# CHAPTER VIII

# HAS THE SYSTEM BEEN AT EQUILIBRIUM BETWEEN 1800 AND 1990?

## PART 1: PHOTOGRAPHIC EVIDENCE

### INTRODUCTION

I previously discussed the somewhat ambivalent argument, contained in the case made for "natural regulation," regarding the equilibrium status and trend of the biota on Yellowstone's northern range. The northern Yellowstone elk population is assumed to have numbered 12,000-15,000 animals far back into prehistory, to have co-evolved with the rest of the biota, and to have achieved an equilibrium with it (see Chapter 1 above). Hence, the large number of elk in the park since its establishment is assumed, by the Park Service, to be no different from the numbers prevailing in prehistory, and by implication the state of the vegetation and other components of the biota today also reflect pre-1872 conditions.

In previous chapters I argued that there is no evidence supporting the hypotheses that historical vegetation changes have been primarily caused by fire suppression, climate change, or normal plant succession. Furthermore, the contemporary differences between vegetation inside and outside the park, and inside and outside Greater Yellowstone ecosystem exclosures, can only be attributed to differences in ungulate use.

In this chapter I will present photographic evidence which gives some indication of the magnitude of vegetation change during the park's history, as well as some sense of the nature of the vegetation during the 1800s and early 1900s. This will test the assumptions that the conditions prevailing today resemble those of 1872 and that contemporary elk numbers are similar to those present when the park was established. In the two following chapters, I will present other lines of evidence testing this elk-numbers assumption.

# RESULTS AND DISCUSSION

## Aspen

I made 61 repeat photosets of aspen communities on Yellowstone's northern range which I divided into three time periods based on the date of the first photograph (Table 50). Comparison of pictures taken from 1880-1910 with my 1986-88 retakes shows an estimated 96% decline in the area occupied by aspen over this time period (Figs. 18 and 19). Comparison of images made during 1911-1949 with my 1986-88 retakes indicates a 92% decline in aspen over that interval. Comparison of photographs taken from 1950 to 1965 with my retakes shows an estimated decrease of 84% in the latter half of this century.

On photos where individual stems could be counted, I compared the number of trees in the original photos with those shown in my retakes. From the 1920s to 1988, aspen trees declined at an average yearly rate of almost 9%. From the 1960s to 1988, the average yearly rate of decline was slightly more than 7%.

Of Kittams' 20 aspen photo-plots (Fig. 4), I was able to locate his steel stakes at 16 sites while two were marked with wooden stakes. I located the remaining two photo sites using the background features on the original pictures. Hence, I was able to obtain 1988 repeat photographs for all Kittams' plots. Since Kittams' pictures were close-up views of aspen stands, I was able to count the number of live aspen trees in his 1947 photos and to compare those figures with the number of aspen alive in 1988. At Kittams' photo-plots, the number of live aspen trees declined an average of 85% from 1947 to 1988, at an average annual rate of 4.6% (Table 51). Clearly the magnitude of the decline in aspen on Yellowstone's northern range is much greater than the 50% previously reported by the Park Service (Houston 1982, see also Chapters 3 and 4 above). The repeat photos also indicate that stands in the park have not successfully regenerated for at least the last 80 years.

Based on 100 sample plots in Jackson Hole's upper Gros Ventre

Table 50. Decline of aspen on Yellowstone's northern range as disclosed by comparing the estimated area occupied by aspen in early and 1986-88 repeat photographs.

| Date of first photo in set | Number of photo sets | Number of stands in first photo | Estimated mean (SEM) percent decline of aspen, first date to 1988 | Percent of original aspen clones with > 10% conifer canopy-coverage in retake |
|---|---|---|---|---|
| 1880 - 1910 | 13 | 20 | 96% (1.3%) | 84% |
| 1911 - 1949 | 37 | 47 | 92% (1.9%) | 57% |
| 1950 - 1965 | 11 | 19 | 84% (3.7%) | 5% |
| Totals | 61 | 86 | | |

Fig. 18. Repeat photoset of two aspen stands on Yellowstone's northern range northeast of Tower Junction. (a) The dense aspen regeneration in this ca. 1890 photo is not high-lined and does not show any evidence of ungulate browsing. Based on the standing snags and lack of sagebrush, it appears this site burned 10-15 years prior to when this photograph was taken. Older conifers, mainly Douglas fir, have had their lower branches removed or killed by fire (see text). According to Houston (1976b:252), "Fire scarred trees cut in this area suggest a historic fire frequency of one fire every 20-25 years for the past 300-400 years." Photograph by J.P. Iddings (No. 152), U.S. Geological Survey, Denver. (b) That same area approximately 100 years later in 1989. Aspen trees are not visible in this photo though a few aspen suckers < 1m tall are still present. Douglas fir has increased and sagebrush now dominates the grassland. This area has not burned since the earlier photo and thus, the lower branches on these conifers could not have been killed by light ground fires. Instead, all conifers must have been high-lined by elk. Charles Kay photo No. 3,272-1, 8/28/89. A similar photoset appears in Houston (1982:316-317) and Despain et al. (1986:93).

a.

b.

Fig. 19. Repeat photoset of aspen above Rainy Lake on Yellowstone's northern range southeast of Tower Junction. (a) Based on the standing snags and height of the regenerating aspen in this ca. 1890 photo, it appears that this site burned 10-15 years prior to when this photograph was taken. The aspen and regenerating conifers, mostly Douglas fir, show no signs of high-lining nor evidence of ungulate browsing. Older conifers have had their lower branches killed by fire since the high-line height is variable and some conifers have had their lower branches removed higher than elk can browse (see text). According to Houston (1976b:264), "A fire-scarred tree cut within 40 yards of the camera point showed fire dates of 1876±, 1840±, 1810±, and several earlier fires." Photograph by J.P. Iddings (No. 148), U.S. Geological Survey, Denver. (b) That same area approximately 100 years later in 1989. Though difficult to see in the retake, one aspen tree is still alive in the center of the photo. Logs in left center are dead aspen. Douglas fir has increased on this site which has not burned since the earlier photo. Thus, the lower branches on the regenerating conifers could not have been killed by fire. Instead, all conifers have been extensively high-lined by elk. Charles Kay photo No. 3,166-31, 5/26/89.

a.

b.

Table 51. Changes in aspen stands shown in Kittams' 1947 photo plots on Yellowstone's northern range (see Fig. 4), based on 1988 repeat photographs.

| Kittams' photo plot | Number of aspen > 2m 1947 | Number of aspen > 2m 1988 | Percent decline | Conifer which invaded original stand | Estimated conifer canopy cover in 1988 | Vegetation which replaced aspen since 1947 |
|---|---|---|---|---|---|---|
| 1A | 72 | 0 | 100 | None | None | river birch |
| 2A | 76 | 0 | 100 | PSME** | < 10% | grass |
| 3A | 5 | 0 | 100 | PSME | 90% | conifers |
| 4A* | 20 | 16 | 20 | PICO | 50% | conifers |
| 5A | 20 | 1 | 95 | None | None | grass - sagebrush |
| 6A | 2 | 0 | 100 | PSME | < 5% | grass - sagebrush |
| 7A | 72 | 25 | 60 | None | None | grass |
| 8A | 1 | 0 | 100 | None | None | grass |
| 9A | 80 | 20 | 75 | None | None | grass |
| 10A | 16 | 2 | 88 | None | None | grass |
| 11A | 100 | 0 | 100 | PSME | < 1% | grass - sagebrush |
| 12A* | 10 | 2 | 80 | None | None | grass - sagebrush |
| 13A* | 42 | 9 | 79 | None | None | grass |
| 14A* | 27 | 9 | 66 | None | None | grass |
| 15A* | 80 | 13 | 84 | None | None | grass |
| 16A* | 43 | 17 | 60 | PICO | 50% | conifers |
| 17A | 25 | 0 | 100 | PIEN | < 10% | grass - sagebrush |
| 18A* | 40 | 2 | 95 | PICO | 80% | conifers |
| 19A | 20 | 1 | 95 | PSME | < 10% | grass - sagebrush |
| 20A | 40 | 2 | 95 | JUSC | 80% | juniper |
| Totals | 791 | 119 | 85 | | | |

* Burned by the 1988 wildfires after being rephotographed for this study.

** PSME = Douglas fir, PICO = lodgepole pine, PIEN = Engelmann spruce, and JUSC = *Juniperus scopulorum* (juniper).

Valley, Krebill (1972) estimated that aspen trees greater than 3 cm DBH had a 3.8% annual mortality rate which he attributed, in part, to elk-induced bark injury. In 1985, Hart (1986) remeasured Krebill's plots and found that over the 1970-85 period, aspen stems greater than 3 cm DBH experienced an average annual mortality of 3.3%. Hart (1986) concluded that aspen-stem mortality was "positively correlated with the amount of prior cervid [elk] injury to stem boles." Thus, the aspen mortality rates which I calculated in Yellowstone are somewhat higher than those reported in other studies where aspen is heavily utilized by elk.

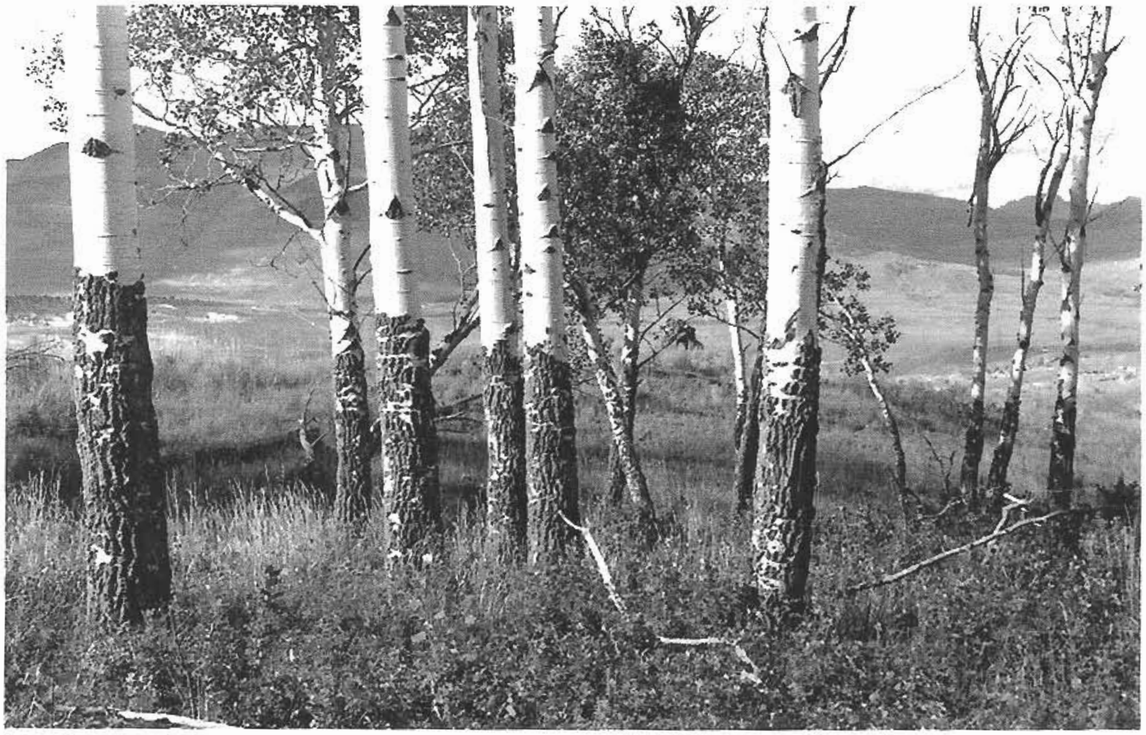
Repeat photos from the 1880-1910 period indicate that 84% of those aspen stands now have more than 10% conifer canopy cover (Table 50, Figs. 18 and 19). Images dating from 1911-1949 indicate that 57% of those aspen have now been invaded by conifers while those taken during 1950-1965 show that only 5% have been similarly affected. This suggests that fast-seral aspen stands were invaded by conifers during the early 1900s and that aspen stands which remain today are those least susceptible to conifer encroachment (see Chapters 3 and 4 above). Only 20% of the aspen stands in Kittams' study have been readily invaded by conifers since 1947 (Table 51).

In recent years, Park Service biologists have formulated a new hypothesis to explain elk-aspen interactions in Yellowstone (D. Despain, pers. commun. 1987; Bjarko 1988; R. Renkin, pers. commun. 1988, 1989). This new hypothesis assumes that aspen coevolved for thousands of years with heavy elk utilization and that aspen has juvenile and adult growth stages. Although the results have not yet been published, Park Service biologists who longitudinally sectioned the lower 3m of aspen trees report that (1) none of the trees had any evidence of branches in their first 2-3m of growth and (2) all trees showed evidence that they had been browsed at least once during their first 2-3m of growth (D. Despain, pers. commun. 1987).

According to this hypothesis, (1) juvenile aspen suckers grow rapidly, are chemically defended against herbivory, and do not grow any lateral branches; (2) burning allegedly produces juvenile-type aspen suckers which grow so fast and are so unpalatable that they grow beyond the reach of browsing ungulates in only a year or 2 even if browsed; and (3) aspen's ability to produce black scar tissue when its bark is damaged (Fig. 20) coevolved as a response to elk bark stripping and wounding. Based on this hypothesis and the usual "natural regulation" assumption that elk in pre-Columbian times were as abundant as they are in Yellowstone today, it seems reasonable to predict that (1) juvenile aspen suckers should send up only one terminal leader after being browsed -- that is they should not produce lateral branches; (2) early (1872-1900) photos should show that aspen in the park had no branches on their lower 2m; and (3) that those aspen exhibited extensive bark wounding and scarring.

There is some evidence that juvenile aspen stems produce secondary compounds. Basey et al. (1988) reported that when presented with juvenile and adult aspen branches in feeding trials, beaver preferred adult aspen because juvenile aspen contained phenolic compounds. However, Jogia et al. (1989) found that juvenile aspen was readily eaten by snowshoe hares (Lepus americanus). Even if juvenile aspen contain repellent chemicals and are not selected in feeding trials, this still does not address the question of whether those defenses are sufficient to significantly reduce their utilization by elk under the conditions which exist on Yellowstone's northern range. As previously noted (Table 27), all of the suckers produced by aspen stands experimentally burned in the park were heavily browsed each of 2 years following fire and averaged less than 0.3m tall after three growing seasons. Data which I have presented on other burned aspen stands do not show that juvenility reduced herbivory enough to permit stems to grow > 2m tall if more than a few elk utilized the area (see Chapter 5 above).

Fig. 20. A typical aspen stand on Yellowstone's northern range showing extensive black scar tissue, induced by elk bark wounding, on the lower 2-3m of aspen trunks. Virtually all aspen on the northern range have been similarly affected and identical bark coloration patterns are clearly visible in any photograph. Compare this with Figs. 22 and 23. Charles Kay photo No. 3,272-24, 8/28/89.

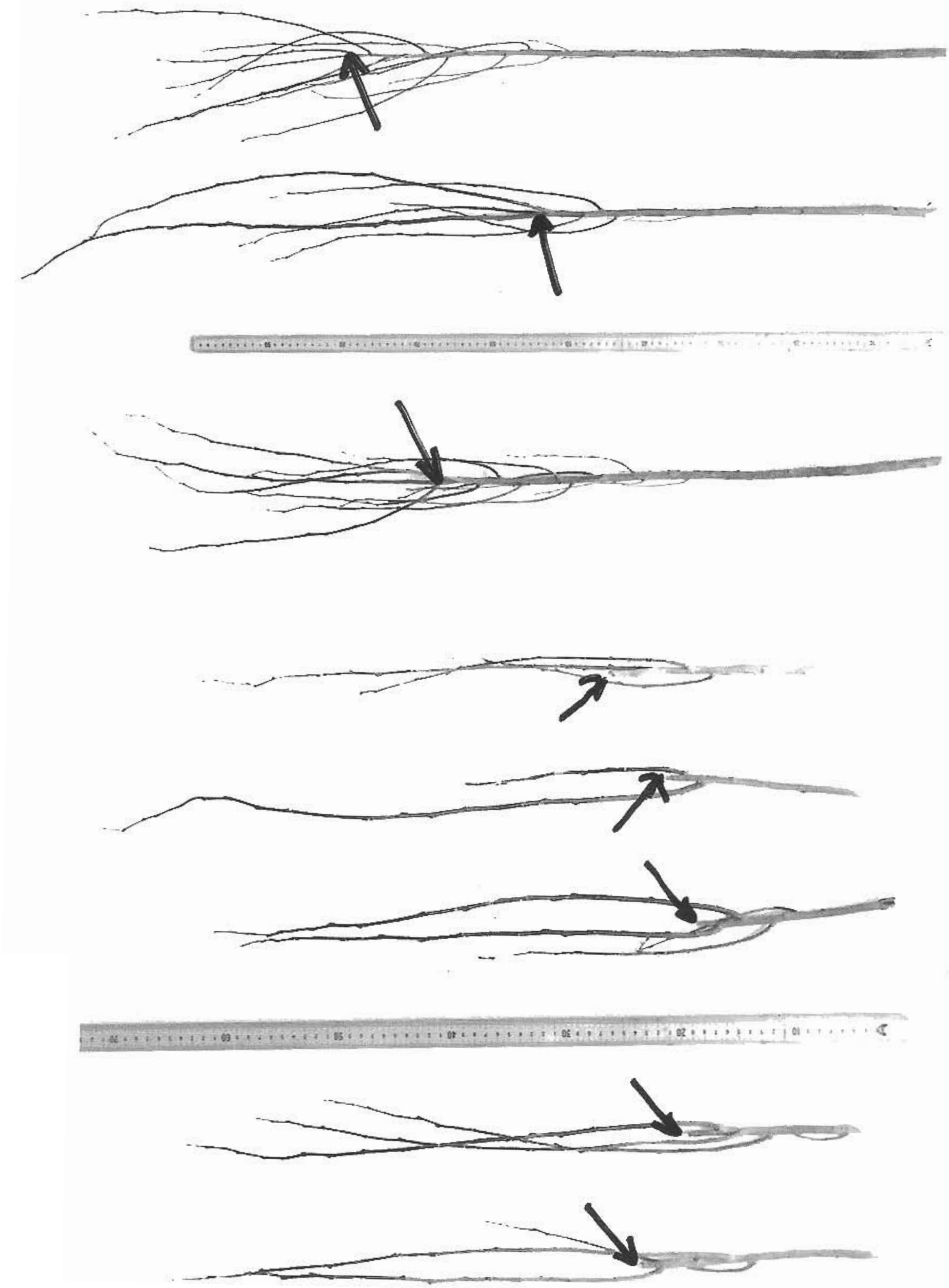


Moreover, browsed juvenile aspen suckers commonly produce multiple lateral branches (Fig. 21). Even if unbrowsed, juvenile aspen suckers produce lateral branches from their first year's stem growth during subsequent growing seasons (Fig. 21). Furthermore, I know of no evidence that aspen more than 1 year old have ever been observed without lateral branches in their lower 2-3m, let alone that this is common (Pers. obs. of several 100,000 regenerating aspen stems; also W. Mueggler, pers. commun. 1988; N. DeByle, pers. commun. 1989, D. Bartos, pers. commun. 1989). Photos of aspen stands on the park's northern range taken from 1872 to 1900 (Figs. 18 and 19) clearly show that (1) all the young aspen had branches all the way to the ground, (2) none were high-lined, and (3) none showed any evidence of elk-induced bark damage (also see Houston 1982:317, Despain et al. 1986:93). However, by 1900-1920, repeat photos show elk had started to high-line aspen and inflict bark damage.

Other photos of aspen on the northern range prior to 1900 (Figs. 22 and 23) show that aspen had branch scars or branches on their lower 2m, and that the bark on their trunks had not been damaged by elk (compare with Fig. 20). Fig. 22, as well as other early photos show that at least some aspen stands on the northern range once contained multi-sized stems and thus were multi-aged, a characteristic of climax aspen (see Chapters 3 and 4 above). Furthermore, understories of the aspen stands shown in Figs. 22 and 23 appear to have been dominated by tall forbs and shrubs, rather than grasses, suggesting they were stable or climax aspen communities.

Early photographic evidence does not support the Park Service's new hypothesis. Instead it indicates that few elk wintered in the park before European influences. If thousands of elk had prehistorically wintered on the northern range, as assumed by the Park Service, early photos should show that aspen was heavily used. Instead, they show little or no elk use. Repeat photographs of willow communities and

Fig. 21. Aspen suckers two growing seasons after the Junction Butte exclosure on Yellowstone's northern range was experimentally burned. (a) Aspen suckers from outside the exclosure show elk browsing (arrows) and multiple lateral branches produced the following year. (b) Aspen suckers from inside the exclosure show height difference (Table 27) and multiple lateral branches produced the second year. Arrows mark the first year's growth of the main stem. None of these aspen suckers produced any branches in their first growing season, but during the following growing season, branches grew from the first year's growth.



b.

a.

Fig. 22. Company D, Minnesota National Guard camp at Little Blacktail on Yellowstone's northern range in 1893. Aspen stands in background show (1) no elk-induced bark injury, (2) branch scars on lower 2m of trees, (3) multi-sized (aged) aspen, (4) tall-forb-dominated understory, and (5) little or no use by elk or other ungulates. Stumps in stand indicate some aspen have been cut, probably related to camp activities. In all likelihood, those woodcutting activities injured surrounding aspen and produced the few black scars evident in this photo since any bark injury will produce black scar tissue. These aspen clearly do not look like today's heavily scarred trees (compare to Figs. 20 and 24). Photo by F. Jay Haynes (H-3070) courtesy Montana Historical Society, Helena.

Fig. 23. Closeup of aspen felled by beaver on Yellowstone's northern range in 1899. Aspen show (1) no elk-induced bark injury, (2) branch scars or branches on lower 2m of trees, (3) multi-sized (aged) aspen, (4) shrub-tall-forb-dominated understory, and (5) little or no use by elk or other ungulates. Compare this with Figs. 20 and 24. Photo by Aven Nelson (N213p-y-nc) courtesy American Heritage Center, University of Wyoming, Laramie.

conifers on the northern range (see below) show this same trend, supporting this conclusion.

In recent years, as the elk herd built up in the park (Kay 1985, Lemke and Singer 1989; Fig. 2, Table 1) and more elk migrated northward (Fig. 5), aspen which regenerated earlier in Eagle Creek (see Chapter 3 above) have been extensively high-lined (Fig. 24). Elk-induced bark wounding and stripping have also increased. This has subjected many aspen stems to pathogen attack and increased stem mortality (J. Hart, pers. commun. 1987). Moreover, small stems now show evidence of repeated elk browsing which prevents them from growing > 2m tall (Fig. 5).

Early photos on the northern range, such as Figs. 18 and 19, show dense, relatively short-statured aspen stands which apparently regenerated after fire. As discussed in Chapter 5 (above), I evaluated over 460 burned aspen stands as part of my research. Based on photographs of those aspen stands several years after they were burned, the only ones which had the same appearance as aspen stands on the northern range ca. 1870-1890, were stands which experienced little or no ungulate use. Hence, aspen stands on the northern range shown in early historic photos apparently regenerated with little or no ungulate utilization.

Not only have most Park Service biologists failed to acknowledge the possibility that aspen communities on the northern range may be potentially stable or climax and assumed that most aspen stands are seral to conifers but they also have implied that Yellowstone's aspen is seral to grasslands or grass-sagebrush associations (Barmore 1981:373, Houston 1982:316, Despain et al. 1986:107-109). Of Kittams' 20 aspen stands, 70% changed from aspen in 1947 to grassland or sagebrush types by 1988 (Table 51, Fig. 25). Other repeat photographs show the same trend.

To the best of my knowledge, there is no evidence to suggest that a successional trend from aspen to grass or sagebrush is a natural

Fig. 24. A typical 1989 aspen stand in Eagle Creek. This stand regenerated when Yellowstone's northern elk herd was reduced during the 1960s (Table 1, Figs. 2, and 5, Chapter 3 above). In recent years, as the elk herd has built up and more animals migrated out of the park, elk began to impact these regenerated aspen. Aspen in this photo show (1) extensive high-lining, and (2) elk-induced bark injury which has led to bark scarring. Charles Kay photo No. 3,272-33, 8/28/89.

Fig. 25. Kittams' aspen photo plot 11A showing 40 years of vegetation change. (a) The aspen stands in this 1948 photograph show the effects of repeated elk browsing. All the downed trees are aspen and standing aspen show elk-induced bark injury. Photo by W. Kittams, 11/19/48; NPS No. 48-137. (b) That same area in 1988. Decaying aspen logs are still visible, but the original aspen stands have been replaced by sagebrush grasslands. Photo No. 3,020-23 by Charles Kay, 8/5/88.

a.

b.

transition in the Yellowstone ecosystem (Youngblood and Mueggler 1981; Mueggler and Campbell 1982, 1986; Mueggler 1988). As discussed in Chapter 4 (above), aspen has actually replaced grass-sagebrush in several of Yellowstone's aspen-containing exclosures (Kay unpub. photos). Also, as noted in Chapter 4 (above), aspen understories in Yellowstone exclosures are dominated by shrubs.

As previously discussed, ungulate-induced reductions in woody vegetation have been reported over a wide range of habitat types while others have concluded that grazing by elk limited woody vegetation and favored grasses (Tiedemann and Berndt 1972, Hanley and Taber 1980, Edgerton 1987). Walter Mueggler (pers. commun. 1990) has observed that aspen communities usually revert to grass-sagebrush only under intense grazing by livestock or wild ungulates. Diseases which kill all the stems in aspen clones (Hinds 1985) can convert aspen communities into grassland or shrub types (W. Mueggler, pers. commun. 1990), but I found little evidence of this in Yellowstone. Thus, aspen stands which have reverted to grassland or sagebrush types in Yellowstone Park represent grazing disclimaxes, not normal plant succession.

## Willows

I made 44 repeat photosets of willow communities on Yellowstone's northern range. The earliest sets date from 1871. Some photosets contain four photographs taken in 1893, 1921, 1954, and 1986-88. Several contain three photos taken in 1921, 1954, and 1986-88. In 41 out of 44 comparative photosets, tall willow communities have totally disappeared (Figs. 26-28). In three other photosets, I visually estimated that only 5-10% of the original tall willows remain.

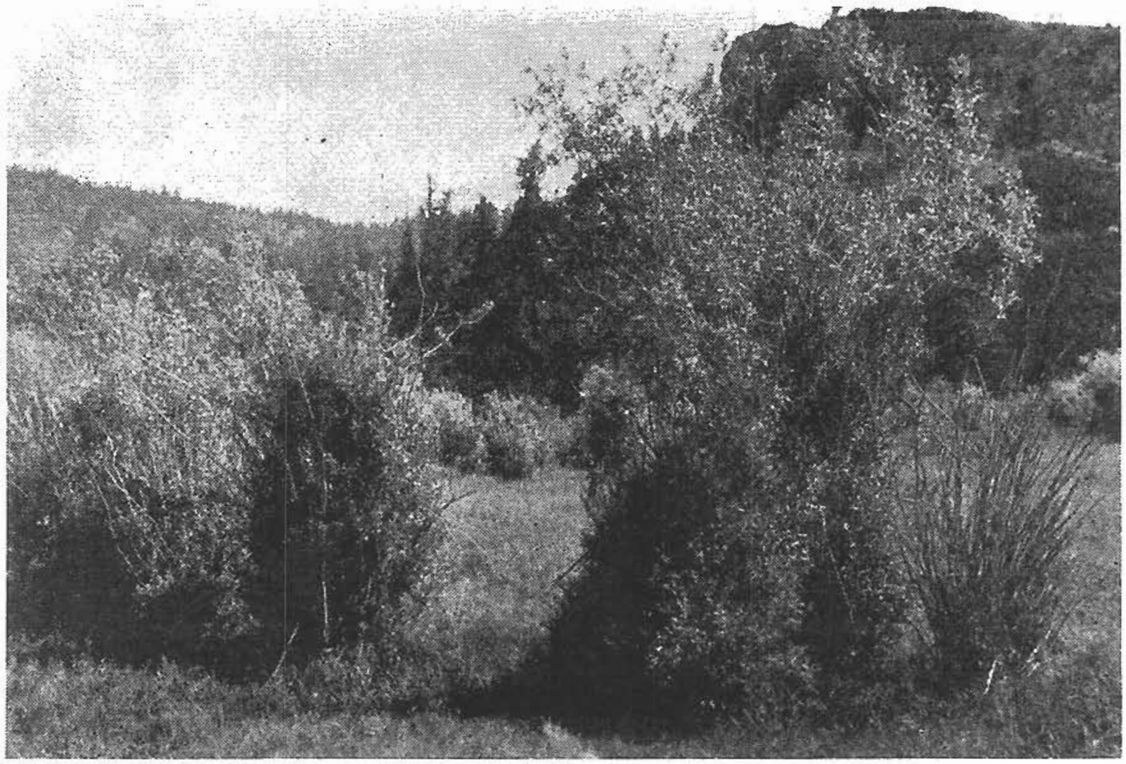
In 1871, Captains Barlow and Heap (1872:40) toured Yellowstone Park. On the northern range, they reported "thickets of willows along the river banks." Norris (1880b:613), Yellowstone's second superintendent, noted that the park was "well supplied with rivulets

Fig. 26. Repeat photoset of tall willow communities in Yancy's Hole on Yellowstone's northern range. (a) None of the tall willows in this 1893 photo show any evidence of ungulate browsing or high-lining. Conifers in right center-top show the results of frequent low intensity ground fires. Older trees have had their lower branches fire pruned since the high-line height is variable and some conifers have had their lower branches removed higher than elk can browse (see text). Young conifers show no evidence of ungulate browsing or high-lining. Photo by F. Jay Haynes (H-3080) courtesy Haynes Foundation Collection, Montana Historical Society, Helena. (b) That same area in 1988. Note the total elimination of tall willow communities in less than 100 years. Other photos of this area show that tall willows had been heavily browsed and were declining by 1921. Tall willows were absent in 1954 photos. Charles Kay photo No. 3,051-11, 8/20-88.

a.

b.

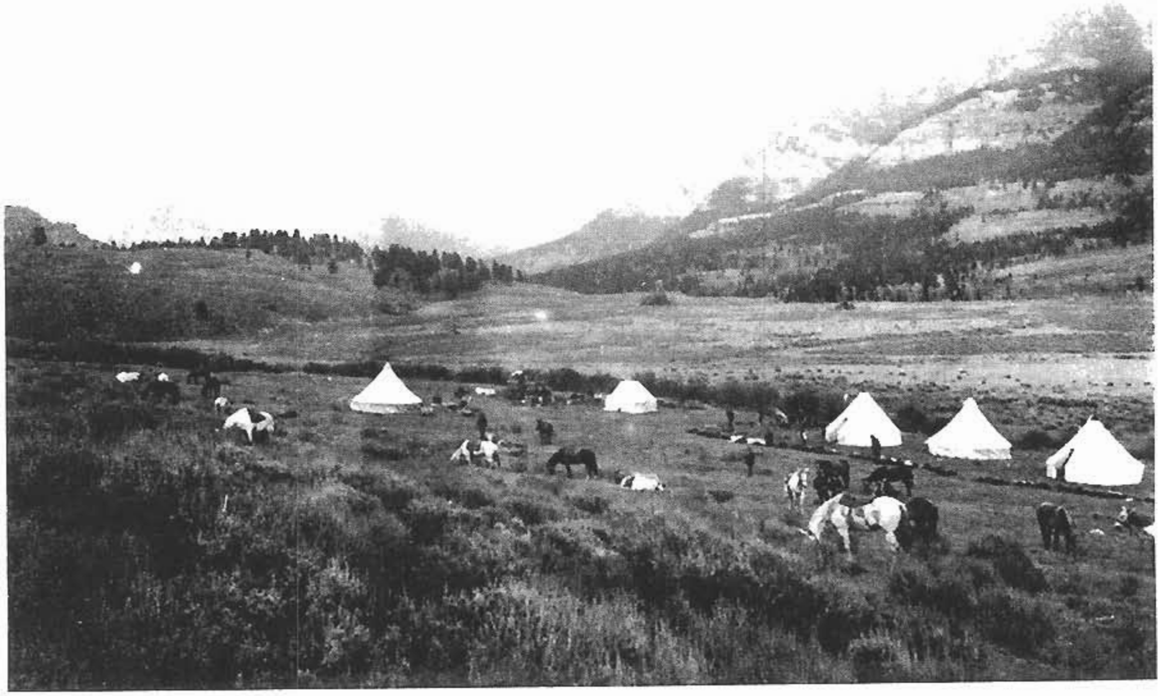
Fig. 27. Closeup of a tall willow community in Yancy's Hole on Yellowstone's northern range. (a) Note the dead willow in the right foreground of this 1915 photo and the hedged appearance of other willows due to "winter browsing by elk." Bailey (1930:55-57) stated that in the early 1910s, "willows of many species are an abundant source of food supply along the streams and meadows. They are often trimmed to mere stumps during winter and in some places they are actually killed out by close browsing." From Bailey (1930:57) courtesy of Charles C. Thomas, Publisher, Springfield, IL. (b) That same area in 1987. Note the total elimination of tall willows since the 1915 photograph. Charles Kay photo No. 2,895-25, 8/11/87.



a.

b.

Fig. 28. Repeat photoset of a tall willow community in the lower Soda Butte Valley on Yellowstone's northern range. (a) Willows in this ca. 1896 photo show no evidence of ungulate browsing or high-lining. Photo by A.E. Bradley courtesy of the A.E. Bradley Collection (72-158), Mansfield Library, University of Montana, Missoula. (b) That same area in 1988. Note the total elimination of tall willows. Charles Kay photo No. 2,976-15A, 6/21/88.



a.

b.

invariably bordered with willows." Norris (1880b:617) added that there were "innumerable dense thickets of willow" in Yellowstone. Based on an analysis of pollen in the sediments from lakes and ponds on the northern range, Barnosky (1988) reported that willow pollen had declined since the early 1900s. Thus, the available evidence indicates that tall willow communities were once common on the northern range but that they are now almost completely absent, the magnitude of the decline being comparable with the 96% reduction in aspen.

I made four additional photosets of willow communities on Yellowstone's Gallatin winter range. Three of those contained four pictures taken in 1924, 1949, 1961, and 1986, while the other included 1937, 1961, and 1989 photos. Historically the Gallatin has had an elk situation similar to that on the northern range (Packer 1963; Patten 1963, 1969; Streeter 1965; Peek et al. 1967; Lovaas 1970). Patten (1968) reported vegetation along the Gallatin River changed rapidly from an area nearly devoid of willows near the park's boundary to extensive willow thickets a few km upstream in the park. He (p. 1107) noted that "between these areas lies a transition zone of stunted and dead willows." The area with the fewest willows had the largest concentrations of wintering elk (Peek et al. 1967, Lovaas 1970). Where deep snow to the south or hunters north of the park limit elk use, willows grew taller.

Based on visual evaluation of the photographic evidence, tall willows decreased almost completely along this section of the Gallatin River and lower Daly Creek between 1924 and 1961. Since the 1970s, the Montana Department of Fish, Wildlife and Parks has made a concerted effort to reduce this elk herd when it migrates from Yellowstone Park. By instituting late-season hunts, the Department has reduced the Gallatin elk population by at least 50% in recent years (Leroy Ellig, pers. commun. 1988). In apparent response to this decline in elk numbers, photos repeated in 1986 and 1989 show that willows have increased in height and canopy-coverage since the 1960s.

Houston (1982:276-277) suggested that willows were seral to conifers. In some instances this is true but not for most willow communities. Of the 48 repeat photosets of willow communities I made, only two show complete replacement by conifers (mainly Englemann spruce). In three others, approximately 20 to 60% of the willow communities in the original photos have now been replaced by conifers. Thus, only five of 48 photosets (10%) show conifer invasion of what were once willow communities. If beaver had not been virtually eliminated from the northern range (see Chapter 6 above), they might have flooded several of these sites and prevented conifer establishment.

## Conifers

One of the conspicuous characteristics of today's northern range, and indeed other parts of the park as well, is the browsing high-line on conifers. Evident to the most casual traveler, the configuration is widely cut into all of the coniferous species. Park Service biologists who have examined early photographs, observed what they interpreted to be ungulate-induced high-lines on conifers. They have taken this as one line of evidence supporting their contention that elk have always been abundant in the park and that vegetative conditions today are similar to pre-Columbian conditions.

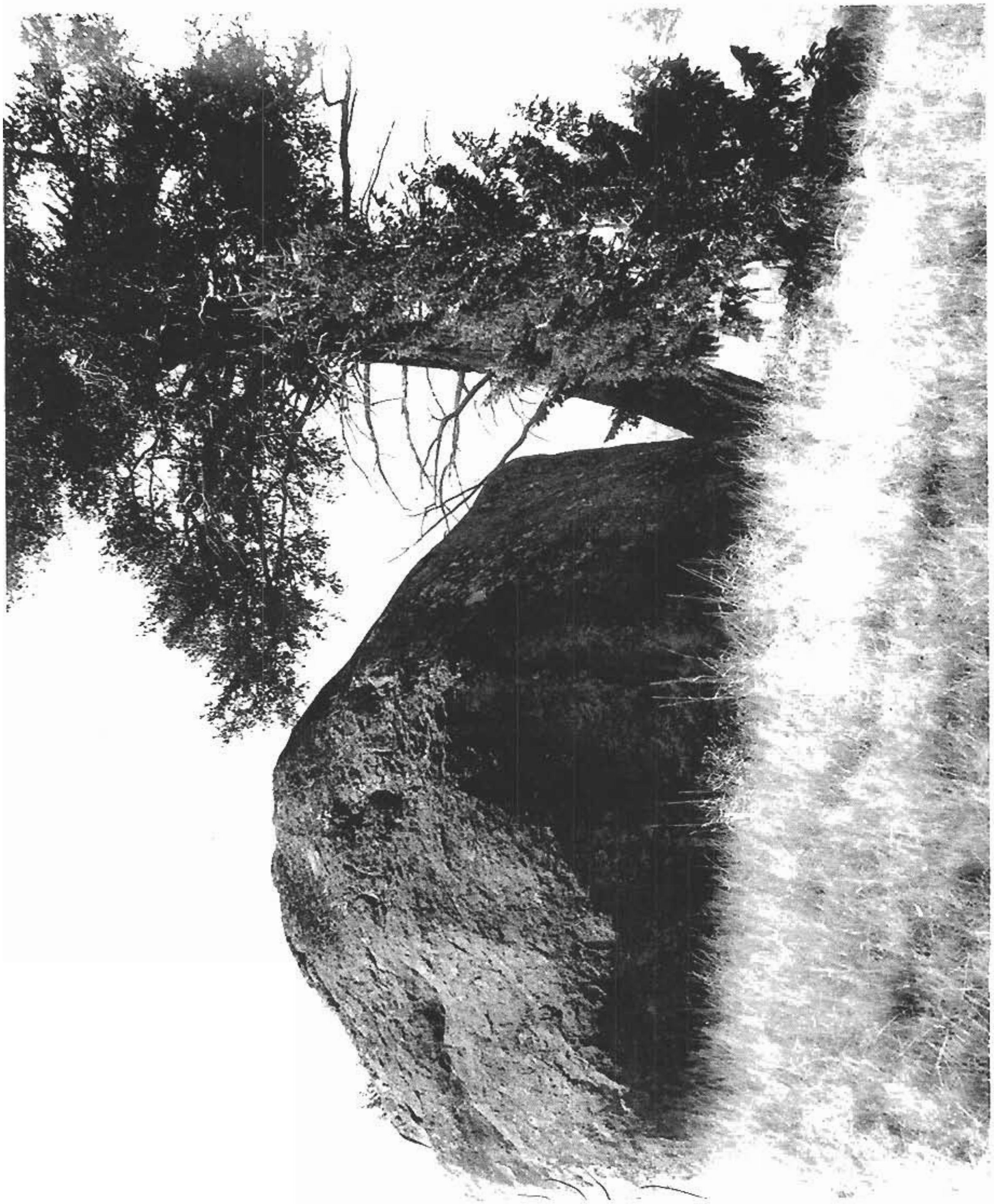
According to Houston (1982:129) "High-lining of conifers (heavy browsing of lower branches) has been interpreted as evidence of range deterioration" on Yellowstone's northern range. But after reviewing 319 repeat photosets of the park and adjacent areas, 244 of which were taken on the seasonal ranges of the northern elk herd, Houston (1982:129) concluded that "Early photos showed high-lined trees [conifers] on the northern range and adjacent areas."

In his study of Yellowstone's Firehole elk herd, Cole (1983) used "57 paired photographs taken at 58 and 104 year intervals" to evaluate vegetation changes. He grouped his repeat photographs according to the vegetation types depicted in the earliest photo. Since some photos contained more than one vegetation type, the total of his groupings is more than 57. Cole (1983) then visually evaluated his pictures to determine whether high-lined conifers were present in the initial photos. He reported that on ridges and slopes, high-lined conifers were present initially in 9 of 20 photos. He also found that 7 of 31 geothermal sites and 21 of 30 meadow and park (grassy openings) sites showed ungulate high-lining of conifers in the original photo.

Cole (1983) did not say how many sites within each grouping contained conifers in the original photos, so it is impossible to calculate what proportion of the original photos showed what he interpreted to be ungulate high-lining. For example, 21 of 30 does not imply that conifers were high-lined in 70% of the original photographs because Cole (1983) failed to state whether all of the original photos showed conifers. If conifers were not clearly visible in the original pictures, they could not have been counted as having been high-lined. This problem notwithstanding, Cole (1983) concluded that high-lined conifers were common in early park photographs. Furthermore, Cole and Houston both implied that high-lined conifers were natural and did not signify "range overuse."

After carefully reviewing all of my repeat photographs plus those published by Houston (1976b, 1982), Despain et al. (1986), and Gruell (1980a), as well as the other 50,000 or so archival photographs which I reviewed for this study (see Chapter 2 above), I can find no evidence that conifers, or any other woody species, had been high-lined by ungulates in the earliest (1871-1890) photos. Some early photos do show several conifers which lacked their lower branches, but that was due to light ground fires burning and killing the lower branches or human high-lining, not ungulate browsing. Previous authors apparently confused fire high-lining and human high-lining with ungulate high-lining.

Fig. 29. Douglas fir trees growing on the north side of a glacial erratic boulder in the lower Lamar Valley on Yellowstone's northern range ca. 1890. Based on the 20-25 year fire interval determined by Houston (1973, 1982) for this area and the lack of sagebrush in this photo, the older Douglas fir's lower branches were probably killed by low-intensity ground fires. The dead branches still retain their fine tips which would not be the case if elk had removed the foliage. Moreover, the branches have been killed to a height beyond the reach of elk or other ungulates. The three young Douglas firs which have grown since the last fire at this site show no evidence of ungulate browsing or high-lining. Photo by J.P. Iddings (No. 149), U.S. Geological Survey, Denver.



As evidence I submit the following. Figure 29 is a photograph taken by J.P. Iddings on Yellowstone's northern range ca. 1890. Iddings, who worked for the U.S. Geological Survey, apparently took this photograph to illustrate glacial erratic boulders which are common in the lower Lamar Valley where this picture was taken. To the right of the boulder are one large and at least three smaller Douglas fir trees. The lower branches on the large tree are all dead. If ungulates had high-lined this tree, these lower branches would have been eaten or broken off; note the small, dead branch tips which remain. Since this Douglas fir grew by itself in the open, its lower branches did not self-prune due to lack of sunlight, as commonly occurs in dense forests. Based on the 20-25 year fire interval Houston (1973, 1982) obtained for this area and the lack of sagebrush in this photo, I conclude that frequent, light ground fires killed the lower branches on this large Douglas fir. Fire pruning of the lower branches of conifers is also evident in other early photos (see Figs. 18a, 19a, and 26a above; and Houston 1976b:215).

Fire pruning of the lower branches of conifers can be distinguished from ungulate high-lining because first, the fire pruning height is variable. This produces an uneven high-line instead of the near constant height high line which results from ungulate browsing. This is most evident in Figs. 19 and 26. Second, unless aided by snow, elk can usually browse to a height of only 3m or less while fires often killed the lower branches of conifers to a much greater height. Again, this is most evident in Figs. 19, 26, and 29 where ground fires apparently killed the lower branches on conifers to a height unreachable by elk.

The young Douglas firs in Fig. 29 which apparently grew after the last fire at the site, show no evidence of ungulate browsing or high-lining. This site is on Yellowstone's winter range where today all conifers have been high-lined by elk to a height of 2-3m (see Figs. 18b and 19b), including Englemann spruce, which is the least palatable conifer (Bergerud and Manuel 1968, Nelson and Leege 1982, Miquelle and Van Ballenberghe 1989). Regenerating conifers in Idding's ca. 1890 photo of Rainy Lake (Fig. 19a) also show no evidence of ungulate browsing.

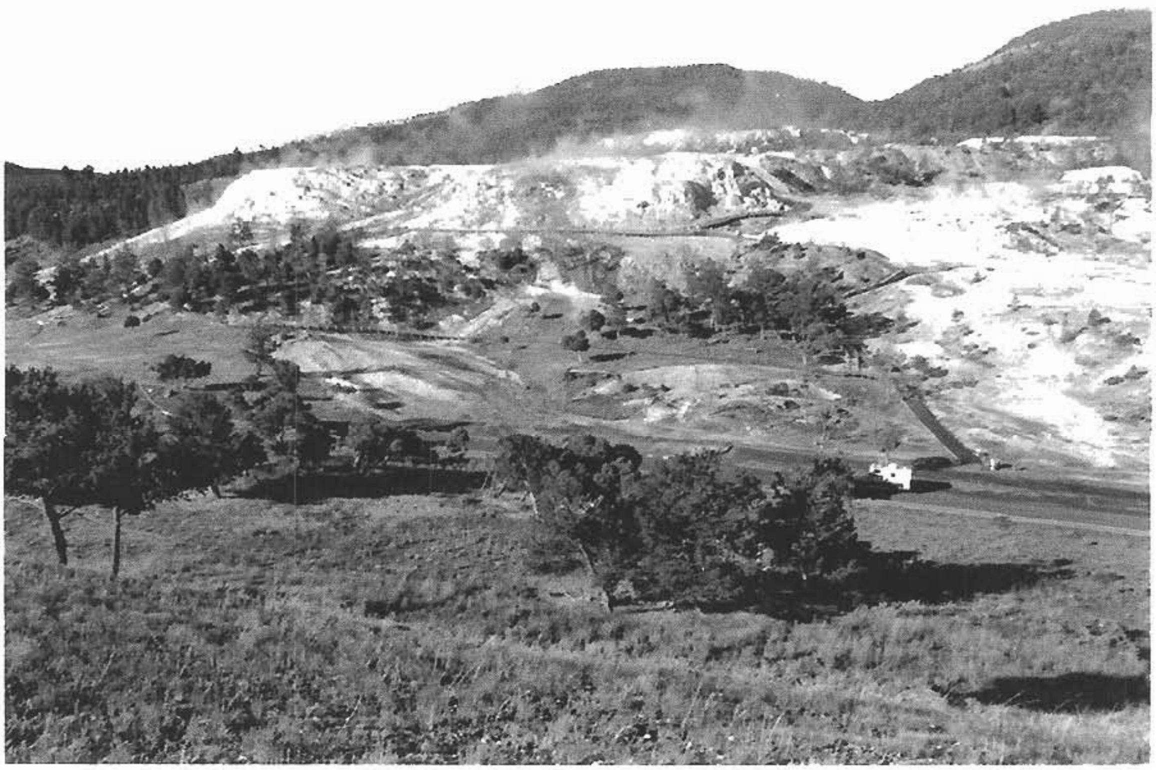
Conifers in William H. Jackson's ca. 1872 photograph of Mammoth Hot Springs on Yellowstone's northern range show no evidence of ungulate browsing or high-lining (Fig. 30a). The conifers in that picture are mostly limber pine and juniper (Juniperus scopulorum) with a few Douglas fir. Limber pine is one of the most palatable conifers in the park; yet it shows no evidence of ungulate browsing in this ca. 1872 photograph. This photo does not support Houston's (1976b:212) claim that conifers show "heavy ungulate utilization" in early (1870s) W.H. Jackson photos taken around Mammoth Hot Springs. Today, those same trees have had all their lower branches removed as high as the elk can reach (Fig. 30b).

Furthermore, aspen and willows are much more palatable than any conifer (Nelson and Leege 1982), yet all early photographs taken on the northern range fail to show evidence of ungulate browsing or high-lining on those species (see Figs. 18a, 19a, 22, 23, 26a, and 28a). This suggests that large herds of resource-limited elk did not winter on the northern range prior to the creation of Yellowstone National Park. Since the conifers in Jackson's ca. 1872 photo of Mammoth Hot Springs (Fig. 30a) appear to be approximately 70-100 years old or older and show no evidence of ungulate use, few if any elk wintered in that area as far back as 1800.

Several historic photos, some as early as the 1880s, show conifers without their lower branches. However, most of that high-lining was due to human (European) use. During Yellowstone Park's early years, there were no designated camping areas or regulations against cutting live trees (Haines 1977). Moreover, draft animals, primarily horses, were the main mode of transportation. As is commonly the practice today,

Fig. 30. Repeat photoset of conifers at Mammoth Hot Springs on Yellowstone's northern range. (a) Conifers in this William H. Jackson ca. 1872 photograph show no evidence of ungulate browsing or high-lining. The conifers between the camera and the hot springs are mostly limber pine and juniper. A few Douglas fir in the left center background show evidence of fire-pruned lower branches (see text). The hot springs apparently kept those fires from burning the conifers in the foreground. Dead trees around the hot springs were most likely killed by changing thermal water runoff patterns as is often the case today. Regenerating conifers in left center background also do not show any evidence of ungulate high-lining. W.H. Jackson photo No. 1,195 (F-28,835), Colorado Historical Society, Denver. (b) That same area in 1989. The conifers are now all high-lined. Charles Kay photo No. 3,255-14, 8/26/89.

a.



b.

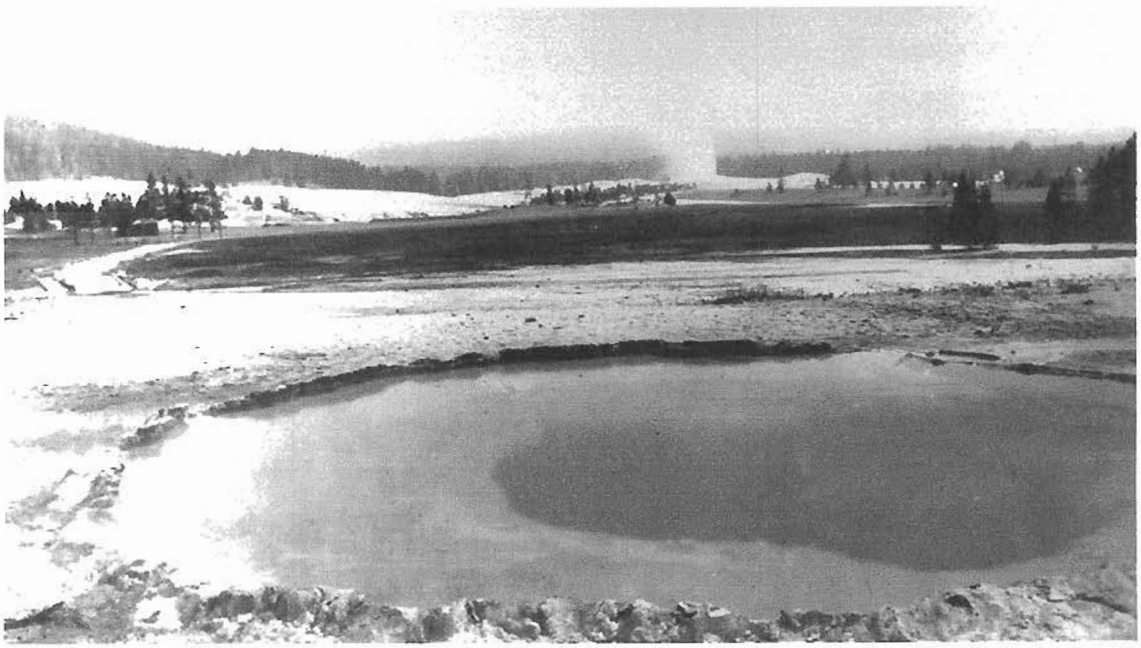
when people tied up their horses, they often first removed a tree's lower branches so that they could tie their animals directly to the main trunk. Horses tied to branches can easily obtain their freedom by rearing back and breaking off the branch to which they were tied.

Early park visitors also cut conifer branches to sleep on, since they did not carry the foam pads or air mattresses used by today's tourists. For example, William H. Jackson's early (1870s) photos of camp life in Yellowstone show pine boughs cut for bedding. Hamp (Brayer 1942:284) refers to the "splendid bed of bows" he slept upon while camping in Yellowstone during the summer of 1872. Moreover, early tourists were no different from campers today who remove the lower branches from trees near their campsites either to burn as fuel or to facilitate other camp activities.

In the early days, people tended to camp near scenic attractions and hence tended to remove the lower branches from trees at those locations. Those same areas were also commonly photographed by early park visitors. Since photography in that day was much more difficult than it is today, people did not "waste" time and effort taking pictures which did not include hot springs or other major attractions. The vast majority of the approximately 50,000 historic images I reviewed for this study were of major park features. Less than 1% contained vegetation subjects of interest, and most of those were taken for other purposes. For example, the only reason 1893 photos of aspen and willows on the northern range were taken by Haynes (Figs. 22 and 26a) was because his subjects happened to be standing in front of them.

William H. Jackson's ca. 1883 photograph of Crested Hot Spring with Old Faithful erupting in the distance (Fig. 31) illustrates the effect of human high-lining on conifers. The conifers in the right center and behind the cabin (left center) do not show evidence of high-lining. Yet the conifers in front of that cabin, along the walkway, and in front of the tent camp on the bench above the Firehole River are all

Fig. 31. Conifers in William H. Jackson's ca. 1883 photograph of Crested Hot Spring with Old Faithful erupting in the distance show evidence of human high-lining. (a) Trees in the right center and behind the cabin (left center) do not show any evidence of high-lining, while conifers in front of that cabin, along the walkway, and in front of the tent camp above the Firehole River have all been high-lined. People apparently removed the lower branches from these conifers to improve the view or to facilitate other camp activities. W.H. Jackson photo No. 235 (F-33,110), Colorado Historical Society, Denver. (b) Closeup of cabin.



a.

b.

high-lined. Apparently people removed the lower branches from these conifers to improve the view.

Finally, I also examined those photos Houston (1976b, 1982) presented as evidence of early high-lining. Surprisingly, he refers to ungulate high-lining in only a few of his early photos. However, even in those photos, I can see no convincing evidence of ungulate high-lining. A few trees in those photographs do apparently lack their lower branches, yet other conifers in the same pictures have branches extending down to the ground.

For instance, in Plate 72 of Houston (1976b) and Plate 38 of Houston (1982), the author infers evidence of ungulate high-lining in the 1885 Iddings photograph. This might be suggested weakly by two trees in the upper right-hand corner of the photo, but the stronger contrary indication is the trees in the upper left-hand corner with branches to the ground. Similarly, Houston (1976b: Plate 73) infers ungulate high-lining in a 1871 Jackson photo. There, a single tree on the skyline in the upper center of the photo apparently lacks its lower branches, but the small trees on the skyline in the upper right all have a full complement of branches. I also do not see evidence of high-lining in the 1885 Iddings photo in Houston's (1982) Plate 1. To the contrary, there are numerous young trees with branches to the ground in the lower right-hand corner and center right of the photo.

The situation is clearly different today, where virtually every conifer exposed to wintering ungulates in Yellowstone has had its lower branches removed by browsing animals. Moreover, none of Houston's (1976b, 1982) earliest photographs of willows or aspen on the northern range show any signs of ungulate utilization on those highly palatable species. In summary, I do not see the evidence of ungulate high-lining on conifers in the early photographs that Cole and Houston infer. To the contrary, I see indications in those same photographs of the absence of ungulate high-lining.

# CONCLUSIONS

In Chapter 1 (above), I discussed the two views regarding the number of elk which wintered on Yellowstone's northern range from 1500 to 1990 (Fig. 2). Prior to 1968, the Park Service believed that the northern herd built up to over 35,000 animals in the early 1900s before crashing, while Houston (1982) maintained that irruption and crash never occurred. Rather, the large number of elk using the northern range in recent years is thought to be similar to herd levels far back into prehistory. However, repeat photographs on the northern range show the following.

1. The vegetation (aspen, willows, conifers) showed no or little impact of elk browsing prior to 1900.

2. From 1900 to 1920, those same woody species showed increasing evidence of heavy elk use -- high-lining and aspen bark stripping became common.

3. Most tall willows were eliminated by the 1950s while aspen have been unable to regenerate successfully since 1900.

4. The extent of aspen clones on the northern range has declined approximately 96% since the creation of Yellowstone National Park, while the number of aspen trees on the northern range declined approximately 85% since 1947. Clearly, the magnitude of aspen's decline is much greater than that previously reported by the Park Service.

5. Tall willow communities have declined approximately 98% during this same period, and again the magnitude of their decline is much greater than previously reported by the Park Service.

6. If current trends continue, it is only a matter of time before tall, sexually reproducing aspen and willows will be eliminated from the park's northern range, as well as other areas in the Greater Yellowstone Ecosystem.

7. Ungulate high-lining of conifers is not "natural" and represents a departure from the conditions which existed prior to the

creation of Yellowstone Park.

8. The condition of the woody vegetation in these repeat photographs supports the earlier idea that Yellowstone was not historic winter range and that the northern herd increased to unprecedented numbers and profoundly altered the vegetation. Whether or not the herd actually rose to 35,000 (although it reached at least 25,000 in 1988 following a series of mild winters) and whether or not it crashed in the early 1900s is immaterial. The evidence points to a significant increase in elk which altered the northern range ecosystem. These photographs do not support Houston's (1982) conclusion that Yellowstone was always a major elk wintering area and that the northern herd did not increase or alter the system.