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PROBLEMS OF REVEGETATION OF ALPINE TUNDRA*

Introduction

The Alpine tundra was one of the primary reasons for establishment of Rocky Mountain National Park. The unique character of this resource continues to attract millions of people to the park. Easily accessible by automobile on Trail Ridge Road since 1932, the average park visitor has been able to actually experience the character of the alpine. To many visitors, a trip to Rocky Mountain is not complete without a walk on the tundra.

The attractiveness of the resource, however, may be the cause for its destruction. As described by Willard and Marr (1970), "visitors to the tundra are affecting its survival in many ways incidental to its use."

The activity that has had the greatest effect is trampling. Low intensity, widely distributed use has little or no impact; however, visitors following the same path day after day soon kill the vegetation, leaving the soil to be eroded away by wind and water. Vehicles driving or parking on the tundra have the same effect if allowed to continue over time.

Historic uses of the area such as the effects of early road construction, in most cases have not been properly restored and still affect the

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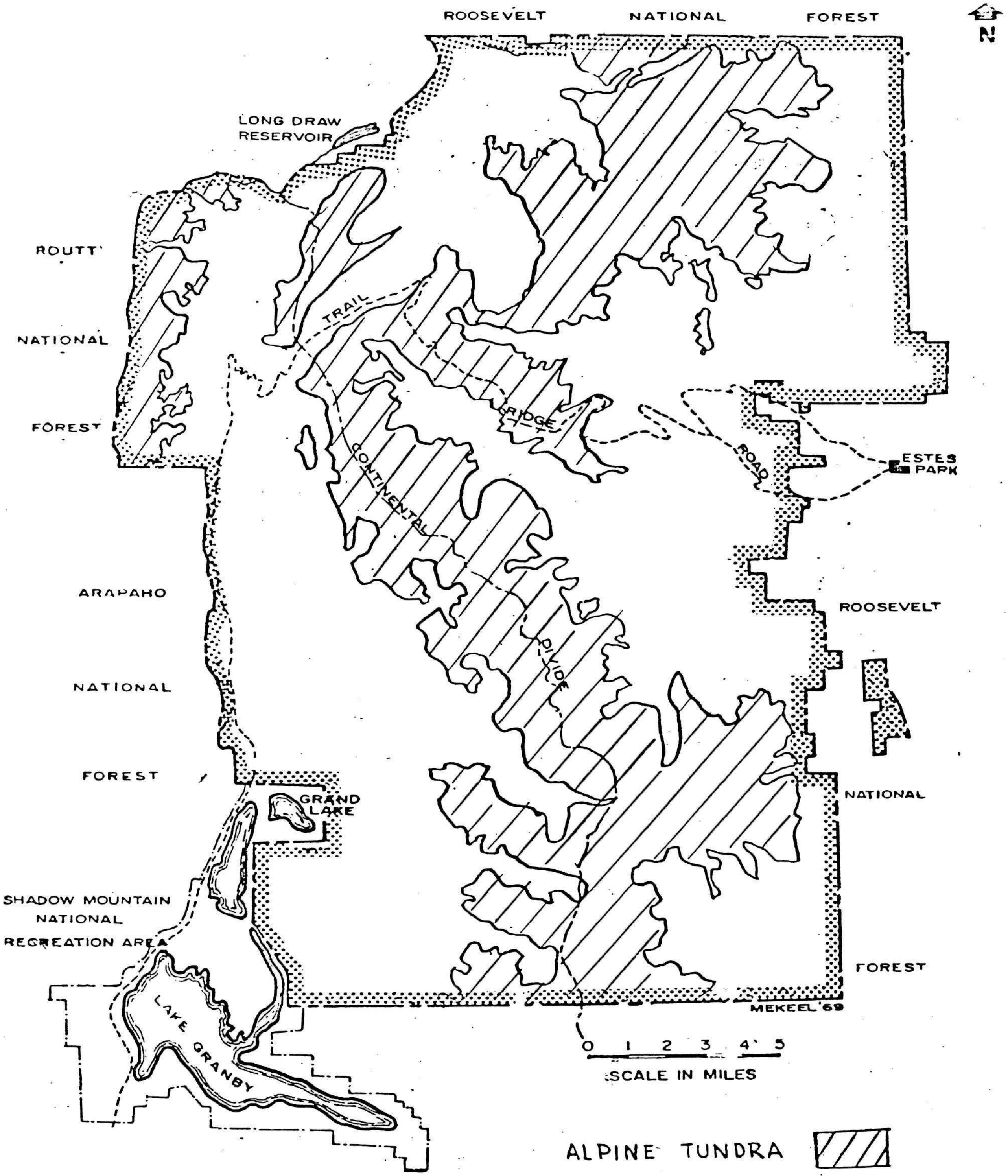
esthetics of the alpine. Several buildings have also recently been removed, leaving scars on the landscape which need to be revegetated. Even in relatively recent development and construction, the effects on adjacent tundra have not received the consideration needed.

The result of these disturbances has been the loss of ground cover and valuable topsoil. The problems of wind and water erosion that plague restoration projects at lower elevations, appear to be considerably more severe over 11,000 feet.

The objective of this paper is to review past restoration efforts, examine the critical environmental factors, and report on studies of what appear to be the most feasible techniques, using modern technology to restore the disturbed sites.

The study area

Rocky Mountain National Park, 412 square miles, lies along the Continental Divide in northcentral Colorado. Elevations range from 7,600 feet to 14,255 feet with about one-third of the total area over 11,000 feet above sea level. Mountains are formed by a series of granitic batholiths intruded into pre-Cambrian mica-schists and pegmatites. The physiography of the east slope is characterized by steep cliffs and U-shaped valleys as altered by local Pleistocene glaciation. The generally more level rolling alpine tundra areas



ROCKY MOUNTAIN NATIONAL PARK

were apparently not glaciated. On the west side, the mountains fall off less steeply to the Colorado River valley at about 9000 feet elevation.

Numerous studies have described the alpine tundra including Kiener (1939), Griggs (1956), and Willard (1963). A good description of the trail ridge is given by Marr and Willard (1971).

The tundra vegetation is characterized by a complex, mosaic of vegetation communities related to physiography, snow accumulation, moisture availability, exposure, temperature, and substrate. Forces of cryopedology as well as other environmental factors also shape the landscape.

The fellfield ecosystem occupies the windiest sites where the soil is coarse, rocks are abundant, and there is no snow cover. The cushion plant fellfield is characterized by plants such as moss campion (Silene acaulis) alpine sandwart (Arenaria obtusiloba), Rocky Mountain nailwart (Paronychia sessiliflora) and dwarf clover (Trifolium nanum). On sites with less rock and some snow cover will be the alpine clover fellfield which is characterized by alpine clover (Trifolium dasyphyllum) along with the cushion plants mentioned above. The mountain dryad fellfield is best developed on gravel sites where mountain dryad (Dryas octopetala) is dominant.

Snowbed ecosystems occur on sites where the snow accumulates for sixty to ninety percent of the year. Vegetation types on these sites include the hairgrass meadow, characterized by hairgrass (Deschampsia caespitosa). The toninia-sibbaldia type is dominated by (Toninia cumulata) and sibbaldia (Sibbaldia procumbens). Another vegetation type common in snow accumulation sites is the Drummond rush type which is characterized by Drummond's rush (Juncus drummondiana).

On sites of high moisture levels such as solifluction terraces, the Rocky Mountain sedge ecosystem is dominant. Characteristic plants are Rocky Mountain sedge (Carex scopulorum), marsh marigold (Caltha leptosepala), and Perry primrose (Primula parryii). On some of these sites a willow type has developed with characteristic willow species of (Salix planifolia), (Salix brachycarpa) and (Salix glauca).

Alpine turf ecosystems are present as persistent vegetation on upland dry sites with good soil formation. They are characterized by Kobresia (Kobresia myosuroides), alpine avens (Geum rossii), sedge (Carex rupestris), and bistort (Polygonum bistortoides).

On zootic ecosystems the characteristic plants are controlled by the activities of small mammals including the pocket gopher (Thomomys talpoides), and voles (Microtus spp).

The tundra environment is cold, windy, and highly variable. Winters are long and cold, summers are short--averaging 40 to 70 days of growing season with hail, sleet, and snow possible year round.

Rocky Mountain National Park is managed as a natural area. Natural resources and processes must remain essentially unaltered. Revegetation projects, therefore, are directed toward duplicating or restoring the natural vegetation composition and structure. The constraints in a natural area mean artificiality should be kept to a minimum. Manipulation of the terrain and vegetation, however, may be carried out to encourage, simulate, or restore natural conditions on lands altered by human activities.

History

Attempts at restoration and revegetation were initiated as early as 1933 in Rocky Mountain National Park. The construction of Trail Ridge Road presented a need for control of erosion along the new route and restoration of the site of the Fall River Road on the west side of the park where it was to be abandoned. The availability of labor from the Civilian Conservation Corps provided manpower for the project. The early efforts were almost entirely a transplanting program. At lower elevations this included shrubs and trees.

In August, 1938, native seeds were collected under the supervision of Dr. H. D. Harrington of Colorado State University. The seed was planted in plots along Trail Ridge Road from 9500 feet at Hidden Valley to 11,800 feet on twenty two plots in September and October. When reported on by Harrington (1946), the experiment was considered a success. Of twenty four species tested, fifteen seemed to offer particular promise. It was concluded that in this experiment, the seeding of denuded areas with native species did help in initiating natural succession of vegetation.

In 1941 one of the most revealing experiments was made in revegetation of the alpine tundra. Approximately 21,000 square yards, or two-thirds of the back slope of Trail Ridge were "spot sodded." Records show 8700 mandays of CCC labor was used to lay tundra sod in spots and strips along Trail Ridge Road. The records are unclear as to the exact technique but vegetative reproduction was expected to fill in the spaces between the spots. Today, however, both the spots and the strips can be seen essentially as they were laid.

In 1958 a study was initiated on the ecosystems of the park to determine the nature and degree of effect of visitors (Marr and Willard, 1970; Willard and Marr, 1970). The five-year study emphasized the alpine tundra. Besides providing excellent data on where and what impact visitors were having, specific data on recovery rates of the tundra without man's aid was obtained. For this purpose two sites, damaged by human use, were fenced to human trespass in order to prevent further disturbance and allow natural recovery.

Studies by Greller (1974) of road cuts and slopes were made to identify plants most successful in occupying newly exposed sites to determine species that provide maximum coverage in the briefest time and to indicate patterns of succession and the extent to which these can be relied upon to repair damaged tundra. His findings indicated extensive human assistance was necessary if road cuts were to be revegetated.

In 1965 the landscaping around the Alpine Visitor Center at Fall River Pass was accomplished by transplanting tundra from areas disturbed by the enlargement of the parking area. This project was very successful and today provides an adequate replica of the undisturbed tundra on similar sites.

Two other studies on lower elevation sites also provided data applicable to the alpine.

In 1969 a short area of cut slope in the subalpine zone above Hidden Valley was restored with two treatments in an attempt to determine a technique to stabilize these areas. One site was laid back to the angle of repose at 1 1/4:1. This required considerable cutting of trees above the slope and removal of fill material. The other treatment built up the slope by using wire gabions to a 1/2:1 slope. Both areas were topsoiled and seeded in the fall. No effort was made to hold the soil against winter winds and, therefore, by spring most of the topsoil was gone along with the seed. Vegetation establishment has been very slow, and today some vegetation is developing at the low edge of both sites.

Another study in 1968 by Gary Jollif attempted to determine techniques of revegetation of deteriorated sites on three roadside campgrounds in the upper montane and subalpine zones. His findings showed critical factors to plant establishment were available nitrogen and soil moisture.

Critical factors

The preceding studies, among others, indicated certain environmental factors that must be considered or compensated for in order for restoration efforts to be successful. These environmental factors do not act independently; they are all interrelated.

Generally, the extreme variability of the alpine environment in almost all aspects is the major difference from lower elevations. This is illustrated by the large number of vegetation types, associations, and stands that are described by most investigators for relatively small areas of tundra (Marr, 1962). Each site is unique, based on geologic substrate, exposure, slope, elevation, and glacial history, and how these factors affect other environmental characteristics.

Soil on the alpine varies from large rocks to fine silty clay. The need of soil for plant growth is well established and is no different for the alpine tundra. Usually soil is lost through wind and water erosion on disturbed sites. The primary consideration in relation to soil is its stability. Plants cannot be established if the substrate is constantly moving or eroded away. The depth of the organically rich layer must be maintained to at least what would be naturally present at the site. Willard (1976) estimated 500 to 1000 years to build an inch of topsoil. This is related to the slow breakdown of organic matter because of the low temperatures in the alpine (Holch *et al*, 1941). Greller (1970) stated that stabilization, increased soil moisture, and increased organic matter greatly facilitated colonization of denuded sites. This was also confirmed by Brown (1976). The water holding capability of the soil is also improved by adding organic matter as mulch.

Soil fertility can also be limiting under alpine conditions. Nishimura (1974) stated that "nitrogen can be limiting in the alpine environment and that cold soils were found to inhibit the absorption of phosporus." He recommended a soil survey be made to determine the need for fertilization. Brown (1976) found productivity 100 times greater where fertilized over a three year period.

The effects of wind may be the most important factor that needs to be considered. Glidden (1974) showed that Trail Ridge may have some of the most extreme wind conditions known. During the period January to May, 1974, 44% of the days had winds greater than 74 miles per hour (hurricane force), and 14% had over 100 miles per hour. The top wind speed recorded was 155 miles per hour. The summers are considerably less windy. Marr and Willard (1971) measured mean wind speeds of 26 mph in December but only 10 mph in July. These effects must be compensated for in restoration projects in order to hold the soil, seed, mulch, and protect from mechanical damage. Wind blown snow and sand can be especially damaging to vegetation. Desiccation from the wind also reduces the effective moisture level and dries out denuded soil rapidly. In winter it lowers the ambient temperature generally maintained by soil radiation.

Wind in relation to physiography of the terrain is responsible for snow accumulation. The distribution and depth of snow in accumulation areas is the factor primarily responsible for the mosaic of vegetation types. The depth of snow cover on the vegetation provides different micro-environments, shortens the growing season, and provides a source of moisture as it melts. Snow also moderates the winter temperature extremes.

Moisture comes to the alpine in the form of snow in the winter and generally thunderstorms in the summer. Summer thunderstorms can be especially severe, causing soil movement and erosion. Marr and Willard (1970) measured a mean annual precipitation of 25 inches with the maximum mean of 3 inches in August. The driest month was October. Bell (1975) reported drouth conditions in June and stated that soil moisture may be limiting at any season.

Some of the most important factors to restoration is the relation of soil moisture and temperature. The formation of "needle ice" as described by Marr (1962) may be an important factor in seedling establishment. As the subsurface moisture freezes on bare areas, it forms long ice crystals that force the surface up. This action disturbs or breaks off the fragile roots of seedlings, causing them to die when the ice melts. Frost heaving can also disturb established vegetation, but it apparently is not as severe because of the insulation provided by the plants themselves.

Temperature extremes are common on the tundra, especially in summer. Bell (1975) measured a maximum change of 14°F in two minutes. These changes may be even more extreme on the surface of organically rich black soil which is open to radiation (Willard and Marr, 1971). They found that bare humus soil of the A horizon supported the fewest seedlings when compared to the B and C horizons and concluded that this was because of needle ice activity in the spring and fall and desiccation under higher summer temperatures. The growing season on the tundra is as short as 45 days (Marr, 1961) with snow possible any day of the year.

The source of seed for restoration efforts is important. If seeds are available, the native alpine plants have evolved over millions of years and should be better adapted to the environment. Brown (1976) results confirmed this on the beartooth plateau. Reports by Cox (1933), Griggs (1956), Osburn (1961), Greller (1974) and Willard (1971) would indicate that seeds are present in sufficient numbers on the alpine to revegetate disturbed sites. Holch et al (1941) and Bell (1975), however, indicate that this may not be the case with at least some species. Brown stated that of the 200 plant species found, less than 10% were active colonizers.

Plant succession, if it occurs at all, must be very slow on the alpine. As stated by Willard (1971), "secondary succession back to a climax kobresia stand is tediously slow; there are no precise data on time intervals, but our joint studies and those of Griggs (1956) Osburn (1958) and Willard (1960-63) all indicate it will take at least several hundred and possibly even a thousand years for ecological processes to produce a persistent (climax) ecosystem." Greller (1975) indicated that plant succession plays a minor role on the road slopes. He also emphasized the importance of stabilization to the establishment of early successional plants.

Present studies

In 1975, on the site where several buildings were removed from the tundra, a study of restoration techniques was initiated. The site is essentially a fellfield ecosystem. Using results from the aforementioned studies and revegetation efforts, a plan of experimental plots was worked out. The primary objective of the project was to test various techniques which appeared to offer some solution to the previously mentioned problems essentially unique to the alpine environment. A secondary objective was to develop a vegetation cover on the site which resembled, at least superficially, the undisturbed tundra. The adverse effects of water and wind erosion, along with temperature extremes, are being reduced through snow fences, burlap mat, and aspen mat. Topsoil was added on several plots, with and without mulch. Mulch was cut from similar sites of alpine tundra in an attempt to include some native plant seeds. No other seeds were planted, assuming the seeds would be available. Fertilizer, mostly nitrogen, was added to some plots. All were treated in September 1975 and water was added initially.

Initial results are encouraging. There was no lack of seedlings the first summer. Many, however, were normal invaders from lower elevations such as Rumex spp. and Chenopodium spp., and may have been imported with the topsoil. Survival of these in succeeding growing seasons will be measured.

This year another site disturbed by vehicle encroachment at Fall River Pass was treated using similar techniques. This site is primarily alpine turf with considerable kobresia. Based on one year's data, the use of burlap to control erosion was not duplicated, but a jute mesh was used instead. The progress of both plots will be monitored both photographically and quantitatively. These studies, however, are considered to be long term with no meaningful results expected for several years.

Conclusions

One of the conclusions of about 40 years of revegetation efforts in Rocky Mountain National Park is that to restore high elevation alpine tundra land requires considerable effort and assistance by man. We find that the best management is protection of the resource before damage exceeds what is naturally repairable. As stated by Bell (1975), "It seems prudent to consider kobresia meadow effectively irreplaceable and to preserve them intact." In the case of visitor trampling, this is being accomplished by channeling the visitor activities with fences, paved walkways, and trails. Education programs also must be utilized to inform the visitor of the seriousness of the loss of tundra vegetation. However, we realize some damage is still going to occur and periodically restoration, if possible, will be necessary.

Experience has demonstrated that transplanting natural tundra turf (from a similar site) is the most successful technique to restore damaged sites. The major problem is that there is usually no source of tundra turf for transplanting purposes without damaging other areas. Without tundra for transplanting, a technique to regenerate alpine tundra must still be developed. This is the major challenge in the management of alpine tundra today. Results of the present studies take time, and tundra revegetation, even with the best assistance available, is going to be a slow, tedious process.

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