Natural Resources and Environmental Issues

Volume 16 *Shrublands: Wildlands and Wildlife Habitats*

Article 31

2011

Long-Term Changes in Southern Utah Upland Shrub Communities: A Study in Repeat Photography

Charles E. Kay

Chad R. Reid

Long-Term Changes in Southern Utah Upland Shrub Communities: A Study in Repeat Photography

Charles E. Kay[1] and Chad R. Reid[2]

ABSTRACT
To evaluate long-term range conditions in southern Utah, 1,879 repeat photographs were made on the Dixie and Fishlake National Forests, and adjoining lower elevation BLM and private lands. Repeat photographs were also made in Zion National Park, Cedar Breaks National Monument, and Bryce Canyon National Park where livestock grazing has been prohibited for many years. Of the total, 926 photo-pairs depict sagebrush (Artemisia *spp.*) *communities and 471 depict mountain brush associations* (Cercocaprus ledifolius, C. mountanus, Amelamchier utahensis, Quercus gambelii, Prunus virginiana)*. Sagebrush decreased in 261 photosets, increased in 386 and remained unchanged in 279, while mountain brush decreased in 10 photopairs, increased in 440, and showed no change in 21. Sagebrush increased on all sites that had been treated and planted to crested wheatgrass* (Agropyron desertorum) *during the 1950s to 1960s. Most of the decline in sagebrush was due to invasion by pinyon* (Pinus *spp.*) *and/or juniper* (Juniperus *spp.*)*, while an absence of fire is the most likely reason mountain brush increased. The observed changes have major implications for wildlife, and especially mule deer* (Odocoileus hemionus) *where sagebrush winter ranges have been lost or where mountain brush has grown beyond the reach of browsing animals. All repeat-photosets and descriptive text have been placed on Utah State University's Extension website and can be accessed at* http://extension.usu.edu.rra.

INTRODUCTION

Certain segments of the public have expressed concern that livestock may be degrading Utah's rangelands, while others fear that logging is destroying Utah's forests. According to some, mineral exploration, including oil and gas activity, is permanently scarring Utah's environment. In addition, governmental agencies are starting to manage for a more "natural" landscape, but what were the original conditions in Utah? And are our rangelands being overgrazed? Are Utah's riparian areas being ravaged? Our forests denuded? Our lands scarred?

One way to address these and similar issues is through repeat photography, where scenes depicted in historical photographs are rephotographed as they appear today, forming sets of images taken or repeated, from the same camera stations (Hall 2002a, 2002b; Magill 1989; Rogers and others 1984). This works best for vegetation types that are clearly identifiable by photographic analysis, such as grasslands, sagebrush (*Artemisia* spp.), pinyon-juniper (*Pinus* spp.-*Juniperus* spp.), aspen (*Populus tremuloides*), conifers (*Abies* spp., *Picea* spp., *Pinus* spp., and *Pseudotsuga* spp.), and willows (*Salix* spp.). Repeat photographs can also be used to estimate rates of soil erosion and plant cover (Rogers and others 1984).

Repeat photographs are extremely valuable because they provide a long-term perspective that is often missing from other studies and because the photo-pairs can readily be interpreted by the public. Want to know what things were like 100 year ago? Find an old photograph. Want to see how things have changed? Locate the original camera station and rephotograph the scene as it appears today. While the process seems simple, it can often be very time consuming because early photographers often failed to record exactly where their pictures were taken. Sometimes it can take days to find the camera station for a single photograph.

The present repeat-photo project was initiated in southwestern Utah at the request of Utah State University Extension Range Specialists and Forest Service officials, who were concerned about the long-term vegetation changes they suspected were occurring on the Fishlake and Dixie National Forests and surrounding areas. Various studies were begun to quantify the range of historical variability, but it was thought that repeat photographs might best convey past and present conditions to the general public. After all, if a picture is worth a thousand words, repeat-photographs are priceless (Kay 2006).

This paper reports on changes that have occurred in sagebrush and mountain brush (*Cercocaprus ledifolius, C. montanus, Amelanchier utahensis, Quercus gambelii*, and *Prunus virginiana*; among others) communities. Papers on aspen, pinyon-juniper, conifers, woody riparian vegetation, and general range conditions will be published elsewhere. It must also be remembered that Europeans began to settle Utah in 1847. Thus, even the earliest photographs often reflect years of livestock grazing, except for the 1872 photographs taken on Boulder Mountain by John Hillers as part of the Powell Survey (Fowler 1989) since that portion of Utah was not settled by Europeans or grazed by livestock until after 1875 (LeFevre 1973; Woolsey 1964). To the best of our knowledge, this is one of only five sets of early photographs that depict vegetation conditions prior to the onset livestock grazing in western North America - - a rare ecological benchmark.

In: Wambolt, C.L. et al. comps. 2011. Proceedings – Shrublands: wildlands and wildlife habitats; 2008 June 17-19; Bozeman, MT. NREI, volume XVI. S.J. and Jessie E. Quinney Natural Resources Research Library, Logan, Utah, USA.
[1]Charles E. Kay, Department of Political Science, Utah State University, Logan, UT
[2]Chad R. Reid, Utah State University Extension, Cedar City, UT

METHODS

We first searched the following archives for historical photographs taken in southwestern Utah: (1) The U.S. Geological Survey's photographic library in Denver, CO; (2) the Forest Service's Regional Office photographic collection housed at Weber State University, Ogden UT; (3) the Utah Historical Society in Salt Lake City, UT; (4) LDS Church Historical Department Archives in Salt Lake City, UT; (5) Southern Utah State University's Archives and Special Collections, Cedar City, UT; (6) University of Utah's Archives and Special Collections, Salt Lake City, UT; (7) the historical files kept by the Supervisor's Office on the Dixie National Forest in Cedar City, UT; (8) the U.S. Geological Survey repeat-photo collection house at Arizona State University, Tucson, AZ; (9) Bryce Canyon National Park photo archives, Bryce Canyon, UT; (10) Zion National Park photo archives, Springdale, UT; (11) the range files held by the Panguitch Ranger District, Dixie National Forest, Panguitch, UT; (12) the range files held by the Teasdale Ranger District, Dixie National Forest, Teasdale, UT; (13) the range files held by the Escalante Ranger District, Dixie National Forest, Escalante, UT; (14) the range files held by the Cedar City Ranger District, Cedar City, UT; (15) the ranger files held by the Pine Valley Ranger District, St. George, UT; (16) Allen DeMill's private collection, Kanab, UT; (17) Worth Brown's private collection, Kanab, UT; (18) the Natural Resources Conservation Service's Snow Survey records, Salt Lake City, UT; (19) Utah State University's Archives and Special Collections, Logan, UT; (20) Kanab City Museum, Kanab, UT; (21) the National Archives, Washington, D.C.; and (22) Lynne Clark's private collection, St. George, UT.

Photo Plot Transects

During the early 1940s, a series of Photo Plot Transects were established on U.S. Forest Service lands throughout Utah to monitor range conditions. The variable-length transects consist of a linear line with three foot square plots ($9ft^2$) at 100 ft, 200 ft, or longer intervals. Basal area was recorded for every plant species on each subplot and close-up photographs were taken each time the subplots were visited. General landscape photos were also taken each time the transects were measured. The Photo Plot Transects were all read twice during the 1940s, twice during the 1950s, and once in 1979. As the Photo Plot Transects were initially sited on key areas located throughout each Forest District, they are an invaluable barometer of long-term range conditions. The existence of these transects was first brought to our attention in 2003 and over the last five years, all Photo Plot Transects on the Dixie National Forest were revisited. The general landscape photographs associated with each transects were retaken. Photo Plot Transects on the Fishlake National Forest were not visited, as we were not made aware of those photos until after the Fishlake part of this project was completed. The same is true for Parker Three-Step Transects.

Parker Three-Step Transects

During the 1950s and 1960s, the Forest Service established a number of Parker Three-Step Transects to monitor range conditions on many grazing allotments. Each transect consisted of one, two, or in some cases three, 100 ft lines designed to measure plant species composition. In addition, landscape photographs were taken of each line and transect. Although the Parker Three-Step method is no longer utilized by land management agencies (Cook and others 1992; Reppert and Francis 1973), the associated photographs can be used to evaluate long-term range conditions. Thus, all range flies on the Teasdale, Escalante, Panguitch, Cedar City, and St. George Ranger Districts on the Dixie National Forest were searched for Parker, as well as other old photographs.

As all Photo Plot Transects and Parker Three-Step Transects were marked with steel stakes, which for the most part still exist, and because Forest Service files usually contain hand drawn site maps, we were able to repeat most of the associated landscape photographs. These, along with historical images obtained from other sources, produced a complete coverage of the vegetation types on the Dixie National Forest, - - - something that has seldom been accomplished in other repeat-photo studies. Thus, we believe this is the most detailed repeat-photo project that has ever been undertaken for a comparable area anywhere in the western United States.

Photography

Repeat photographs were taken with both color slide film (Fujichrome 100) and black and white print film (Kodak Plus-X). We used a Nikon FM2 with a 24 to 50mm lens and a L-37 filter for the color slides, and a Nikon FM2 with a 24 to 50mm lens and a Y-48 filter for the black and white prints. Nikon 28 to 80mm and 80 to 200mm lens were also used, as needed, to match original focal lengths. Multiple images were made at each site with both color slide and black and white print film. Depending on the focal length of the original photograph, wider angle retakes were also made. All cameras were hand-held and retakes were generally made at the same time of day as the original photographs. In addition, each photopoint was marked on U.S. Geological Survey 1:24,000 topographic maps. Camera station elevation and UTM coordinates were acquired either via GPS or estimated from topographic maps. While at each site, a detailed description of the present vegetation was recorded, as were any changes from the original photograph. Upon returning from the field, a systematic evaluation of all the photosets was conducted and detailed descriptions written for each photopair (Kay 2003). Each photoset was visually evaluated and vegetation types were recorded as having increased, remained the same, or decreased in aerial extent, height, and density (Kay 2003). The photosets or Plates were consecutively numbered according to the order in which the repeat photographs were completed. Plates on the Fishlake were numbered from 1 to 355, while those on the Dixie were numbered from 1x to 1524x.

RESULTS AND DISCUSSION

To eliminate possible bias, we attempted to locate and repeat all the early photographs that existed in major collections for the Fishlake and Dixie National Forests and surrounding areas. To be repeated, however, photographs need to contain features that could be relocated in the field. Close-ups of vegetation, or pictures in which there were no clearly identifiable landmarks, proved impossible to relocate, despite help from long-time area residents. In all we were able to complete 1,879 repeat photographs and as those photosets cover a broad array of vegetation types, time periods, elevation zones, and landforms, (figures 1 and 2), we believe they are representative of the changes that have occurred throughout southern Utah.

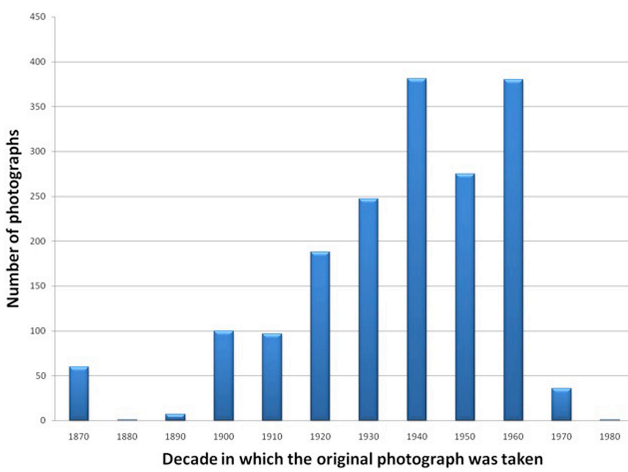


Figure 1—The decade in which the original photographs were taken on the Fishlake and Dixie National Forests (n = 1,879).

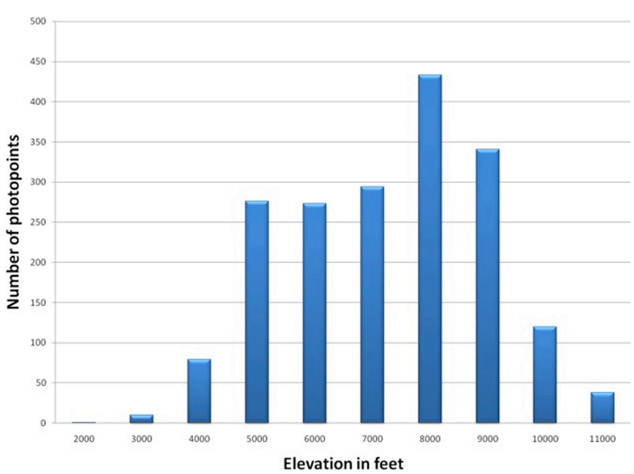


Figure 2—Photopoint elevation on the Fishlake and Dixie National Forests (n = 1,879).

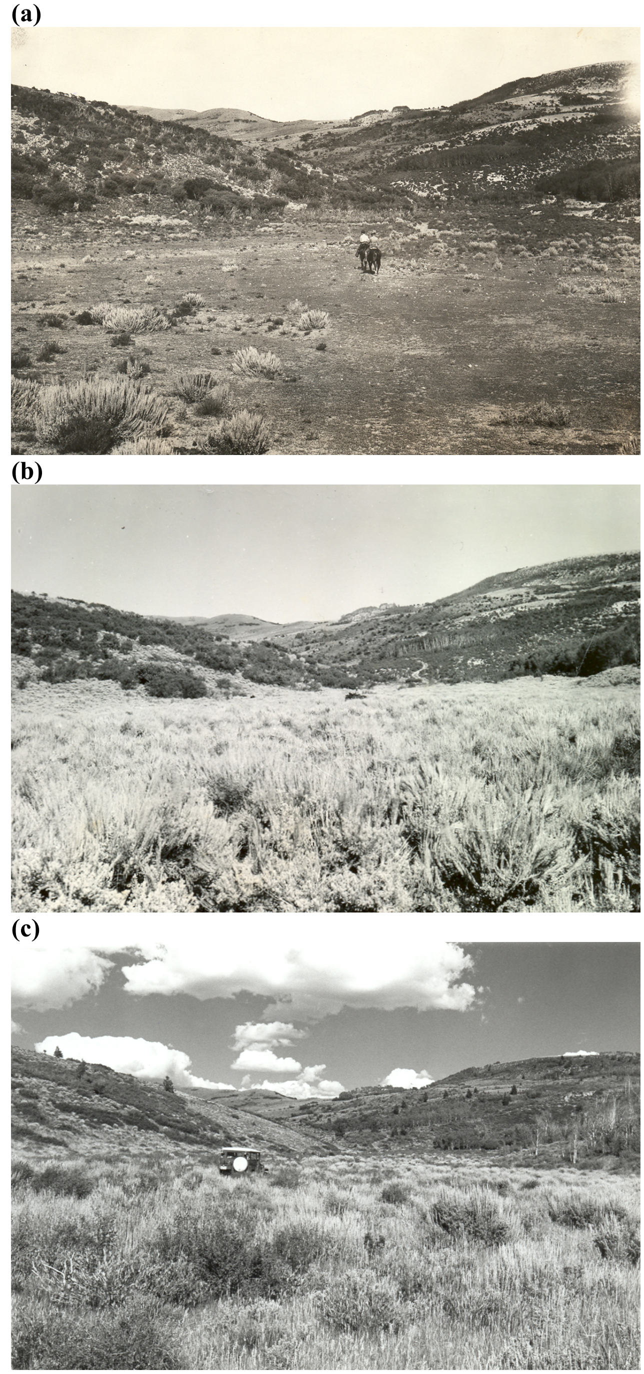


Figure 3—Sagebrush increased in more than 40 percent of the Fishlake and Dixie repeat photosets. (a) The range was very heavily grazed on Sargent Mountain in 1919 - - note the horsemen for scale (Forest Service photo 41735A). (b) The Forest Service instituted measures to reduce grazing and by 1943 sagebrush had increased - - again note the horseman in the distance for scale (Forest Service photo 468731). (c) Today, though, sagebrush cover has declined as the site has been prescribed burned by the Forest Service (Charles E. Kay photo 4446-13). For more details see Plate 46 on USU Extension's website.

Of the 1,879 total, 926 photo-pairs depict sagebrush communities and 471 depict mountain brush associations. Sagebrush decreased in 261 photosets, increased in 386, and remained unchanged in 279, while mountain brush decreased in 10 photo-pairs, increased in 440, and showed no change in 21. That is to say, sagebrush increased in 42 percent of the photosets, declined in 28 percent and remained about the same in 30 percent. While mountain brush increased in 93 percent of the repeat photographs, declined in 2 percent and showed no change in 5 percent. All repeat photographs and descriptive text have been placed on Utah State University's Extension website and can be accessed at http://extension.usu.edu/rra. This is the only large-scale, repeat-photo project where all the completed photosets and supporting information are available through the internet to land managers and the general public. As only a small selection of photo-pairs can be included in this publication, we encourage readers to view the entire collection on USU Extension's website.

Sagebrush

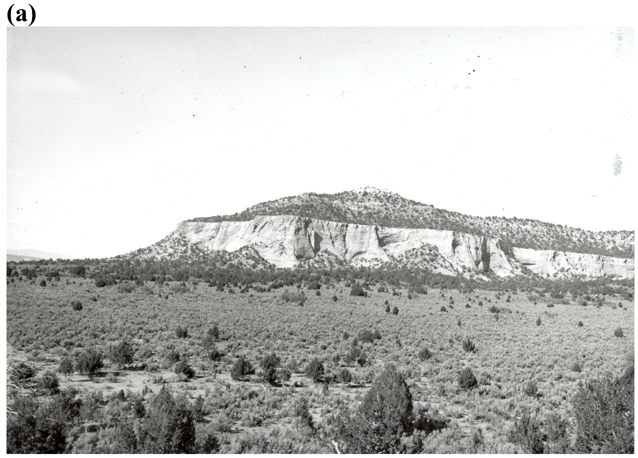
Sagebrush increased in density, cover, and aerial extent on most sites that had been heavily grazed during the late 1800s and early 1900s (figure 3). This is similar to what others have reported in Utah and across the Intermountain West (Christian and Johnson 1964; Cottam 1947; Cottam and Stewart 1940; Hall and Cottam 1955; Stewart 1941). Sagebrush declined on a few sites due to wildfire, agricultural clearing, or industrial development — for example, see Plates 179, 479x, and 1474x on USU Extension's website. However, conifer encroachment was by far and away the number one reason sagebrush has declined in southern Utah. Many sagebrush stands were lost to ever expanding pinyon-juniper forests (figure 4), which is not surprising because pinyon-juniper increased in 96 percent of our repeat photographs in which it occured. Again this is similar to what has been reported in Utah and throughout the western United States (Burkhardt and Tisdale 1976; Ffolliot and Gottfried 2002; Johnson and Miller 2008; Miller and Rose 1995; Miller and Wigard 1994; Miller and others 2008; Yorks and other 1994).

Treated Sagebrush

During the 1950s, 1960s, and early 1970s, the Forest Service and other land management agencies attempted to improve range conditions by using herbicides or mechanical treatments to reduce the cover of sagebrush prior to reseeding with crested wheatgrass (*Agropyron desertorum*) or other non-native species. Concerns have now been raised that this created millions of ac of monoculture throughout the West. Repeat photographs, though, indicate that this has not happened in southern Utah.

Of the 14 photo-pairs on the Dixie and Fishlake that depict sprayed sagebrush stands, all show that sagebrush has returned to its former abundance or actually increased. For instance, see Plates 213, 4x, 5x, 197x, 198x, and 199x on USU Extension's website. Of the 99 photosets that depict root-plowed and reseeded sagebrush stands, 94 percent show that sagebrush has now reinvaded those sites (figures 5 and 6). Others have reported similar trends on treated sagebrush sites across the West (Johnson 1969; Thilenius and Brown 1974; Wambolt and Payne 1987; Watts and Wambolt 1996).

(a)



(b)

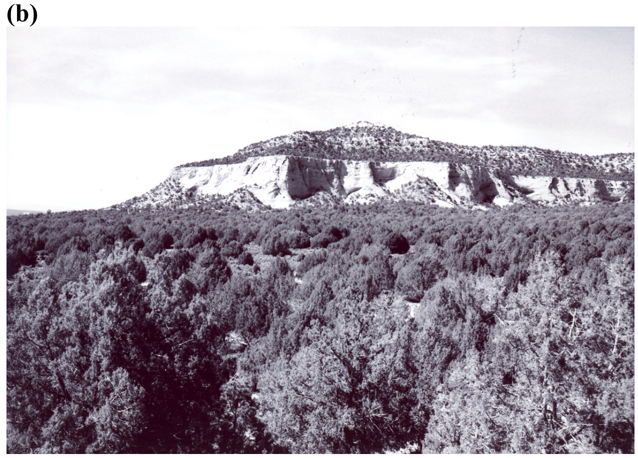


Figure 4—Most of the decline in sagebrush on the Fishlake and Dixie National Forests was due to expanding pinyon-juniper woodlands. (a) Pinyon and juniper had started to invade the sagebrush flat below Harris Point in 1936 and by (b) 2006 there was very little sagebrush left. 1936 photo by the U.S. Geological Survey (J.C. Anderson 5) and 2006 photograph by Charles E. Kay (photo 5633-6). For additional details see Plate 1190x on USU Extension's website.

Mountain Brush

On most sites in southern Utah, mountain brush species have increased in height, density, and aerial extent (figure 7). This is most likely due to an absence of fire and a reduction in livestock grazing (Austin and others 1986). On a few sites, however, ponderosa pine (*Pinus ponderosa*) and white fir (*Abies concolor*) have begun to invade mountain brush communities (figure 8). This is not surprising since

92 percent of the photosets that depict upland forests on the Fishlake and Dixie show that conifers have increased, often markedly.

Other Shrubs

On some higher-elevation rangeland sites, shrubs such as snowberry (*Symphoricarpos oreophilius*) and currants (*Ribes* spp.) have increased (figure 9). This is most likely due to the elimination of grazing by domestic sheep, as many Forest Service allotments have been converted from sheep to cattle over the years. Cattle do not normally graze either snowberry or currants, but sheep will, especially on heavily stocked ranges.

Why Have Things Changed?

Other repeat-photo studies have reported the same long-term vegetation changes that we documented in southern Utah (Bradford and others 2004; Creque and other 1999; Rogers 1982; Turner and other 2003; U.S Forest Service 1993; among others). Several hypotheses have been proposed to explain why woody vegetation has increased on western rangelands, as well as on rangelands around the world (Branson 1985; Britz and Ward 2007; Pyne 1991; Roques and others 2001; Van Auken 2000; among others). These include climatic change, excessive livestock grazing, increase in atmospheric carbon dioxide, and fire suppression by land management agencies.

Sagebrush and other unpalatable woody species do increase with heavy livestock use (Young 1989) but pinyon and juniper have also invaded ungrazed sagebrush communities (Knapp and Soule 1998; Soule and Knapp 1999, 2000). Although sagebrush and other shrubs often respond positively to increased moisture, climate alone has not been shown to be the main factor in brush encroachment. Similarly, while woody species grow better in a carbon dioxide enriched environment, carbon dioxide alone has not caused the increase in woody vegetation (Archer and other 1995; Johnson and others 1993; Knapp and Soule 1996), which leaves fire, or the lack thereof, as the most likely reason woody plants have increased in Utah and throughout the West (Bond and Keeley 2005; Bond and others 2005; Lesica and others 2007; Miller and Tausch 2002).

While we agree that the lack of fire is the most parsimonious explanation as to why woody vegetation has increased on western ranges, we do not believe the cause lives soley with fire suppression. Vale (2002) and others contend that lightning historically caused most range and forest fires, but that appears not to be true. Kay (2007) recently compared known lightning-ignition rates in the United States with potential aboriginal-ignition rates, based on pre-European contact estimates of native populations and estimates of how many fires each native person set per year.

(a)
(b)
(c)

Figure 5—A sagebrush stand on the Fishlake National Forest that was root-plowed, burned, and reseeded. (a) The site as it looked before treatment in 1949. (b) The same site in 1954 after it had been root-plowed, burned, and reseeded to crested wheatgrass. (c) By 2000, however, sagebrush again dominated the area. Photos (a) and (b) by the Forest Service (unnumbered), 2000 photo by Charles E. Kay (4651-14). For more details see Plate 220 on USU Extension's website.

"Using the lowest published estimate of native people in the United States and Canada prior to European influence (2 million) and assuming that each individual started only 1 fire per year -- potential aboriginal ignition rates were 2.7 to 350 times greater than current lightning ignition rates. Using more realistic estimates of native populations, as well as the number of fires each person started per year, potential aboriginal ignition rates were 270 to 35,000 times greater than known lightning ignition rates. Thus, lightning-caused fires may have been largely irrelevant for at least the last 10,000 years. Instead, the dominant ecological force likely has been aboriginal burning" (Kay 2007:16).

In the Great Basin, for instance, even using a low estimate of only one native person per 9 mi^2 (Vale 2002:81) and assuming that only one fire was set per person per year, native people would still have started 10 times more fires than lightning (Kay 2007:20). Using more realistic estimates of the number of native people in the Great Basin prior to European influences, such as smallpox which decimated native populations throughout North America ca. 1550, aboriginal-started fires were likely two or three orders of magnitude greater than known lightning-ignition rates. As discussed elsewhere, native people made extensive use of fire to manipulate their environment and to make it more productive (Anderson 2005; Kay 2007; and references therein). In fact, native people actually created many ecosystems heretofore thought to be "natural" (Kay 1995, 2003, 2007).

Impact on Wildlife

As with any vegetation change, some animals will benefit, while others will not. Two species that are harmed by the loss of sagebrush are sage grouse (*Centrocercus urophasianus* and *C. minimus*) and mule deer (*Odocoileus hemionus*) (Crawford and others 2004; Kay 2006). As pinyon and juniper invade critical sagebrush winter ranges (figure 10), mule deer populations decline, as there are fewer shrubs for the wintering deer to eat. In fact, forage loss due to increasing woody vegetation has been identified as a major problem on western ranges (Kay 2003:18-19). While fire certainly reduces the cover of sagebrush at least temporarily, it is still one of the best ways to rejuvenate decadent sagebrush communities and to create the diversity of different age sage, as well as forbs, needed by sage grouse and other sage obligate species (Crawford and others 2004).

Other Considerations

The response to our repeat-photo work in southern Utah has been extremely positive and we have made invited presentations to various user groups. As all our photosets are available over the internet, they have been widely used by the public, as well as land managers. Based on our experience, we believe that every National Forest, BLM Resource Management Area, National Park, National Wildlife Refuge, and the like should undertake their own repeat-photo projects. Data on the range of historical variability are fine, but the general public is not trained to make sense of oftentimes complicated datasets. Moreover, many segments of the public do not trust the agencies to collect unbiased data. On the other hand, just about everyone can look at an old photograph and a modern retake and see for themselves what has changed. Besides, given our modern visual culture, people tend to believe what they see with their own eyes. This is one reason why digital photography should never be used in repeat-photo work -- because the images are too easy to manipulate. In addition, all repeat-photo work should include black and white photography. This is because black and white prints and negatives, if properly stored, will last forever while color photographs start to deteriorate as soon as they are made, even if stored under archival conditions.

(a)

(b)

Figure 6—A sagebrush stand that was treated on the Dixie National Forest. The site is on Sheep Creek and the view is west to Bryce Canyon National Park. (a) The area as it looked in 1961 after it had been root-plowed to remove sagebrush and reseeded to crested wheatgrass. (b) That same site 43 years later in 2004. Sagebrush has reinvaded the area and pinyon-juniper encroachment has begun. 1961 photograph by the Forest Service (unnumbered), while the 2004 retake was made by Charles E. Kay (5287-12). For additional information see Plate 401x on USU Extension's website.

(a)

(b)

Figure 7—100 years of vegetation change in the mountain brush zone on Lone Tree Mountain southeast of Cedar City, Utah. (a) In the 1906 image, the shrubs are low-statured and widely spaced. The high-lined shrubs in the foreground indicate the area was heavily grazed, most likely by domestic sheep. U.S. Geological Survey photograph (W.T. Lee 219). (b) Today, the shrubs have increased in height, cover, and probably density, as well. Invasion by pinyon-juniper has also begun. The area is no longer grazed by livestock. 2006 photo by Charles E. Kay (5693-12). For more details see Plate 1332x on USU Extension's website.

Finally if repeat-photo projects are undertaken, all the photosets should be protected in clear, archival quality, plastic pages and all photos clearly identified. Arrangements also need to be made to properly archive the collection, so that researchers in the future can reoccupy the original camera stations; in other words, three-peat and four-peat photography (Klement and others 2001;Turner and others 2003). Our experience has been that these photographs should not be stored in agency files or at the bottom of some desk where they invariably will be lost as people retire or are transferred. Instead, completed photosets should be deposited with institutions, whose mission it is to preserve historical material. We have made arrangements to permanently store our Fishlake repeat photos with Utah State University's Archives and Special Collections and our Dixie photos with the Archives and Special Collections at Southern Utah University. We have little doubt that future generations of ecologists and land managers will appreciate this foresight.

(a)

(b)

Figure 8—Vegetation change in the mountain brush zone above Boulder, Utah. The view is south to Ormand Point. The exact camera station could not be reoccupied due to the growth of woody vegetation but the retake was made as close as possible to the original camera station. The tall shrubs are mostly oakbrush (*Querus gambelii*) and Utah serviceberry, while the lower-growing shrubs are primarily bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*), and snowberry (S*ympnoricarpos oreophilius*). (a) Ponderosa pine had begun to invade the mountain brush community when the 1936 image was made. Forest Service photo (307746). (b)That same site in 2002. Without fire the area is slowly changing to a pine forest. Photo by Charles E. Kay (4966-24). For more information see Plate 38x on USU Extension's website.

(a)

(b)

Figure 9—Vegetation change on the Parker Three-Step transect on Roundup Flat, Boulder Mountain, Utah. (a) The 1953 image shows a grass dominated site with few shrubs. At the time the allotment was grazed by domestic sheep. Forest Service photograph (unnumbered). (b) The allotment has since been converted to cattle and snowberry has invaded the site. 2003 photo by Charles E. Kay (5263-28). For additional details see Plate 362x on USU Extension's website.

(a)

(b)

Figure 10—The impact of pinyon-juniper invasion on mule deer winter range on the Dixie National Forest. Although it may be difficult to believe that the two photographs were taken from the exact same camera station, this is part of a Photo Plot Transect established by the Forest Service in 1943 and marked with steel stakes that still exist. As pinyon and juniper have increased, forage and shrub production have dramatically declined (Kay 2003). (a) 1943 image. Forest Service photograph (unnumbered). (b) The exact same camera station in 2005. Photo by Charles E. Kay (5516-15). For additional information see Plate 1033x on USU Extension's website.

ACKNOWLEDGEMENTS

This project was supported by mineral leasing funds provided by the Utah Legislature through Utah State University, as well as grants provided by the Utah Department of Agriculture and Food, the U.S. Forest Service, the Utah Division of Wildlife Resources Habitat Council , the Zion National History Association, and Utah State University Extension. We would also like to extend our appreciation to the many archivists and Forest Service officials, who helped locate photographs for this study, as well as the private property owners who allowed access to their lands so that we could reoccupy some original camera stations. Finally, we would like to thank Tom Hatch, Brad Johnson, Dennis Stowell, Leonard Blackham, Randy Simmons, Dave Thomas, Dave Grider, Marian Jacklin, Gretchen Merrill, Clint Reese, Evan Boshel, Kim Anderson, Kurt Robins, Bob Campbell, Dale Bartos, Kelly Fuhrmann, Dave Sharrow, Kristen Legg, Steve Robinson, Leslie Newkirk, and Kevin Heaton for their continued support and assistance on this project. The National Park Service provided research permits for Zion National Park, Bryce Canyon National Park, and Cedar Breaks National Monument. In 2004, we were able to hire Darrell McMahon to repeat photographs in the Pine Valley Mountains under a U.S. Department of Agriculture CSREES grant - - Project No. UTA-00556 - - to Dr. Randy Simmons. Borge Anderson Photography in Salt Lake City processed and printed the black and white film.

REFERENCES

Anderson, M.K. 2005. Tending the Wild: Native American knowledge and management of California's natural resources. Berkely: University of California Press. 562p.

Archer, S., Schimel, D.S., Holland, E.A. 1995. Mechanisms of shrubland expansion: land use, climate or CO_2? Climatic Change 29:91-99.

Austin, D.D., Urness, P.J., Riggs, R.A. 1986. Vegetal change in the absence of livestock grazing, mountain brush zone, Utah. Journal of Range Management 39:514-517

Bond, W.J., Keeley, J.E. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution 20:387-394.

Bond, W.J., Woodward, F.I., Midgley, G.F. 2005. The global distribution of ecosystems in a world without fire. New Phytologist 165:525-538.

Bradford, D., Reed, F., LeValley, R.B. 2004. When the grass stood stirrup-high: facts, photographs and myths of west-central Colorado. Lawrence, KS: Allen Press. 182p.

Branson, F.A. 1985. Vegetation changes on western rangelands. Society for Range Management. Range Monograph 2:1-76.

Britz, M-L., Ward, D. 2007. Dynamic of woody vegetation in a semi-arid savanna, with a focus on brush encroachment. African Journal of Range and Forage Science 24:131-140.

Burkhardt, J.W., Tisdale, E.W. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 57:472-484.

Christensen, E.M., Johnson, H.B. 1964. Presettlement vegetation and vegetation change in three valleys in central Utah. Brigham Young University Science Bulletin Biological Series 4(4):1-16.

Cook, J.W., Brady, W.W., Aldon, E.F. 1992. Handbook for converting Parker loop frequency data to basal area. Gen. Tech. Rep. RM-212. Fort Collins, CO. Forest Service, Rocky Mountain Research Station. 22p.

Cottam, W.P. 1947. Is Utah Sahara bound? Bulletin of the University of Utah 37(11):1-40.

Cottam, W.P., Stewart, G. 1940. Plant succession as a result of grazing and meadow desiccation by erosion since settlement in 1862. Journal of Forestry 38:613-626.

Crawford, J.A., Olson, R.A., West, N.E., Mosley, J.C., Schroeder, M.A., Whitson, T.D., Miller, R.F., Gregg, M.A., Boyd, C.S. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2-19.

Creque, J.A., West, N.E., Dobrowolski, J.P. 1999. Methods in historical ecology: a case study of Tintic Valley, Utah. *In*: Monson, Stephen B., Stevens, R. comps. 1999. Proceedings: ecology and management of pinoyn-juniper communities within the interior West. Proceedings RMRS -P-9. Fort Collins, CO. Rocky Mountain Research Station:121-133.

Ffolliott, P.F., Gottfried, G.J. 2002. Dynamics of a pinyon-juniper stand in northern Arizona: a half-century history. Res. Pap. RMRS-RP-35. Fort Collins, CO. Forest Service, Rocky Mountain Research Station. 10p.

Fowler, D.D. 1989. Myself in the water: the western photographs of John K. Hillers. Washington D.C.: Smithsonian Institution Press. 166p.

Hall, F.C. 2002a. Photo point monitoring handbook: Part A - field procedures. Gen. Tech. Rep. PNW-526. Portland, OR. USDA, Forest Service, Pacific Northwest Research Station 48p.

Hall, F.C. 2002b. Photo point monitoring handbook: Part B - concepts and analysis. Gen. Tech Rep. PNW-526. Portland OR. USDA, Forest Service, Pacific Northwest Research Station. 86p.

Hall, H.H., Cottam, W.P. 1955. The impact of man on the vegetation and soil of the Upper Valley area, Garfield County, Utah. Proceedings of the Utah Academy of Science, Arts, and Letters 32:105-106.

Johnson, D.D., Miller, R.F. 2008. Intermountain presettlement juniper: distribution, abundance, and influence on postsettlement expansion. Rangeland Ecology and Management 61:82-92.

Johnson, H.B., Polley, H.W. Mayeux, H.S. 1993. Increasing CO_2 and plant-plant interactions: effects on natural vegetation. Vegetatio 104/5:157-170.

Johnson, W.M. 1969. Life expectancy of a sagebrush control in central Wyoming. Journal of Range management 22:177-182.

Kay, C.E. 1995. Aboriginal overkill and native burning: implications for modern ecosystem management. Western Journal of Applied Forestry 10:121-126.

Kay, C.E. 2003. Long-term vegetation change on Utah's Fishlake National Forest: a study in repeat-photography. U.S. Forest Service and Utah State University Extension. 2003-53-084/42159 Region No. 8. 175 p.

Kay, C.E. 2006. Mule deer habitat: past and present. Mule Deer Foundation Magazine No. 8 (Sept.-Oct.):22-26.

Kay, C.E. 2007. Are lightning fires unnatural? a comparison of aboriginal and lightning ignition rates in the United States. Tall Timbers Fire Ecology Conference 23:16-28.

Klement, K.D., Heitschmidt, R.K., Kay, C.E. 2001. Eighty years of vegetation and landscape changes in the northern Great plains. USDA, Agricultural Research Service Conservation Research Report 45. 91p.

Knapp, P.A., Soule, P.T. 1996. Vegetation change and the role of atmospheric CO_2 enrichment on a relict site in central Oregon:1960-1994. Annals of the Association of American Geographers 86:387-411.

Knapp, P.A., Soule, P.T. 1998. Recent *Juniperus occidentalis* (western juniper) expansion on a protected site in central Oregon. Global Change Biology 4:347-357.

LeFevre, L.H. 1973. The Boulder County and its people: a history of the people of Boulder and the surrounding country - - one hundred years 1872-1973. Springville: Art City Publishing. 294p.

Lesica, P., Cooper, S.V., Kudray, G. 2007. Recovery of big sagebrush following fire in southwest Montana. Rangeland Ecology and Management 60:261-269.

Magill, A.W. 1989. Monitoring environmental change with color slides. Gen. Tech. Rep PSW-117. Berkely, CA. USDA, Forest Service, Pacific Southwest Forest Range Experiment Station. 55p.

Miller, R.F., Rose, J.A. 1995. Historic expansion of *Juniperus occidentalis* in southeastern Idaho. Great Basin Naturalist 55:37-45.

Miller, R.F., Tausch, R.J. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Tall Timbers Research Station Miscellaneous Publication 11: 15-30.

Miller, R.F., Tausch, R.J., McArthur, E.D., Johnson, D.D., Sanderson, S.C. 2008. Age structure and expansion of pinyon-juniper woodlands: a regional perspective in the Intermountain West. Res. Pap. RMRS-RP-69. Fort Collins, CO. Rocky Mountain Research Station. 15p.

Miller, R.F., Wigand, P.E. 1994. Holocene changes in semiarid pinyon-juniper woodlands. Bioscience 44:465-474.

Pyne, S.J. 1991. Burning bush: a fire history of Australia. New York: Henry Holt and Company. 520p.

Reppert, J.N., Francis, R.E. 1973. Interpretation of trend in range condition from 3-step data. Res. Pap. RM-103. Fort Collins, CO. USDA, Forest Service, Rocky Mountain Research Station. 15p.

Rogers, G.F. 1982. Then and now: a photographic history of vegetation change in the central Great Basin desert. Salt Lake City: University of Utah Press. 152 p.

Rogers, G.F., Malde, H.E., Turner, R.M. 1984. Bibliography of repeat photography for evaluating landscape change. Salt Lake City: University of Utah Press. 179p.

Roques, K.G., O'Connor, T.G., Watkinson, A.R. 2001. Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology 38:268-280.

Soule, P.T., Knapp, P.A. 1999. Western juniper expansion on adjacent disturbed and near-relict sites. Journal of Range Management 52:525-533.

Soule, P.T., Knapp, P.A. 2000. *Juniper occidentalis* (western juniper) establishment history on two minimally disturbed research natural areas in central Oregon. Western North America Naturalist 60:26-33.

Stewart, G. 1941. Historic records bearing on agricultural and grazing ecology in Utah. Journal of Forestry 39:362-375.

Thilenius, J.F., Brown, G.R. 1974. Long-term effects of chemical control of big sagebrush. Journal of Range Management 27:223-224.

Turner, R.M., Webb, R.H., Bowers, J.E., Hastings, J.R. 2003. The changing mile revisited. Tucson: University of Arizona Press. 334p.

U.S. Forest Service. 1993. Vegetation changes on the Manti-LaSal National Forest: a photographic study using comparative photographs from 1902-1992. USDA, Forest Service, Price, UT. 128p.

Vale, T.R., ed. 2002. Fire, native peoples, and the natural landscape. Washington D.C.: Island Press. 315p.

Van Auken, O.W. 2000. Shrub invasions of North America semiarid grasslands. Annual Review of Ecological Systems 31:197-215.

Wambolt, C.L., Payne, G.F. 1986. An 18-year comparison of control methods for Wyoming big sagebrush in southwestern Montana. Journal of Range Mnagement 39:314-319.

Watts, M.J., Wambolt, C.L. 1996. Long-term recovery of Wyoming big sagebrush after four treatments. Journal of Environmental Management 46:95-102.

Woolsey, N.G. 1964. The Escalante story: a history of the town of Escalante, and description of the surrounding territory, Garfield County, Utah. Springville: Art City Publishing. 463p.

Yorks, T.P., Wrest, N.E., Capels, K.M. 1994. Changes in pinyon-juniper woodlands in western Utah's Pine Valley between 1933-1989. Journal of Range Management 47:359-364.

Young, J.A. 1989. Intermountain shrub-steppe plant communities: pristine and grazed. National Wildlife Federation Scientific and Technical Series. 12:3-14.