stand of vegetation must be appraised on a case-by-case basis, using the sorts of performance curves mentioned in the Methods Section above.

We conclude that the dominant plant species on Fishtail Mesa are over sampled based upon performance curve results for the shrub type (Figure 16). For example, sagebrush is a dominant species in the shrub type. The overall mean linear cover is 4.4 ± 1.0 ft per 20 foot line intercept section, or 22% cover. The mean stabilizes after five 20 ft line intercept sections, or 100 feet. Mutton grass in the shrub type has lower cover and a more patchy distribution than sagebrush. It tends to occur under shrub canopies. The mean for mutton grass takes more sampling for it to stabilize, about twelve 20 ft line intercept sections, or 240 feet. The cover of dominant species, such as sagebrush, requires less intensive sampling than less common species, such as mutton grass. On the whole, twenty 20 foot sections, or one elb arm, is more than sufficient to sample the shrub type dominants and common species. When both elb arms are sampled, rarer species are picked up. There are eventually limitations for there will almost always be "rarer" species and one runs the risk of leaving a homogenous vegetation type.

We also conclude that the dominant plant species in the tree type are also over sampled as shown by the performance curves (Figure 17). Pinyon has a mean cover of 2.5 ± 2 ft per 20 ft line intercept section or 6% cover. The mean appears to stabilize after 20 of the 20 ft sections – but this is somewhat uncertain. Sagebrush, as in the shrub type, has a more homogeneous distribution and the mean stabilizes after seven of the 20 ft line intercept sections, or 140 feet. Mutton grass is also very patchy in the tree type. In addition, there is evidence of a different pattern of cover for each of the elb arms: 0 to 20 is the left arm as taken from the origin and 20 to 40 is the right arm as taken from the origin. We surmise that this may be due to changes in aspect or an ecotone gradient.

Vegetation Changes Since 1958

The comparison of the 1958 and 1996 data for the line intercept and Parker loop sampling shows that vegetation on Fishtail Mesa has not changed appreciably over the 38 years. The relative cover percentages from the line intercept data (Appendix 3) show that for the shrub type sagebrush has declined, while mutton grass has increased. Other species like joint-fir, prickly pear, and snakeweed have decreased since 1958. Pinyon and Utah juniper have increased in the shrub type. In the tree type, the cover of most plants has

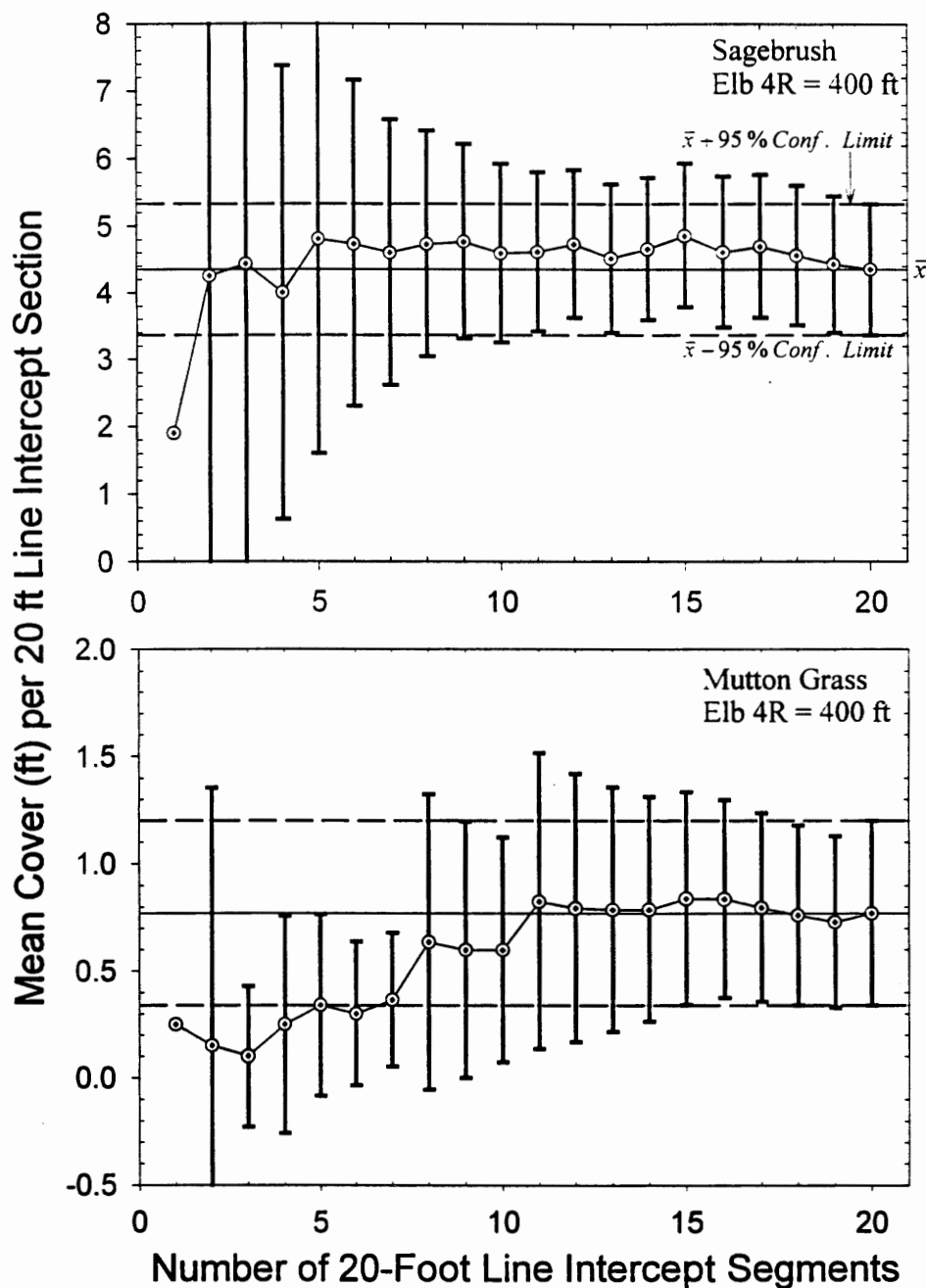


Figure 16. Performance curves in the form of the running mean of plant cover estimates for the shrub type as represented by Elb 4R. Sagebrush and mutton grass are the dominant and subdominant plant species in the shrub type vegetation. Mean plant cover is recomputed according to the cumulative increase in the number of 20 ft line-intercept sub-samples, or segments. Ninety-five percent confidence limits around the mean are indicated for each estimated mean and for the sample as a whole.

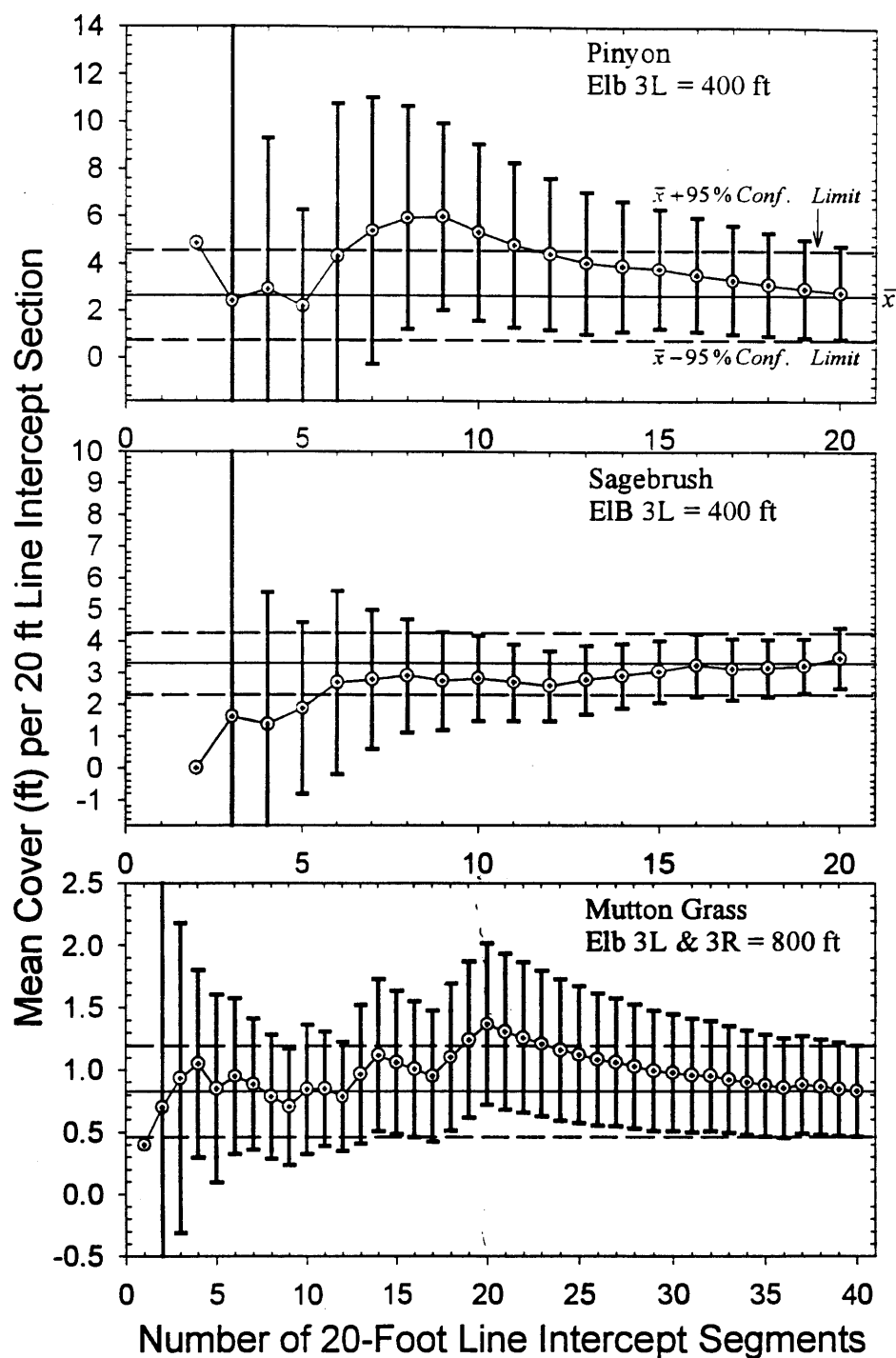


Figure 17. Performance curves in the form of the running mean of plant cover estimates. Pinyon and sagebrush are codominant and mutton grass is the subdominant plant species in the tree type vegetation. Mean plant cover is recomputed according to the cumulative increase in the number of 20 ft line-intercept sub-samples, or segments. Ninety-five percent confidence limits around the mean are indicated for each estimated mean and for the sample as a whole.

remained somewhat stable. The changes are not significant (Table 10) and may actually reflect differences in the precision of the field personnel. The 1958 and 1996 Parker loop basal and crown data for the four major species in the shrub and tree types (Appendix 4) are not appreciably different either. The comparison of the 1958 and 1996 percent frequency of the four major species (Table 11) is less clear. Mutton grass is the most frequent in the shrub type in 1996, replacing sagebrush, which was most important in 1958. Mutton grass and sagebrush were the most important species in the tree type for both years, followed by sagebrush. The differences may be due to the small number of three foot square plots and the apparent differences in placement along the elb strip.

Table 10. Comparison of absolute cover values, measured in 1958 and 1996, of selected, important species, on Fishtail Mesa. Cover is expressed in mean linear feet per elb-arm. Values for 1958 were back-calculated using data from Jameson et al. (1962). Their cover data was presented as percent absolute cover for each species according to shrub and tree type. Conversion to linear feet per elb arm was done by converting the percent cover to a decimal, then multiplying by 3200 ft total elb length for the shrub type (2800 for the tree type) followed by division by 8 (7 for the tree type).

Species	Mean Linear Feet of Cover Per Elb Arm ¹									
	Shrub Type (n = 8)					Tree Type (n = 7)				
	Year		Δ % ²			Year		Δ %		
	1996 $\pm$ 95%		Based on			1996 $\pm$ 95%		Based on		
	1958	Confidence Limit	Lower C.L.	Mean	Upper C.L.	1958	Confidence Limit	Lower C.L.	Mean	Upper C.L.
Mutton grass ³	0.3	18.6 $\pm$ 3.4	1033.3	6100.0	7233.3	0.3	10.1 $\pm$ 3.9	1966.7	3266.7	4566.7
Joint-fir	2.7	3.6 $\pm$ 0.9	-66.7	33.3	66.7	3.5	1.5 $\pm$ 1.4	-97.1	-57.1	-17.1
Sagebrush	97.6	76.8 $\pm$ 9.8	-90.0	-21.3	-11.3	39.7	39.6 $\pm$ 17.6	-44.6	-0.3	44.1
Pinyon	0.0	2.96 $\pm$ 3.3	---	---	---	41.4	45.6 $\pm$ 18.1	-33.6	10.1	53.9
Utah Juniper	0.0	0.8 $\pm$ 0.8	---	---	---	40.4	38.0 $\pm$ 20.6	-56.9	-5.9	45.0

¹ Nineteen fifty-eight absolute vegetation cover values, in terms of mean linear feet of cover per elb, were back calculated from data contained in Jameson et al. (1962, Table 1 ff.).

² Δ % or, percent change, is defined as the [(present value - the past value)/(past value)]*100.

³ Jameson et al. (1962) measured plant cover to an accuracy of 0.01 ft. We decided that such precision was not reasonable considering deflection of the line (tape) by wind, and the general placement of the line above the shrub canopy. Therefore we measured to an accuracy of 0.03 feet (0.5 cm). The difference in precision could well account for the large difference in cover of mutton grass between 1958 and 1996. However, Parker loop results also show an increase in mutton grass cover.

Table 11. Comparison of absolute cover values, measured in 1958 and 1996, of selected, important species, on Fishtail Mesa as estimated by the Parker loop method

Species	Mean Number of Parker Loop Hits Per Elb Arm ¹									
	Shrub Type (n = 8)					Tree Type (n = 7)				
	Year		Δ %			Year		Δ %		
	1996 $\pm$ 95%		Based on			1996 $\pm$ 95%		Based on		
	1958	Confidence Limit	Lower C.L.	Mean	Upper C.L.	1958	Confidence Limit	Lower C.L.	Mean	Upper C.L.
Mutton grass	3.0	11.1 $\pm$ 6.8	43.3	270.0	496.7	3.0	9.7 $\pm$ 4.7	66.7	223.3	380.0
Joint-fir	2.4	2.3 $\pm$ 0.9	-64.3	-4.2	-33.3	1.4	1.0 $\pm$ 0.9	-92.9	-28.6	35.7
Sagebrush	107.9	87.4 $\pm$ 10.7	-28.9	-19.0	-9.1	40.2	39.0 $\pm$ 17.7	-47.0	-3.0	41.0
Pinyon	0.0	1.6 $\pm$ 3.2	---	---	---	43.7	46.4 $\pm$ 18.9	-37.1	6.2	49.2
Utah Juniper	0.0	0.6 $\pm$ 1.0	---	---	---	43.3	39.3 $\pm$ 21.5	-58.9	-9.2	40.4

¹ Nineteen fifty-eight values for Parker loop hits were back calculated from data contained in Jameson et al. (1962, Table 1 ff.).

The picture of tree reproduction would have been complete had the number and size of tree species under three ft in height been recorded in 1958. Cravens and Pase (1954) reported that reproduction by pinyon and juniper was limited. The 1996 data (Table 6, Figures 9 and 18) shows a large number of pinyon seedlings and immature plants, with low reproduction of Utah junipers.

It is difficult to compare the density and frequency results for the tree species for 1958 and 1996. The 1958 data was reported by 2,000 ft² sections within two soil types, a limestone and sandy limestone upland (Elbs 1, 2, 3, 5, 6, and 7) and cherty ridges (Elb 8). Apparently, the alluvial soil type (Elb 4) was not included in these two soil types. If the data is analyzed by these elbs, we found approximately 5.0 pinyon trees in the limestone uplands, identical to that reported for 1958. We found 1.0 pinyon trees on the cherty ridges, as compared to 3.2 reported for 1958. Similarly, we found 3.0 juniper trees for the limestone uplands as compared to 4.2 for 1958. Also, there were no juniper trees as compared to 3.1 in 1958.

Vegetation Dynamics of Pinyon-Juniper

Studies of pinyon-juniper woodlands suggest that when fire removes all vegetation and seed sources, recolonization occurs in five general stages. First, annuals colonize disturbed areas in two to four years. After four to six years, perennial grasses and forbs become important cover components. After ten to 35 years shrubs become prominent. After 84 to 100 years, shrubs become more important and small pinyon and juniper trees become established (Erdman 1970, Barney and Frischknecht 1974, Noble 1990). Eventually, providing that no catastrophic disturbance, such as a stand-replacing fire, violent wind storm or human impact (i.e., chaining) takes place, the stand progresses to an all-aged pinyon-juniper woodland. Of course, these general stages do not take into account the wide variety in plant species, the frequency and degree of disturbance, site quality, distribution and size relationships, climatic regimes, and the availability of seed dispersal agents, such as birds.

Many studies in the southwest have reported similar findings in the various types of pinyon-juniper ecosystems (Jameson 1965 and 1967, Everett 1987, Gottfried 1987, Shaw et al. 1995). Junipers, as a species, have a broader ecological amplitude than pinyons. They are more xeric adapted and are known to invade an area first (Johnsen 1962). Sagebrush may act as a nurse plant for establishment of juniper seedlings. Juniper seeds are either residual in the soil or are dispersed by birds. In the Grand Canyon region, over-wintering Townsend solitaires and American robins, along with spring/fall transients such as cedar waxwings and Western blue birds are responsible for dispersing juniper berries (Balda 1987, Brown, Carothers and Johnson 1987). The seeds can also be dispersed by large and small herbivores, such as rabbits, jackrabbits, deer, elk, and livestock, and even carnivores, such as coyotes, fox, and raccoons, that consume the berries. These junipers do not act as a seed source until they mature, typically 30 years later.

The junipers then serve as nurse trees for pinyon seedlings, which require shade or closed canopy communities (Blackburn and Tueller 1970). Originally, the pinyon seeds are often brought to an area by four species of seed caching corvid birds: Clark's nutcracker, pinyon jay, Steller's jay, and scrub jay (Balda 1987). Once established the pinyons can grow quickly and produce seeds in 10-20 years (Jeffers 1995). They eventually dominate a site, especially ones that are more mesic, or higher elevation. Tree density and dominance of pinyons have been shown to increase in the Great Basin over the last 150 years (Jameson 1965, Tausch et al. 1981). As the junipers and pinyons age, the sagebrush understory declines and may be partially or totally eliminated due to competition, shading, or other factors.

Junipers and pinyon have probably reinvaded the sagebrush steppe on Fishtail Mesa in these cycles for millennia. In the short-term of less than 50 years, such as the period of time between the 1958 and 1996 surveys, and the 1940 and 1994 aerial photography (Figure 13), the vegetation may appear relatively stable or to be in equilibrium. We surmise that sagebrush will decline under the woodland canopy as well as in the shrub type, albeit perhaps more slowly in the latter. In the long-term of 100-300 years, the vegetation dynamically responds to fire or reflects changing climatic conditions. At this point in time, we consider Fishtail Mesa to be a sagebrush shrub-steppe with pinyon-juniper woodland patches. However, in the absence of fire, pinyon and juniper could eventually reoccupy the Mesa. In which case, in the future, the shrub-steppe would exist as patches or perhaps not at all.

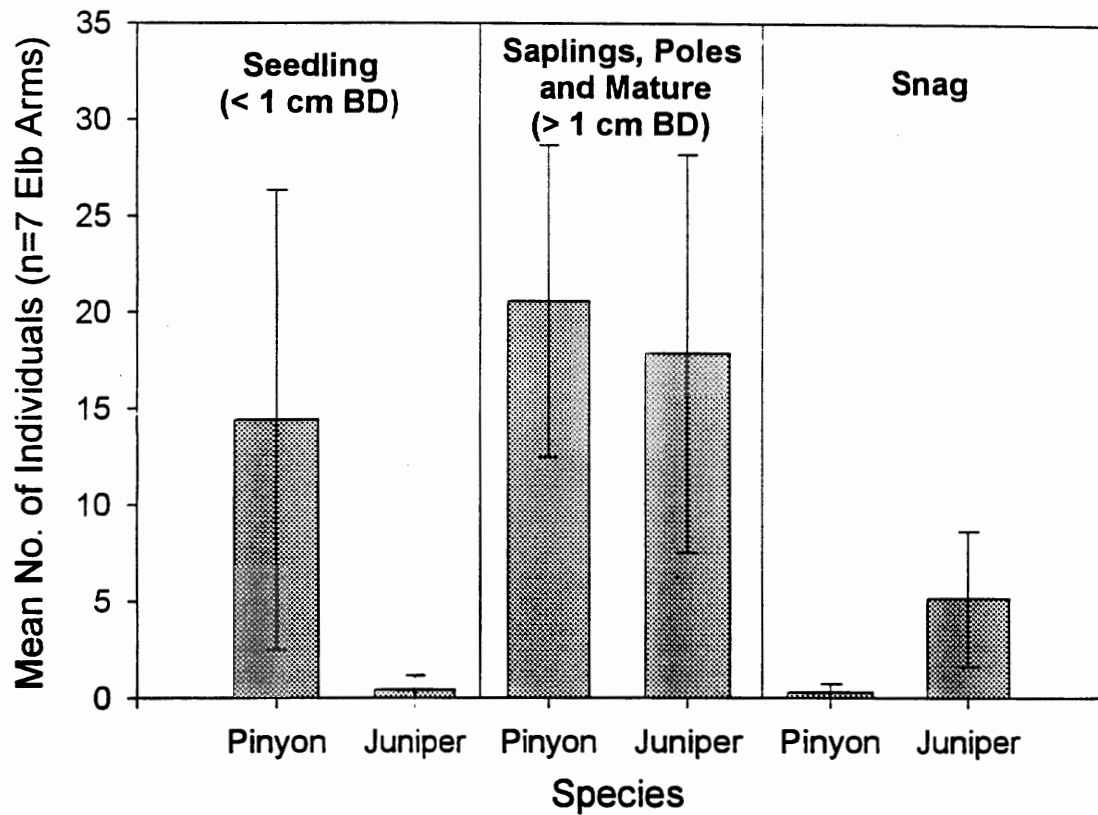


Figure 18. The mean number of pinyon and Utah juniper in three broad life cycle classes: seedling (<1 cm in stem diameter [BD]); sapling, pole and mature (>1 cm in stem diameter); and snags (standing dead) for seven elb arms of the tree type on Fishtail Mesa in 1996.

We found that mutton grass was a significant secondary member of the shrub and tree types on Fishtail Mesa. Its absence on the mainland in the post-settlement era (Jameson et al. 1962, Schmutz et al. 1967) is probably due to land management practices. Beginning with intensive pioneer use in the 1880's, this highly palatable, native cool season grass (Forest Service 1937) suffered decades of decline due to ungulate grazing, in the form of domestic livestock and irruptions of mule deer populations. Mutton grass plants are gynodioecious. Most plants are female and a few are male, although a few plants may be found with perfect florets with both male and female parts. Where both sexes are present it reproduces from seed. However, if only one sex is present, it can reproduce from tillers and rarely from rhizomes (Welsh et al. 1993, Stubbendieck et al. 1982). There is some doubt if mutton grass reproduce sexually as there is evidence that only crosses with members of the *Pratenses* group enable seed production (Cronquist et al. 1977). Mutton grass starts growth in the spring and matures in June or July. Since mule deer have departed Fishtail Mesa by early spring, reproduction is probably more successful when compared to the mainland, where they are grazed year-round. While mutton grass had 0.06 and 0.07% absolute cover in the shrub and tree types in 1958 (see Table 1 in Jameson et al. 1962), we found 2.6 and 2.5% respectively in 1996. The dramatic increase in the cover figures for mutton grass between the two study dates may be a reflection of a significant increase, a difference in the precision of the field workers, a change in the deer use, a response of the plant to climate, a combination of factors, or other unknown reasons.

The pinyon-juniper woodland is slow growing, long lived, and resistant to decomposition, especially in arid areas. A study of pinyon growth in New Mexico (Little 1987) showed growth was extremely slow. The average height increased 4.3 ft after 47 years (about 1.1 inch per year), while average diameter at breast height increased 2.8 inches after 47 years (about 0.06 inch per year). Using this figure, trees on Fishtail Mesa would have grown about 3.5 ft since 1958. The oldest dated pinyon on Fishtail Mesa, based upon tree-ring counts, was approximately 358 years old (Appendix 6). Mature pinyon trees in Grand Canyon National Park have been dated at greater than 400 to 600 years (Ferguson and Black 1952, Klopatek 1987), while trees of the species have been aged at more than 1,275 years (Welsh et al. 1993). While we did not date Utah junipers, juniper snags along the Colorado River in nearby Marble Canyon have been shown by radiocarbon dating to have died about AD 1400 (Webb 1996). One snag was rephotographed after 100 years in the same location and condition. We presume that the weathered juniper snags on Fishtail Mesa may be of similar dates.

Soil texture, stoniness, or depth does not limit distribution of the pinyon-juniper woodland (Leonard et al. 1987). The community appears to be limited by precipitation on the lower end of the elevational range and by temperature on the higher end (Wright et al. 1979). In the absence of fire, pinyon-juniper has been shown at a relict area on the Arizona Strip, northwest of Grand Canyon National Park, to be the dominant species regardless of soil type (Thatcher and Hart 1974). However, minor soils differences, presence or absence of fire, and the direction and degree of slope have been shown to cause dramatic differences in species composition and production in pinyon-juniper ecosystems.

Merkle (1952) studied a pinyon-juniper community on the South Rim of Grand Canyon. He reported that pinyon covered about 40% and Utah juniper covered 15-20%, with both not covering over 60%. He found that mature pinyon were typically taller than mature juniper and a great abundance of pinyon in the less than 25 cm dbh size classes. Five times as many pinyon were found in two size classes less than 7.5 cm dbh and three times in the 7.5 to over 25 cm dbh size classes. He concluded that this indicated normal reproduction and maintenance of a climax community, rather than pinyon replacing Utah juniper. The resurvey of the tree type elbs on Fishtail Mesa showed a similar picture (Figure 10). The absolute cover of pinyon and Utah juniper may have remained stable in the tree type between 1958 and 1996, however it looks as though these tree species have begun to colonize the shrub type by 1996.

Floristics

Turner (1982) and Schmutz et al. (1967) have compared the vegetation of Fishtail Mesa and nearby Boysag Point. Plants occurring on Boysag Point but not found on Fishtail Mesa include, among others: Fendler three-awn (*Aristida purpurea* var. *longiseta*), sideoats grama (*Bouteloua curtipendula*), various species of muhly (*Muhlenbergia* spp.), prairie sagewort (*Artemisia frigida*), *Brickellia scabra*, rabbit brush

(*Chrysothamnus nauseosus* var. *junceus*), three species of joint-fir (*Ephedra nevadensis*, *E. trifurca*, and *E. viridis*), burrograss (*Scleropogon brevifolius*), *Tridens* spp., *Haplopappus cervinus*, one-seed juniper (*Juniperus monosperma*), silver buffalo berry (*Sphepherdia argentea*), turpentine broom (*Thamnosma montana*), and bastard toadflax (*Comandra pallida*). Other plants "missing" from Fishtail, but present in similar but perhaps more mesic habitats in Grand Canyon include native species such as rock goldenrod (*Petradoria pumila*), Gambel oak (*Quercus gambelii*), fernbush (*Chamaebatiaria millefolium*), mountain-mahogany (*Cerocarpus* spp.), rabbit thorn (*Lycium pallidum*), and New Mexico locust (*Robinia neomexicana*).

Faunal Analyses

General Observations

Reptiles found on other desert buttes (Johnson 1986) and to be expected on Fishtail Mesa (Rasmussen 1941, Miller et al. 1982), but were not seen in 1996, include the short horned lizard, tree lizard, western or northern whiptail, black collared lizard, mountain short horned lizard, northern plateau lizard, Great Basin gopher snake, black-tailed rattlesnake, Great Basin rattlesnake, and California kingsnake. The absence of their prey items on Fishtail Mesa may explain their absence. Mammals which may be expected (Hoffmeister 1971), but were not seen nor scat collected, include bighorn or mountain sheep, porcupines, badgers, ringtails, spotted skunks, pocket gophers, pocket mice, rabbits, or kangaroo rats. In 1973, McCulloch (1996) reported signs of badger diggings. We made no notes of any species of bats, though they do fly over the mesa. Donald Jameson (pers. comm. 1996) noted that he saw more rattlesnakes in 1958 than in 1996, when only one was observed. Jeffrey Klopatek (pers. comm. 1996), who visited the area for five days in 1984, saw many rattlesnakes.

Forage Utilization by Deer and Elk

The use of forage on Fishtail Mesa by mule deer will undoubtedly continue and may increase. Elk use may potentially increase, given the successful range expansion of this species throughout Arizona and the Kaibab Plateau (Britt 1983). However, given that no water sources are found on Fishtail Mesa, use will be minimal or accidental. In years of low snow accumulation, browsers will utilize low growing shrubs, such as cliff rose, mountain mahogany, immature Utah juniper, and associated grasses. In deep snow years little forage will be available. There is no evidence that the current forage on Fishtail Mesa is over-utilized. The abundant presence of mutton grass gives added support to this observation, as it is palatable to mule deer, especially in early spring (Sampson 1952). Jameson (pers. comm. 1996), however, notes that mule deer, because of their mouth shape, do not utilize mutton grass extensively. During our field examination of Fishtail Mesa, we noticed that cliff rose was the only woody plant species which showed signs of deer browsing.¹

Soils

The 1958 and 1996 soils maps (Figures 14 & 15, respectively) and estimates of areas necessarily differ due to the different techniques and methods used by the investigators. Both maps are interpretations based upon field inspection and photographic interpretation. Soils units were similar, with the addition of small gypsum pockets in the 1996 map. Field checking of the preliminary 1996 soils map is necessary. Additional analysis of physical and chemical properties of the four soil pits, not done due to cost considerations, would clarify any differences in the soil properties.

Julander (as cited by Bostick 1949) noted that some places on Fishtail Mesa showed severe erosion. However, at the time of the 1958 field studies, there was no head cutting or even minor rilling of the soil

¹ Plants on Elb 8, identified as cliff rose may actually prove to be antelope bitterbrush (*Purshia glandulosa*).

surface on Fishtail Mesa. A pavement of limestone and chert fragments covered soft, vesicular upper soil horizons, which were 1-3 inches thick. Soils of this type are indicative of old, stable surfaces (Wells 1994, Wells et al. 1985). Likewise, no parts of Fishtail Mesa exhibited severe erosion in 1996. Therefore Fishtail Mesa exhibits relict-like qualities in that accelerated erosion appears to be minimal to non-existent.

It may also suggest that fire has not been an important factor for many years on Fishtail Mesa. Anecdotal, during June 20 to July 26, 1996 a major stand-replacing fire, the Bridger Fire, occurred on the adjacent mainland north and east of Fishtail Mesa. About 53,500 ac of pinyon-juniper and ponderosa pine woodlands were burned following a region-wide drought. Subsequently, monsoon rains caused extensive erosion and gullying. Large amounts of the upper soil layers were removed in the process. The influx of charcoal laden silt carried downstream to the mainstem by Kanab Creek caused the lower reach of the Colorado River below Kanab Creek to be blackened for several days. No remnants or signs of such a catastrophic erosional event are visible anywhere on Fishtail Mesa.

Based upon the apparent stability of the vegetation on Fishtail Mesa as seen by the elb strip methodologies, observation, and photographic interpretation, fires on Fishtail Mesa are apparently infrequent to rare. The last fire on the mesa may date from the turn of the century or earlier. We saw no evidence of burned sites at different seral stages for either the tree or shrub type.

SUMMARY

The resurvey of the vegetation on Fishtail Mesa conducted by this study shows that no significant vegetation changes have occurred during the last 38 years. We surmise that Fishtail Mesa has experienced repeated waves of juniper establishment within the sagebrush-mutton grass steppe, followed by a secondary wave of establishment by pinyons. Subsequently, reproduction of the junipers in the densely wooded areas declined and the remaining individuals became over mature. Concomitantly, germination and seedling establishment of the pinyons increased in the shadow or canopy of the maturing juniper woodland. Eventually the pinyons may become dominant, in number, height, and canopy. Sagebrush beneath the tree canopy will decline, but due to the relatively open nature of the canopy, will always be an associate species and the dominant subshrub. Following episodic events of drought, parasitism, disease, or lightning caused wildfire, the wooded areas will revert to a sagebrush steppe if residual sagebrush plants or their seeds remain. Portions of Fishtail Mesa, especially in the vicinity of Elbs 6 and 7, are representative examples of a mature, all-aged pinyon-juniper woodland. The deep alluvial soils in the center of Fishtail Mesa (north of Elb 4) will probably remain a needle-and-thread grassland with some associated sagebrush. The utilization of Fishtail Mesa's forage by mule deer during the winter months appears to be similar between the two dates of study.

Retaining examples of pristine natural environments is one of the National Park Service's missions. It is important for inspiration, education, and interpretation, as well as for park-based and academic study of "research natural areas" (Tuhy and MacMahon 1988, Van Pelt and Tuhy 1991). These relict areas offer baselines for gauging impacts occurring elsewhere, defining productive potentials of woodlands, providing sanctuaries for native species, and for study of ecological processes (Hanson 1939, Hermann 1989, Van Pelt et al. 1991). The study of "dynamic ecology" or succession is often hampered because of the length of time involved, the absence of control over desirable communities, and the difficulty of securing long-term management cooperation (Clements 1930).

Sites in the pinyon-juniper ecosystem have been impacted for hundreds of years, first by Native Americans and then by Anglo settlers and their domestic livestock (Fleischner 1994). Since the middle of this century, the increase in wood gathering for fuel and building materials, off-road vehicle use, human-caused fire, and physical manipulation (i.e., chaining) has continued to impact these sites. The ecosystem has received much scientific study (among them Howell 1941, West 1984, Shinn 1980, and Evans 1988) and attention by land managers (Everett 1987, Gifford and Busby 1975). But in spite of this and the occurrence of over 80 million acres of pinyon-juniper woodland in the western United States (Sauerwein 1984), this woodland type was not included as one of the vegetation types for the Long-term Ecological Research Program of the National Science Foundation (Callahan 1984, 1991).

There are only a few pinyon-juniper sites in the Southwest which reflect presettlement or undisturbed conditions, among them Boysag Point (Schmutz et al. 1967), Wide Top Mesa (Schmutz et al. 1976), Timber Top Mesa (Mason and West 1970), Spy Mesa (Thatcher and Hart 1974), and No Man's Land Mesa (Mason et al. 1967). Fishtail Mesa offers an excellent natural area research site or benchmark for long-term study and surveillance of a pinyon-juniper-sagebrush woodland and sagebrush-mutton grass steppe. Its large size makes it unique. The descriptive historical record begins in the 1930s. Aerial photography is available beginning in 1940. Permanent study areas with fixed photo sites were established in 1958. Our study recorded additional vegetation, soil, and GPS data, prepared rectified maps, and had the participation of the previous, principle ecologist, Don Jameson. Additionally, the 1996 field notes, photographs, records, herbarium specimens, and computerized data spreadsheets are archived in the Grand Canyon National Park's Museum Collections. The data base will receive permanent curatorial care. We hope that future surveys will build upon these efforts to provide further insight into changes in naturally functioning ecosystems of the pinyon-juniper woodland and sagebrush steppe.

RECOMMENDATIONS FOR FUTURE RESEARCH

Vegetation Data Collection

Because the rate of change in this ecosystem is slow, we suggest that a resurvey be completed every 30 years or earlier. However, we recommended that additional studies be conducted in the immediate future to answer questions brought up by this resurvey:

- Slab and date standing dead Utah junipers to determine their age.
- Revisit the site to record grasses in a year following high winter moisture to determine if mutton grass was overestimated and other species were underestimated.
- Collect additional voucher specimens of grasses, joint-fir, antelope bitterbrush, rabbitbrush, and sagebrush species.
- Prepare a better vegetation map using relevé information.
- Collect additional material to confirm the identity of the three unidentified species, thought to be *Coryphantha vivipara* var. *desertii*, *Echinocereus triglochidiatus* aff. var. *toroweapensis*, and *Phacelia* aff. *constancei*.
- Collect and identify the non-vascular plants (i.e., mosses, lichens, and cryptogamic crusts).

Fire History Studies

Additional information to confirm or resolve the history of fire on Fishtail Mesa would be very useful in understanding the role of vegetation succession following fire:

- Search for fire scars, charcoal, and other evidence of wildfire.
- Conduct fire history studies of stumps and snags.
- Determine if a fire had burned in the vicinity of Elbs 1, 4, and 6 as suggested in the 1996 field notes.

Data Collection Design Improvements

The following protocols would improve data collection:

- Use all metric units for measurement (not U.S. customary).
- Determine frequency from line intercept data, deleting the collection of data from the three foot square plots (unless these are to be used for rephotography).
- Establish an additional 400 ft line strip on Elb 8.
- Establish a grazing exclosure to document use of palatable trees, shrubs, and grasses by mule deer.
- Separate the elb arms and treat them as independent sampling units or begin sampling observations at the end of the left (or right) elb arm and continue, contiguously through the origin to the end of the right (left) arm. Be consistent in the pattern of observations thereafter.
- Set up an additional elb in the needle-and-thread (i.e., *Stipa* sp.) grassland in the center of Fishtail Mesa.

Other Studies

To complete an integrated study of the biota of Fishtail Mesa, the following studies would be valuable:

- Determine mule deer use by placing a "deer counter" motion camera on the north end of Fishtail Mesa (north of Elb 5) to record the time and numbers of animals accessing the mesa in the winter months.
- Determine a more accurate mule deer population estimate by using the proper protocols for deer pellet counts (i.e., clear away the deer pellets along the elbs several months prior to field counts).

- Survey the area for other mammalian, reptile, bird, and insect use.
- Inventory the mesa for pre-historic and historic cultural sites. We recorded four sites, one historic and three prehistoric.
- Collect air quality, climate, and meteorological data, such as solar radiation, storm events, wind speed and direction, and relative humidity.
- Determine if elk are utilizing Fishtail Mesa.
- Compare the soil and vegetation of Fishtail Mesa with an analogous area such as Sowats Point.

ACKNOWLEDGMENTS

The resurvey of Fishtail Mesa could not have been accomplished without the interest and enthusiasm of the following individuals. The elb crew consisted of Nancy Brian, Don Jameson, Peter Rowlands, John Spence, and Julie Zimmerman. Donald (Don) Jameson was actively involved, first during the two years of correspondence about the study and then during the week of data collection in May 1996. Don collected all the Parker loop data and answered numerous, daily questions about methodology. He continued to provide advice during data analysis and offered many useful suggestions. His participation, experience, and historical perspective made this resurvey especially meaningful. We were saddened to learn that Don passed away on August 30th, 1998. We are thankful to have had the opportunity to revisit Fishtail Mesa with Don and dedicate this paper to his memory. John Spence, botanist with the Glen Canyon National Recreation Area, contributed a report on the birds and reptiles of Fishtail Mesa. Wendy Hodgson, herbarium curator and research botanist of the Desert Botanical Garden, collected, identified, and documented the flora of the mesa. Julie Zimmerman, biotech with the Rocky Mountain Station, assisted with the elb surveys, pellet counts, and plant collection. Daniel Spotskey, Geographical Information Specialist for the Grand Canyon Science Center, and Tim Dolan, independent consultant, located and flagged the elbs, rephotographed the landscape pictures, collected coordinate data for the mesa perimeter and elbs, identified archeological sites, and collected soil information. Tim also contributed a report on the soils of Fishtail Mesa. We thank both the staff of the Division of Fire and Aviation and Jerry Bonner, pilot of the Bell Long Ranger III helicopter, for logistical support and transportation of people and supplies. We thank David Haskell, Grand Canyon Science Center Director, for funding the helicopter transport. We are indebted to our reviewers Jack Bohning, David E. Brown, Jay Cravens, and Charles Pase who provided comments and suggestions on a draft of this manuscript.

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Appendix 1. Fishtail Mesa elb notes from 1996 field work. Measurements in feet and tenths of feet. See Appendix 2 for translations of scientific names into common names.

Elb 1: A "shrub" elb. Fence post is 28.7 feet from origin. We noted, "Evidence of old burn" in the field notes. Species lists includes: *Juniperus osteosperma*, *Artemisia tridentata*, *Poa fendleriana*, *Yucca baccata*, *Ephedra torreyana*, *Berberis fremontii*, *Ceratoides lanata*, *Chrysothamnus Greenei*, *Hilaria jamesii*, *Xylorhiza tortifolia*, *Eriogonum ovalifolium*, *E. corymbosum*, *Stipa comata*, *Opuntia polyacantha*, *Agropyron* sp., *Atriplex canescens*, *Poa secunda*, *Agave utahensis*, *Erigeron concinnus*, *Castilleja chromosa*, *Echinocereus engelmannii*, *Astragalus newberryi*. Don Jameson noted that deer use was more noticeable than in 1958.

Elb 1 Left: No notes of angle irons at any location. Left elb is to south.

Elb 1 Right: Angle irons at 100.3, 200.0, 299.9, and 400.5. Right elb is to west.

Elb 2: A "shrub" elb. Fence post is 29 feet from origin. Species lists includes: *Sphaeralcea* sp., *Gutierrezia sarothrae*, *Lomatium nevadense* var. *parishii*, *Bromus tectorum*, *Bromus rubens*, *Bouteloua gracilis*, *Oryzopsis hymenoides*, *Echinocereus triglochidiatus* and *E. engelmannii*, *Opuntia polyacantha*, *Pinus edulis*, *Ephedra torreyana*, *Juniperus osteosperma*, *Astragalus calycosus*, *A. newberryi*, *Ceratoides lanata*, *Hymenoxys richardsonii*, *Poa fendleriana*, *Townsendia exscapa*, *Erigeron concinnus*, *Leucelene ericoides*, *Stipa comata*, *Sitanion hystrix*, *Artemisia tridentata*, *Eriogonum corymbosum*, *E. ovalifolium*, *Lesquerella arizonica*, *Phlox longifolia*, *Coleogyne ramosissima*, *Castilleja chromosa*.

Elb 2 Left: Angle irons at 100.2, 200.1, 300.0 and 399.6. *Bromus rubens* starts at 292 feet from origin. Left elb is to northwest.

Elb 2 Right: Angle irons at 200.6 and 300.7. No record of angle irons at 100 and 400. Right elb is to northeast.

Elb 3: A "tree" elb. No fence post present. Species lists includes: *Pinus edulis*, *Artemisia tridentata*, *Shepherdia rotundifolia*, *Poa fendleriana*, *Opuntia polyacantha*, *Ephedra torreyana*, *Juniperus osteosperma*, *Cordylanthus* sp., *Streptanthus cordatus*, *Yucca baccata*. Don Jameson noted *Koeleria cristata* between Elbs 3 and 4.

Elb 3 Left: Angle irons at 100.5, 200.1, 300.1. No record of angle iron at 400. Left elb is to southeast.

Elb 3 Right: Angle irons at 100.5, 200.7, 300.0, and 400.2. Right elb is to southwest.

Elb 4: A "shrub" elb. Fence post is 28 feet from origin. In the vicinity are standing snags without bark within a stand of *Stipa* spp. grassland. Species lists includes: *Artemisia tridentata*, *Poa fendleriana*, *Sitanion hystrix*, *Penstemon pachyphyllus*, *Townsendia exscapa*, *Astragalus calycosus*, *A. pinionis* var. *atwoodii*, *A. newberryi* var. *newberryi*, *Phlox longilobus*, *Coryphantha vivipara*, *Juniperus osteosperma*, *Pinus edulis*, *Ephedra viridis*, *Opuntia polyacantha*, *Streptanthus cordatus*, *Castilleja chromosa*, *Ceratoides lanata*, *Gutierrezia sarothrae*, *Hymenoxys richardsonii*, *Euphorbia fendleri*, *Lesquerella arizonica*.

Elb 4 Left: Angle irons at 100.5, 200.4, 300.0, and 399.10. Left elb is to north.

Elb 4 Right: Angle irons at 100.3, 200.2, and 300.2. No record of angle iron at 400. Right elb is to west.

Elb 5: A "shrub" elb. Note that most of the *Poa* species look to be *Poa longiligula* and that there was minimal grazing of *Poa*. Fence post is 29 feet from origin (I put two deer antlers on the origin stake). Species lists includes: *Artemisia tridentata*, *Juniperus osteosperma*, *Castilleja chromosa*, *Oryzopsis hymenoides*, *Eriogonum corymbosum*, *Poa fendleriana*, *Poa longiligula*, *Ephedra torreyana*, *Astragalus pinionis* var. *atwoodii* (generally noted as "tall and thin" in field notes), *Bromus tectorum*, *Cowana mexicana* var. *stansburiana*, *Opuntia polyacantha*, *Leucelene ericoides*, *Astragalus calycosus*, *Penstemon pachyphyllus*, *Euphorbia fendleri*, *Lomatium nevadense* var. *Parishii*, *Ceratoides lanata*, *Hymenoxys acaulis*, *Streptanthus cordatus*, *Shepherdia rotundifolia*.

Elb 5 Left: Angle irons at 100.5, 200.3, 300.5, and 399.5. Left elb is to southeast.

Elb 5 Right: Angle irons at 99.65, 200.0, and 300.3. No record of angle iron at 400. Right elb is to northeast.

Elb 6: A "tree" elb. We noted that an "old burn" was evident on the last 100 foot section (i.e., 300-400 ft.). Fence post is 33.6 feet from the origin. Species lists includes: *Pinus edulis*, *Juniperus osteosperma*, *Poa fendleriana*, *Cordylanthus* sp., *Artemisia tridentata*, *Hymenoxys richardsonii*, *Astragalus calycosus*, *Coryphantha vivipara*, *Streptanthus cordatus*, *Xylorhiza tortifolia*, *Phoradendron juniperinum*, *Shepherdia rotundifolia*, *Bouteloua gracilis*, *Leucelene ericoides*, *Penstemon pachyphyllus*, *Yucca baccata*. Collected one scat that looked like elk.

Elb 6 Left: Angle irons at 100.2, 300.1, and 400.3. The angle iron was missing from the 200 location. Left elb is to east.

Elb 6 Right: No record of angle irons at any location. Right elb is to south.

Elb 7: A "tree" elb. Fence post is 29 feet from origin. Species lists includes: *Pinus edulis*, *Juniperus osteosperma*, *Artemisia tridentata*, *Ephedra torreyana*, *Yucca baccata*, *Astragalus calycosus*, *Chrysothamnus Greenei*, *Echinocereus triglochidiatus*, *Coryphantha vivipara*, *Bouteloua gracilis*, *Orobancha cf. fasciculata*, *Fallugia paradoxa*, *Eriogonum corymbosum*.

Elb 7 Left: Angle irons at 100.7, 200.6, and 300.7. No record of angle iron at 400. Left elb is to south.

Elb 7 Right: No record of angle irons at any location. Right elb is to west.

Elb 8: A "tree" elb with only one elb. Fence post was down, it was replaced, but no note was made as to distance to origin. Species lists includes: *Artemisia tridentata*, *Yucca baccata*, *Poa fendleriana*, *Ephedra torreyana*, *Bouteloua gracilis*, *Cowania mexicana* var. *stansburiana*, *Coryphantha vivipara*, *Fallugia paradoxa*, *Echinocereus* sp., *Opuntia polycantha*, *Opuntia whipplei*, *Leucelene ericoides*, *Chrysothamnus Greenei*, *Juniperus osteosperma*, *Vulpia octoflora*, *Poa secunda*, *Erigeron concinnus*, *Arceuthobium didvaricatum*. There were many cliff-roses in vicinity, in full bloom, one had four branches (21, 22, 10.5, and 10 cm in diameter each) with a 42 cm diameter at ground level.

Elb 8: Angle irons at 200.5 and 300.4. No record of angle irons at 100 and 400. The elb direction was east to west.

Appendix 2. An alphabetical list by scientific name of plant species from Fishtail Mesa. Synonyms are listed as an equivalent, or earlier taxonomic name. Common names are listed, however when one is not available, this is indicated by "ncn" meaning "no common name." The six letter botanical code is listed under "Acronym." It is made from the first three letters of the genus followed by the first three letters of the species. When the species is not known, this is indicated by spp. Plants reported are listed under the following dates: "1996" is this report, "1958" is Jameson et al. (1962), "1947" is Ellison (1947), "1954" is Cravens and Pase (1954), and "1973" is McCulloch (pers. comm. 1996). "O" means observed and "R" means data reported along an elb in 1996 and 1958. "*" indicates plants also reported from Boysag (Schmutz et al. 1967) and "+" indicates species new to the check-list of plants of Grand Canyon National Park (Phillips et al. 1987).

Species, synonym, and common names:	Acronym	1996	1958	1947	1954	1973
<i>Abronia nana</i> , sand verbena	ABRNAN	O				
<i>Acourtia wrightii</i> (= <i>Perezia wrightii</i>)*, brownfoot	ACOWRI	O				
<i>Actinea</i> sp., actinea (= <i>Hymenoxys acaulis</i>)	ACTSPP				O	
<i>Agave utahensis</i> var. <i>utahensis</i> *, Utah century plant	AGAUTA	O	O		O	
<i>Allium</i> sp., onion	ALLSPP		R			
<i>Agropyron smithii</i> , western wheatgrass	AGRSMI	O				
<i>Amelanchier utahensis</i> , Utah serviceberry	AMEUTA	O	O		O	
<i>Arabis perennans</i> , rock cress	ARAPER	R	O			
<i>Arceuthobium divaricatum</i> , pinyon dwarf mistletoe	ARCDIV	R				
<i>Aristida</i> sp., three-awn	ARISPP				O	
<i>Artemisia bigelovii</i> *, sagebrush	ARTBIG		O			
<i>A. ludoviciana</i> *, sagebrush	ARTLUD		O		O	
<i>A.</i> sp., sagebrush	ARTSPP			O		
<i>A. tridentata</i> *, big sagebrush	ARTTRI	R	R		O	
+ <i>Astragalus argophyllus</i> var. <i>panguicensis</i> , milk vetch	ASTARG	O				
<i>A. calycosus</i> , Gray locoweed	ASTCAL	R	R			O

<i>A. newberryi</i> var. <i>newberryi</i> , Newberry milk-vetch	ASTNEW	R				
+ <i>A. pinonis</i> var. <i>atwoodii</i> , milk- vetch	ASTPIN	R				
<i>A. sp.</i> , milk-vetch	ASTSP2		O	O	O	
<i>Aster</i> spp., aster	ASTSP1		R	O		
<i>Atriplex canescens</i> *, four-wing salt- bush	ATRCAN	R	R	O		
<i>Berberis fremontii</i> , Fremont barberry	BERFRE	O	O	O	O	
<i>Bouteloua eriopoda</i> *, black grama	BOUERI		O			
<i>B. gracilis</i> , blue grama	BOUGRA	R	R	O	O	
<i>Brickellia atratyloides</i> *, ncn	BRIATR	O				
<i>Bromus rubens</i> , red brome	BRORUB	O	R			
<i>B. tectorum</i> , downy chess	BROTEC	O		O		
<i>Calochortus nuttallii</i> , mariposa lily	CALNUT	O				
<i>Castilleja chromosa</i> *, Indian paint brush	CASCHR	R	R	O		
<i>C. sp.</i> , Indian paint brush	CASSPP				O	
<i>Ceanothus</i> sp., buck brush	CEASPP				O	O
<i>Ceratoides lanata</i> * (= <i>Eurotia</i> <i>lanata</i>), winter fat	CERLAN	R	R	O	O	
<i>Chrysothamnus Greenei</i> *, Greens rabbit brush	CHRGRE	R				
<i>C. viscidiflorus</i> , sticky-leaved rabbit brush	CHRVIS	O				
<i>C. sp.</i> , rabbit brush	CHRSPP			O	O	O
<i>Cirsium</i> sp., thistle	CIRSPP	O				
<i>Coleogyne ramosissima</i> *, black brush	COLRAM	R	R			
<i>Cowania mexicana</i> var.	COWMEX	R	R	O	O	

<i>stansburiana</i> * (= <i>Purshia mexicana</i> var. <i>stansburyi</i>), cliff-rose						
<i>Cordylanthus</i> sp. *, bird beak	CORSPP	O				O
<i>Coryphantha vivipara</i> var. <i>arizonica</i> , Pincushion cactus	CORVIV	R	R	O		
<i>Cryptantha confertiflora</i> , golden cryptantha	CRYCON	O				
<i>C. flava</i> , ncñ	CRYFLA		O			
<i>C. pterocarya</i> , wing nut cryptantha	CRYPTTE		O			
<i>Delphinium nelsoni</i> forma <i>pinetorum</i> , larkspur	DELNEL	O		O		O
<i>Descurainia pinnata</i> *, yellow tansy mustard	DESPIN		R			
<i>Draba cuneifolia</i> , whitlow grass	DRACUN		R			
<i>D. sp.</i> , ncñ	DRASPP			O		
<i>Echinocactus polycephalus</i> var. <i>xeranthemoides</i> , many-headed barrel cactus	ECHPOL	O				
+ <i>Echinocereus engelmannii</i> var. <i>chrysocentrus</i> , hedgehog cactus	ECHENG	O		O?		
<i>E. triglochidiatus</i> (var. <i>melanocanthus</i> & aff. var. <i>toroweap-ensis</i>), hedgehog cactus	ECHTRI	R	O			
<i>Elymus</i> sp. * (<i>E. salinus</i> ?), wild rye	ELYSPP		R		O	
<i>Ephedra torreyana</i> *, Torrey joint-fir	EPHTOR	R				
<i>E. viridis</i> , mountain joint-fir	EPHVIR		R	O		
<i>Erigeron concinnus</i> * (= <i>E. pumilus</i> ssp. <i>concinoides</i> var. <i>condensatus</i>), tidy fleabane	ERICON	R	R	O		
<i>Eriogonum corymbosum</i> *, wild buckwheat	ERICOR	R				
<i>E. fasciculatum</i> , wild buckwheat	ERIFAS		R		O	
<i>E. inflatum</i> , inflated wild buckwheat	ERIINF	O				

<i>E. ovalifolium</i> var. <i>vineum</i> *, oval-leaved buckwheat	ERIOVA	O	O	O		
<i>E. sp.</i> , wild buckwheat	ERISP1	O		O		
<i>Erodium cicutarium</i> *, filaree	EROCIC			O		O
<i>Euphorbia fendleri</i> var. <i>chaetocalyx</i> , Fendler spurge	EUPFEN	R				
<i>Fallugia paradoxa</i> *, Apache plume	FALPAR	R	R	O	O	
<i>Fendlera rupicola</i> *, Fendlerbush	FENRUP	O				
<i>Fendlerella utahensis</i> *, ncn	FENUTA	O				
<i>Fraxinus cuspidata</i> ssp. <i>macropetala</i> , fragrant ash	FRACUS	O			O	
<i>Galium watsonii</i> (= <i>G. multiflorum</i> var. <i>multiflorum</i>), bedstraw	GALWAT	O				O
<i>Gilia simuata</i> , Gilia	GILSIN		R	O		
<i>Grimmia sp.</i> , moss	GRISPP			O		
<i>Gutierrezia sarothrae</i> *, snake weed	GUTSAR	R	R	O	O	
<i>Hilaria jamesii</i> , galleta	HILJAM		O		O	
<i>Hymenoxys acaulis</i> , Arizona actinea	HYMACA	O	O			
<i>Hymenoxys cooperi</i> , ncn	HYMCOO		R			
<i>H. richardsonii</i> var. <i>floribunda</i> , pinque	HYMRIC	R				
<i>Ipomopsis aggregata</i> (= <i>Gilia aggregata</i>), sky rocket	IPOAGG	O				
<i>Juniperus osteosperma</i> , Utah juniper	JUNOST	R	R	O	O	
<i>Koeleria cristata</i> , June grass	KOECRI	O			O	
<i>Lappula redowskii</i> , stickseed	LAPRED		R			
<i>Lesquerella arizonica</i> , bladder pod	LESARI	R		O		
<i>L. gordonii</i> *, Gordon bladderpod	LESGOR		R			
<i>Leucelene ericoides</i> (= <i>Chaeto-</i>	LEUERI	R	R			

<i>pappa ericoides</i>), white aster						
<i>Lomatium macdougalii</i> , wild parsley	LOMMAC		R			
<i>L. nevadense</i> var. <i>parishii</i> *, Parish wild parsley	LOMNEV	R		O		
<i>Lotus</i> sp., deer vetch	LOTSPP		R			O
<i>Machaeranthera grindelooides</i> aff. var. <i>depressa</i> , ncn	MACGRI	O				
<i>Mammillaria</i> sp.*, fishhook cactus	MAMSPP		R		O	
<i>Mentzelia albicaulis</i> *, small-flowered blazing star	MENALB	O	O			
<i>Mirabilis multiflora</i> *, Colorado four o'clock	MIRMUL	O				
<i>Nolina</i> sp. aff. <i>microcarpa</i> , beargrass	NOLSPP	O				
+ <i>Oenothera caespitosa</i> var. <i>crinita</i> , evening primrose	OENCAE	O				
<i>Opuntia chlorotica</i> , pancake pear	OPUCHL	O				
<i>O. erinacea</i> var. <i>utahensis</i> * (=O. <i>pinkavae</i>), porcupine prickly pear	OPUERI	O				
<i>O. polycantha</i> , prickly pear	OPUPOL	R	R	O	O	O
<i>O. whipplei</i> *, Whipple cholla	OPUWHI	O	R			
<i>Orobanche</i> sp., broom rape	OROSPP	O		O		
<i>Oryzopsis hymenoides</i> *, Indian ricegrass	ORYHYM	R	R	O	O	
<i>Penstemon eatoni</i> var. <i>undosus</i> , Eaton firecracker	PENEAT	O				
<i>P. bridgesii</i> (= <i>P. rothrockii</i>), beard tongue	PENBRI	O				
<i>P. pachyphyllus</i> var. <i>congestus</i> , beard tongue	PENPAC	R				O
<i>P.</i> sp., beard tongue	PENSPP		R	O	O	O
<i>P. utahensis</i> , Utah firecracker	PENUTA		O			

<i>Perityle congesta</i> , rock daisy	PERCON	O				
<i>Phacelia corrugata</i> , ncn	PHACOR		O			
<i>Philadelphus</i> sp., mock orange	PHISPP				O	
<i>Phlox austromontana</i> , phlox	PHLAUS	O				
<i>P. longifolia</i> , phlox	PHLLON	R		O		
<i>P. sp.</i>	PHLSPP		R			
<i>Phoradendron juniperinum</i> , mistletoe	PHOJUN	R				O
<i>Pinus edulis</i> *, pinyon pine	PINEDU	R	R	O	O	O
<i>Poa fendleriana</i> * (includes <i>P. longiligula</i>), mutton grass	POAFEN	R	R			
<i>P. secunda</i> , Sandberg bluegrass	POASEC	O	R	O		
<i>Polygala rusbyi</i> , milk wort	POLRUS		R			
<i>Polygala</i> sp., milk wort	POLSPP	O				
<i>Ptelea trifoliata</i> ssp. <i>pallida</i> , hop tree	PTETRI	O				
<i>Rhus trilobata</i> *, squaw bush	RHUTRI				O	
<i>Rosa stellata</i> ssp. <i>abyssa</i> , Grand Canyon rose	ROSSTE	O				
<i>Shepherdia rotundifolia</i> *, round leaf buffalo berry	SHEROT	R	R	O	O	
<i>Sitanion hystrix</i> *, squirrel tail	SITHYS	R	R	O	O	
<i>Sphaeralcea grossulariaefolia</i> , globe mallow	SPHGRO	R	O	O	O	
<i>S. parvifolia</i> *, globe mallow	SPHPAR		O			
<i>Sporobolus cryptandrus</i> *, sand dropseed	SPOCRY		R			
<i>Stanleya pinnata</i> , prince's plume	STAPIN	O				
<i>Stipa comata</i> *, needle-and- thread	STICOM	R	O	O	O	
<i>S. speciosa</i> *, desert needlegrass	STISPE	R	R		O	

<i>S. sp.</i> , needlegrass	STISPP	R			O	O
<i>Streptanthus arizonicus</i> , twist flower	STRARI		R	O		
<i>S. cordatus</i> , twist flower	STRCOR	R				O
<i>Symphoricarpus sp.</i> , snowberry	SYMSP				O	
<i>Townsendia exscapa</i> , ncñ	TOWEXS	O				
<i>T. sp.</i> , ncñ	TOWSP		R			
<i>Vulpia octoflora</i> * (= <i>Festuca octoflora</i>), six-weeks fescue	VULOCT	R				
<i>Xylorhiza tortifolia</i> var. <i>imberbis</i> (= <i>Machaeranthera tortifolia</i> var. <i>imberbis</i>), Mohave aster	XYLTOR	O				
<i>Yucca baccata</i> *, banana yucca	YUCBAC	R	R	O	O	

Appendix 3. Absolute cover (in inches and tenths of inches) for each elb in 1996 by left (L) and right (R) sides. Elbs 1-4 are presented by plants species in part 3A, followed by Elbs 5-8 and the sum for all elbs in part 3B. Relative and absolute cover percentages are also presented in 3B.

3A.

Common Names of Plants	Elbs 1 through 4 (Left and Right)							
	1-L	1-R	2-L	2-R	3-L	3-R	4-L	4-R
Sagebrush	70.60	90.95	61.11	71.39	67.31	72.94	99.86	87.57
Wild buckwheat	0.93	1.82	0.16	0.01				0.35
Mutton grass	8.28	6.80	6.63	12.82	3.03	4.58	8.93	6.14
Four-wing saltbush	0.60	0.01						
Prickly pear	1.55	2.18	0.55		1.60	2.35		0.25
Needle-and-thread	4.49	0.36						
Squirrel tail	3.07	0.27		1.03		0.17	0.43	
Snakeweed	5.82			1.02				0.25
Gray locoweed	0.16		0.02	0.10	0.01	0.01	0.18	0.16
Torrey joint-fir	3.57	2.24	0.46	0.19	3.80	0.34	3.05	1.76
Twist flower	0.01			1.41		0.01		0.05
Indian paintbrush	0.01				0.01			
Newberry milk-vetch	0.01			0.17				0.14
Desert needlegrass		0.64						
Winter fat		0.73	0.60				0.35	
Pinque		0.01		0.08			0.21	
Greens rabbit brush		2.95						
Blue grama			0.95					
Parish wild parsley			0.26					
Globe mallow			0.11					
Indian ricegrass			0.01					
Black brush				1.46				
Tidy fleabane				0.01				
Rock cress				0.01				
Pinyon					52.90	50.18		13.30

Round leaf buffalo berry					3.30	4.67		
Bladder pod					0.15	T		
Utah juniper					11.05	19.53	0.17	
Pinyon milk- vetch						0.01	0.18	2.55
Phlox							0.24	
White aster								0.55
Fendler spurge								
Beard tongue								
Hedgehog cactus								
Cliff rose								
Mistletoe								
Banana yucca								
Pinyon dwarf mistletoe								
Apache plume								
Pincushion cactus								

3B.

Common Names of Plants	Elbs 5 through 8 (Left and Right)							Sum of Cover for Elbs 1 - 8	Rela- tive Cover	Abso- lute Cover
	5-L	5-R	6-L	6-R	7-L	7-R	8			
Sagebrush	62.98	70.22	31.99	27.98	9.98	19.97	46.82	891.67	48.24	14.86
Wild buckwheat	0.02	0.04				0.14		3.47	0.19	0.06
Mutton grass	20.49	13.41	7.92	10.25	16.62	16.46	11.53	153.89	8.33	2.56
Four-wing saltbush								0.61	0.03	0.01
Prickly pear	0.40	0.17	2.15	0.16	0.22	0.14	0.29	12.00	0.65	0.2
Needle-and- thread								4.86	0.26	0.08
Squirrel tail			0.01					4.98	0.27	0.08
Snakeweed								7.10	0.38	0.12
Gray locoweed	0.12	0.05	0.06	0.24		0.19		1.31	0.07	0.02
Torrey joint-fir	3.44	1.36	0.12	0.02	1.69		4.39	26.46	1.43	0.44
Twist flower								1.49	0.08	0.02
Indian paintbrush								0.02	0.001	0.0003
Newberry milk- vetch								0.31	0.02	0.01
Desert needlegrass								0.64	0.03	0.01
Winter fat								1.68	0.09	0.03
Pinke		0.25		0.01				0.56	0.03	0.01

Greens rabbit brush				0.12				3.07	0.17	0.05
Blue grama			0.89	1.17	0.26	0.20	46.86	50.33	2.72	0.84
Parish wild parsley								0.26	0.01	0.004
Globe mallow								0.11	0.006	0.002
Indian ricegrass	0.02							0.04	0.002	0.0007
Black brush								1.46	0.08	0.02
Tidy fleabane								0.01	0.0005	0.0002
Rock cress								0.01	0.0005	0.0002
Pinyon			17.80	58.54	74.13	59.21	6.08	332.14	17.97	5.54
Round leaf buffalo berry			4.15					12.12	0.66	0.2
Bladder pod								0.15	0.008	0.003
Utah juniper		3.25	34.40	56.95	91.37	33.30	19.35	269.36	14.57	4.49
Pinyon milk-vetch	0.94	0.17		0.18	0.12	0.11		4.25	0.23	0.07
Phlox				0.01				0.25	0.01	0.004
White aster		0.38		0.01				0.94	0.05	0.02
Fendler spurge	0.10							0.10	0.005	0.001
Beard tongue		0.08						0.08	0.004	0.001
Hedgehog cactus			0.40					0.40	0.02	0.007
Cliff rose			3.10	0.55	0.68			4.33	0.23	0.07
Mistletoe			0.65	4.17				4.82	0.26	0.08
Banana yucca			7.97	3.71	7.00		29.89	48.57	2.63	0.81
Pinyon dwarf mistletoe				0.01				0.01	0.0005	0.0001
Apache plume							4.13	4.13	0.22	0.07
Pincushion cactus							0.43	0.43	0.23	0.01
Subtotal	88.52	89.37	111.6	164.0	202.1	129.7	169.8	1848.42		

Appendix 4. Summary of 1996 Parker loop data for shrub and tree types.

Elbs	Bare Ground	Litter	Rock	Subtotal	Plants	Total
1-L (shrub)	286	14	0	300	100	400
1-R (shrub)	275	13	0	288	113	401
2-L (shrub)	297	24	2	232	77	400
2-R (shrub)	259	46	2	307	94	401
4-L (shrub)	238	30	0	268	132	400
4-R (shrub)	254	1	0	255	145	400
5-L (shrub)	288	13	0	301	103	404
5-R (shrub)	256	20	0	276	126	402
Sum Shrub-type (% cover)	2153 (67.11)	161 (5.02)	4 (0.12)	2318 (72.26)	890 (27.74)	3208 (100)
3-L (tree)	228	32	1	261	142	403
3-R (tree)	230	33	0	263	145	408
6-L (tree)	261	15	0	276	131	407
6-R (tree)	224	6	0	230	199	429
7-L (tree)	230	4	0	234	179	413
7-R (tree)	251	3	0	254	157	411
8 (tree)	270	20	0	290	118	408
Sum Tree-type (% cover)	1694 (58.84)	113 (3.92)	1 (0.03)	1808 (62.8)	1071 (37.2)	2879 (100)
Sum All Elbs	3847	274	5	4126	1961	9087
Total % Cover	63.2	4.5	0.08	67.78	32.22	100

Appendix 5A. Summary of percent frequency by plant species in three foot square plots for shrub type elbs by left and right sides of elbs.

Species	1-L	1-R	2-L	2-R	4-L	4-R	5-L	5-R	Sum	% Frequency
Mutton grass	4	3	4	3	4	4	4	4	30	94
Sagebrush	4	3	4	3	3	3	3	2	25	78
Milk-vetch	1	2	1	1	4	3	5	5	22	69
Wild buckwheat	2	2	1	2		3		1	11	34
Prickly pear		1	1			1	1		4	13
Torrey joint-fir		1		1				1	3	9
Pinque	1	1				1			3	9
Beard tongue					2				2	6
Indian ricegrass	1								1	3
Blue grama			1						1	3
Winter fat			1						1	3
Wild parsley			1						1	3
Fendler spurge							1		1	3
Phlox					1				1	3
Red brome			1						1	3
Indian paintbrush								1	1	3
Townsendia					1				1	3

Appendix 5B. Summary of percent frequency by plant species in three foot square plots for tree type elbs by left and right sides of elbs.

Species	3-L	3-R	6-L	6-R	7-L	7-R	8	Sum	% Frequency
Mutton grass	4	3	3	3	4	3	4	24	86
Sagebrush	3	1	2	2		2	1	11	39
Milk-vetch		1	1	1	1	1	1	6	21
Prickly pear	1		1	1		1	1	5	18
Torrey joint-fir	1		1		1		1	4	14
Bladderpod	2	1						3	11
Six-weeks fescue							2	2	7
Blue grama			1				1	2	7
Pinyon pine	1	1						2	7
Pinque	1	1						2	7
Squirrel tail	1						1	2	7
Pincushion cactus							1	1	4
Downy chess	1							1	4
Bird beak	1							1	4
Snakeweed	1							1	4

Appendix 6. Tree-ring data for 42 pinyon and one cliff-rose on Fishtail Mesa in 1996. “^” indicates cross sectional slabs and “*” indicates no center pith.

Elb No.	Tree No.	No. Radial Rings (=estimated age in years)	Basal Diameter (cm)	Height (m)
1	1^	20	3.0	1.03
	2	56*	13	2.78
	3	35	10	2.38
	4	105*	25	5.2
	5	140*	25	4.1
2	1	136	18.5	3.55
	2	150	27.0	5.55
	3	70	4.8	2.8
	4	244	17.5	4.0
	5^	43	4.0	1.25
3	1	135	17.1	3.05
	2	120*	12.0	3.1
	3	328	28.4	4.75
	4	89	10.7	3.1
	5^	28	2.2	0.78
	6	57	5.0	1.63
4	1	50	11.5	2.9
	2	95	30.0	3.7
	3	358*	51.0	5.5
	4	34*	6.5	2.18
	5	32	8.0	2.5
5	1	58	12.5	3.1
	2	25*	15.4	3.35
	3^	18	1.4	0.61
	4	42*	22.0	4.83
	5^	21	5.0	1.30
6	1	98	14.8	5.5

	2^	50	4.2	1.33
	3	46	7.7	2.5
	4	64	12.0	3.1
	5	214	23.9	5.24
7	1	103*	21.0	5.5
	2	73	8.0	2.7
	3	384*	37.2	5.7
	4	262*	21	4.4
	5^	45	2.8	0.90
8	1	189	37	6.1
	2	140*	30.2	5.3
	3	66	15.0	4.05
	4	57	15.0	2.2
	5^	29	4.5	1.35
8	Cliff-rose	72	21	4.2

Appendix 7. Elb 3L data for “bubble diagram” (Figure 11) for pinyon, juniper, and snag x- and y-coordinates with diameter(s) at one foot above ground level and canopy spread. Negative y-coordinates indicates trees to the right of the elb when viewed from the origin, while positive y-coordinates indicates trees to the left of the elb when viewed from the origin.

Tree Species	X-Coordinate (ft)	Y-Coordinate (ft)	Height (m)	Basal Diameter (cm)	Canopy Diameter (m)
Pinyon	351.6	-2.8	0.56	1.3	0.45
Pinyon	105.0	2.4	1.2	3.1	0.9
Pinyon	77.5	-3.5	1.25	3.4, 2.5	0.75
Pinyon	376.0	1.5	1.4	3.8	0.55
Utah juniper	344.3	5.0	1.25	3.8	0.6
Pinyon	376.4	1.5	1.3	3.9	0.6
Pinyon	106.7	0.8	1.75	4.4	1.25
Pinyon	271.2	3.0	1.45	4.7	0.85
Pinyon	262.6	4.8	1.4	5.0	1.35
Pinyon	395.0	-3.2	1.5	5.3	1.1
Pinyon	74.6	2.0	1.8	5.6	1.3
Pinyon	97.4	-4.1	2.3	7.6, 7.3	2.0
Pinyon	102.8	0.9	1.45	8.5	1.8
Pinyon	120.2	-2.4	1.95	9.1	1.75
Utah juniper	307.5	-5.7	1.72	9.3	1.4
Pinyon	178.8	1.3	1.93	10.2	1.9
Pinyon	163.6	-8.5	2.7	12.2	1.65
Pinyon	398.5	2.2	3.3	13.3	2.3
Pinyon	70.0	6.6	2.41	14.7	2.15
Pinyon	65.0	-3.6	3.47	14.8	2.35
Pinyon	29.8	3.1	2.7	15.0	2.25
Pinyon	160.0	-5.0	4.1	16.7	2.7
Utah juniper	160.6	-6.8	3.45	19.0	1.1
Pinyon	140.7	-4.7	4.75	22.3	4.1
Utah juniper	396.7	-7.8	2.5	23.3	2.0
Pinyon	101.0	9.5	3.6	23.6	3.6
Utah juniper	102.0	9.6	2.2	27.0	1.4
Pinyon	346.5	5.9	2.9	30.2	3.8
Utah juniper	397.6	-1.9	3.15	30.5	1.0
Pinyon	174.4	8.0	4.6	31.8	5.0
Utah juniper	204.3	3.4	3.25	33.7	1.9
Utah juniper	163.6	-3.9	3.17	38.4	2.3
Snag	390.2	-7.8	2.7	24.5, 11.6, 19.7	
Snag	264.6	-3.2	1.75	26.6	
Snag	74.4	0.5	2.2	34.0	
Snag	170.8	6.2	1.5	14.1, 9.4	

Appendix 8. Alphabetical list of fauna from Fishtail Mesa observed during May 1996 with habitat, abundance, and status notes. Codes notes are Habitat: PJ = pinyon-juniper woodland; SM = sagebrush-mutton grass meadows; RC = rocky outcrops and cliff margins; AO = aerial over flight; Abundance: R = rare or 1; F = few or 2-4; C = common or 5-9; A = abundant or 10-49; U = ubiquitous or very common or 50-100; Bird Status: SR = summer resident (probably breeds); MI = migrant; WR = winter resident; PR = permanent resident (probably breeds). Other: Mc = wildlife also noted by McCulloch (1973), B = Beymer (1984), K = Klopatek (1984), ? = questionable or unconfirmed observation.

Species	Habitat	Abundance	Bird Status	Other
Birds:				
Ash-throated Flycatcher	PJ	A	SR	
Bewick's Wren	PJ	A	PR	
Black-chinned Hummingbird	PJ	C	SR	Mc
Black-throated Gray Warbler	PJ	U	SR	
Black-throated Sparrow	SM	C	SR	
Blue-gray Gnatcatcher	PJ	A	SR	
Brewer's Sparrow	SM	A	SR	
Broad-tailed Hummingbird	PJ	C	MI	
Brown-headed Cowbird	PJ	F	SR	
Bushtit	PJ	A	PR	
Canyon Wren	RC	R	PR	
Chipping Sparrow	PJ	C	SR	Mc
Chukar	SM/PJ	R	PR	Mc
Common Poorwill	SM	R	SR	Mc
Common Raven	AO	F	PR	Mc
Cordilleran Flycatcher	PJ	F	MI	
Gray Flycatcher	PJ	A	SR	
Green-tailed Towhee	PJ	F	SR	Mc
House Finch	PJ	C	SR	
Lark Sparrow	SM/PJ	A	SR	
Mountain Chickadee				Mc

Mourning Dove	PJ	F	SR	Mc
Nashville Warbler	PJ	R	MI	
Northern Flicker (feathers only)	PJ	R	WR	
Northern Mockingbird	PJ/SM	F	SR	
Peregrine Falcon	AO	R	PR	
Pinyon Jay	PJ	U	PR	Mc
Plain Titmouse	PJ	A	PR	
Red-tailed Hawk	AO	R	PR	
Ruby-crowned Kinglet	PJ	F	MI	
Say's Phoebe	PJ/SM	C	SR	
Spotted Towhee	PJ	A	SR	Mc
Turkey Vulture	AO	F	SR	
Violet-green Swallow	AO	A	SR	
Western Bluebird (feathers only)	PJ	R	WR	
Western Screech-owl	PJ/RC	R	PR	
Western Scrub Jay	PJ	C	PR	
Western Tanager	PJ	F	MI?	
White-throated Swift	AO	A	SR	Mc
Yellow-headed Blackbird				Mc
Reptiles:				
Collared Lizard (<i>Crotaphytus collaris</i>)	PJ/SM	F		
Eastern Fence Lizard (<i>Sceloporus undulatus</i>)	PJ	C		
Grand Canyon Rattlesnake (<i>Crotalus viridis</i> ssp. <i>abyssus</i>)	RC	R		B, K
Plateau Striped Whiptail (<i>Cnemidophorus velox</i>)	PJ	C		
Sagebrush Lizard (<i>Sceloporus graciosus</i>)	SM	F		
Side-blotched Lizard (<i>Uta stansburiana</i>)	SM	R		
? Black-headed Snake (<i>Tantilla sp.</i>) ¹	RC	R		

¹Species may be *T. hobartsmithii* or *T. utahensis*.

Mammals:				
? American badger (<i>Taxidea taxus</i>)				Mc?
Bats (species not identified)	AO	?		B
Bobcat (<i>Lynx rufus</i>)	-Scat PJ	R		
Coyote (<i>Canus latrans</i>)	-Scat PJ	R		Mc
? Elk (<i>Cervus canadensis</i>)	-Scat PJ	R		B
Gray fox (<i>Urocyon cinereoargenteus</i>)	-Scat PJ	R		Mc
Mountain lion (<i>Felis concolor</i>)	-Scat PJ	R		
Mule deer (<i>Odocoileus hemionus</i>)	-Scat PJ/SM	A		Mc, B, K
? White-tailed antelope squirrel (<i>Ammospermophilus leucurus</i>)	-seen SM	F		
Insects:				
Giant hairy scorpion (<i>Hadrurus spadix</i>)	SM	R		B
Small green thrips?	SM	A		
Velvet Ant (<i>Mutillidae</i>)	SM	R		

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