Plant Inventory, Succession, and Reclamation Alternatives on Disturbed Lands in Grand Teton National Park

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Abstract—Sixteen study areas ranging in size from 12 to 870 hectares were selected for inventory and analysis in sagebrush-grass, meadow, and lodgepole pine plant communities. All study areas had some human-induced disturbance, ranging from grazing to intensive agriculture, prior to incorporation into the National Park System. Vegetation data including density and cover were collected. Disturbance values (D) were determined for each study area and compared among the study areas by a method that considered frequency, density, and life form, in eight different significance classes. Soils were characterized for each study area. All study areas had good vegetative cover, but badly disturbed sites were virtually covered with exotic, aggressive grass species (mainly smooth brome and Kentucky bluegrass). Management options are suggested that could restore the disturbed sites to more natural conditions. Some of these options would require chemical or mechanical eradication of existing vegetation, followed by seeding or transplanting native stock. Natural succession to the pre-agricultural vegetative state could take centuries or may not occur at all without human intervention.

Grand Teton National Park is located in northwestern Wyoming (fig. 1). It is dominated by the magnificent Teton Mountain Range of the Rocky Mountain System. The Teton Range, an upthrown fault block, forms the western half of the Park (National Park Service 1984). The balance of the Park is a downthrown, sediment filled, fault block known as Jackson Hole. The Snake River flows through Jackson Hole where it is joined by several smaller tributaries. There are several lakes in Jackson Hole including Jackson Lake, which was enlarged by a dam constructed several decades ago to increase water storage for downstream irrigation purposes.

The lands disturbed by human agency in Grand Teton National Park are found in Jackson Hole. The Teton Range is so rugged it remains largely undisturbed except for ski, cabin, and road development. These developments are outside the Park.

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The vegetation of Jackson Hole consists of a patchwork of communities. Clark (1981) listed several principal riparian (aquatic, shrub-swamp, willow) and valley (meadow, sagebrush) plant communities for Jackson Hole. Upland communities, those above the valley floor, include juniper, aspen, lodgepole pine, Douglas fir, spruce-fir, and alpine (Clark 1981). The upland types most prone to human disturbance are the lower elevation, open parks amid the sagebrush, juniper, aspen, and lodgepole pine communities. The main disturbance sites in the Park have resulted from livestock grazing, hayfield and pasture development, and small grain farming by private interests before the Park was established. Other disturbances resulted from Park management activities, such as the establishment of pastures for holding horses and buffalo (bison) and camp construction. The main disturbance areas are on the valley floor and lower slopes.

Grand Teton National Park, as presently constituted, derived from the original Grand Teton National Park of 1929 (the Teton Range) and incorporation of the Jackson Hole National Monument in the Park in 1950 (Stark 1984). The National Monument was established in 1943 and included the Jackson Hole Valley areas currently in the Park (Stark 1984). The John D. Rockefeller, Jr. Memorial Parkway is a land corridor connecting Grand Teton and Yellowstone National Parks that is administered by the National Park Service (fig. 1).

The National Park Service mandate is, in part, to preserve natural ecosystems for the education and enjoyment of future generations. To that end we obtained a competitive grant from the University of Wyoming/National Park Service Research Center to meet the objectives described in this report:

1) describe the composition and abundance of woody and herbaceous species on moderately and severely disturbed sites (study areas),

2) describe the soils of the study areas, and

3) make recommendations for restoration of native plant communities based on ecological principles and agronomic properties of existing and desired vegetation.

Methods

Field work was performed during the 1985 field season. Sixteen areas were selected for study after reconnaissance visits and consultation with National Park Service personnel. Seven of these areas had been farmed or ranched and

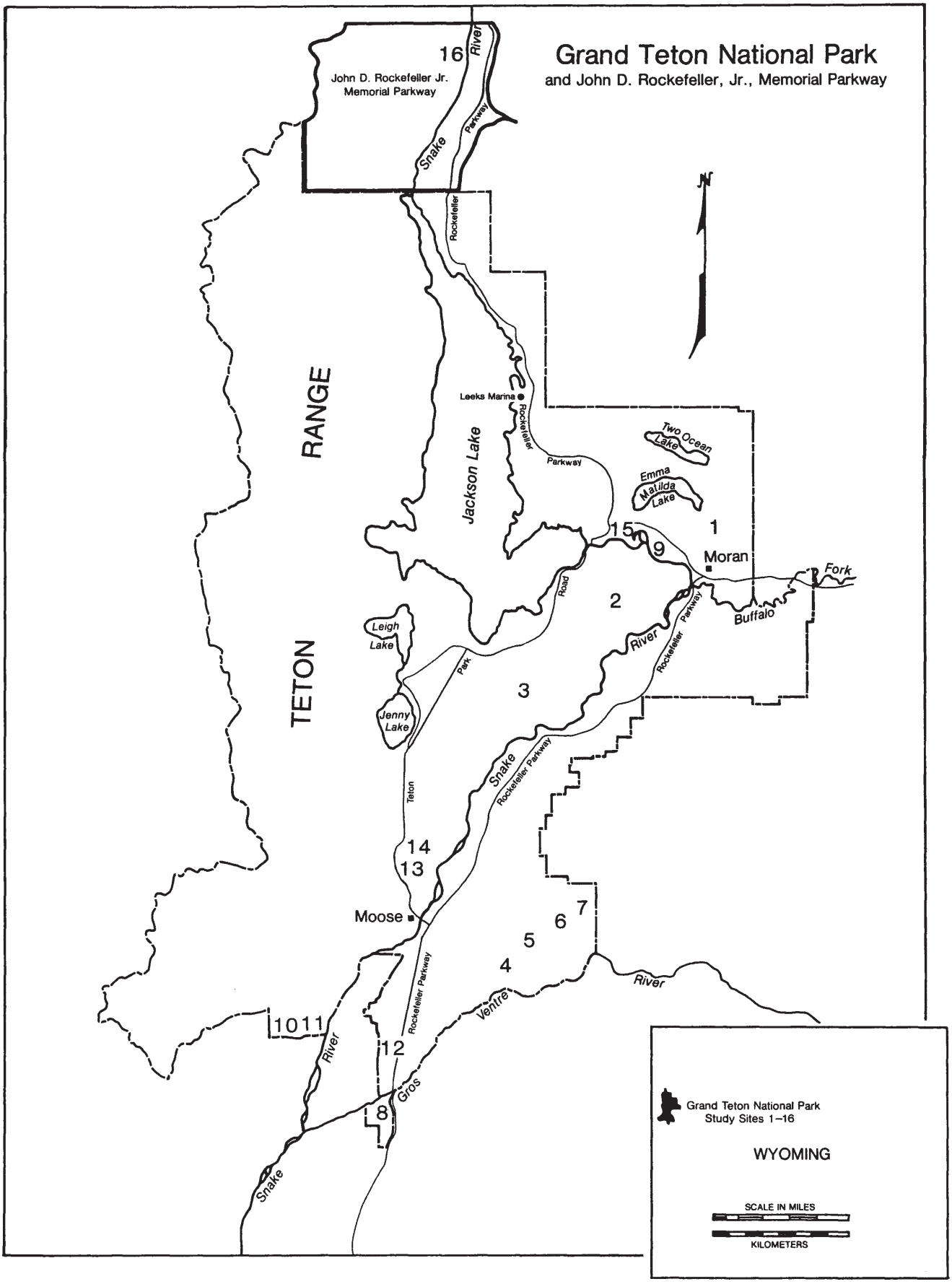

Figure 1—Grand Teton National Park Study Areas.

Table 1—Study areas used to assay disturbance of plant communities in Grand Teton National Park

Number	Name	Location	Size (hectares)	Year of last major disturbance	Approximate species	
					Number	Percent introduced
1	Three Rivers Ranch	T45N, R114W Sec. 13, 14	35	[1]1949	36	33.3
2	Cow Lake	T45N, R114W Sec. 28,29,32,33	180	1957	45	4.2
3	Pot Holes	T44N, R115W Sec. 1-3,10-15,22,23	870	1957	48	2.1
4	Mormon Row Hayfields	T42-43, R115W Sec. 3-5,32,33	445	1974	16	56.2
5	Mormon Row Sagebrush	T43N, R115W Sec. 34	145	1950	41	17.1
6	Clark Moulton Sagebrush	T43N, R115W Sec. 35	65	1930	41	4.9
7	Clark Moulton Dry Farm	T43N, R115W Sec. 26	65	1979	20	50.0
8	Abercrombie Warm Sprs. Ranch	T41-42N, R116W Sec. 2,35	95	1975	33	15.1
9	Buffalo Pasture	T45N, R114W Sec. 16,21	30	1970	64	9.4
10	Aspen Ranch Corp.	T42N, R116W Sec. 17,18	13	[1]1969	13	38.5
11	Rocky Mountain Energy Corp.	T42N, R116W Sec. 17	40	1970	49	12.2
12	Heim Hayfield	T42N, R116W Sec. 23	15	1949	8	50.0
13	Cottonwood Creek Hayfield	T43N, R116W Sec. 13,14	30	1930	35	22.9
14	Cottonwood Creek Sagebrush	T43N, R116W Sec. 13	[2]135	1950	38	7.9
15	Oxbow Bend Horse Pasture	T45N, R114W Sec. 17	15	1975	50	16.0
16	Huckleberry Hot Springs	T48N, R115W Sec. 20	12	1983	74	16.2

[1]Trespass grazing continues.
[2]Stand is much larger, extending into R115W and into sections 7, 12, 18, 24, but we sampled only from section 13.

had been disturbed by plowing and/or had sustained heavy grazing. One area was a former campground. Two areas were formerly fenced Park Service pastures for horses or buffalo, and six were formerly grazed by livestock but in recent years had received only occasional trespass grazing (table 1). Twelve of the study areas were sagebrush-grass sites or had been sagebrush grass sites before disturbance; three were meadow sites, and one was a lodgepole pine site. These study areas ranged in size from 12 to 870 hectares.

Each study area was subdivided into five or more equal parts. These site divisions were sections (section = 640 acres or 259.1 hectares) wherever possible (the large sites), quarter sections (64.8 hectares) on smaller sites, and five more or less equal subdivisions on the smallest sites. A 50-m line transect was established in each of five subdivisions at each site. Where there were more than five subdivisions, the five chosen were selected by random means. The starting points and compass directions for each transect were also determined by random means within the typical homogeneous vegetation matrix of each study area. Ditches and edges and other non-typical areas were avoided. Starting points on each transect were marked by iron rebar stakes and recorded on U.S. Geological Survey topographic maps (7.5 minute, 1: 24,000 scale) stored at the Shrub Sciences Laboratory and at the Rocky Mountain Regional Office of the National Park Service, Denver, Colorado. The vegetation along the transects was characterized by placing 1 m^2 quadrats on alternate sides of the transect every 5 m beginning at the transect starting point. Thus, data were collected from 10 quadrats from each subdivision and 50 from each study area.

The data collected included the number of individuals of each plant species within the quadrat (density); the cover class of each species and litter, rock, bare ground, and cryptogams; and the aspect, slope, and direction of each transect. For dense intermixed stands of rhizomatous or clonal species the number of ramets or stems was estimated by converting the mean cover values to stem numbers obtained from 10 closed stand values (table 2). Species were identified and classed as annuals, biennials, or perennials and whether they were native to the Park, native to North America, or alien following Cronquist and others (1972, 1977, 1984), Hitchcock and Cronquist (1973), and Shaw (1976) (table 3, McArthur and others 1986). Species cover

Table 2—Number of stems for rhizomatous species. Means are based on ten 625 cm^2 (96.9 in^2) samples per species in pure stand sample sites

Species	Number of stems per m^2 mean + se	range	Sample sites
Bromus inermis	635.6 + 21.2	552- 736	Heim Hayfield (3), Mormon Row Hayfield (7)
Poa pratensis	980.0 + 53.7	728-1,172	Heim Hayfeld (3), Mormon Row Hayfield (7)
Aster chilensis ssp. *adscendens*	249.6 + 17.6	176- 332	Aspen Ranch (10)
Smilicina stellata	223.6 + 28.8	116- 392	Huckleberry Hot Springs (4), Cow Lake (6)

Table 3—Master species list. Numbers in Table header: 1-16 are the sites (table 1) with x = taxon present, 17, Longevity; 1 = Annual, 2 = Biennial, 3 = Biennial-perennial, 4 = Perennial; 18, Distribution; 1 = Native, 2 = Exotic (from NA), 3 = Exotic (extra-NA). References: Anderson 1986; Cronquist and others 1972, 1977, 1984; Hitchcock and Cronquist 1973; Shaw 1976

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
GRASSES:																		
Agropyron trachycalum (*A. caninum* var. var, *majus*)				x	x	x	x	x	x		x	x	x	x	x	x	4	1
Agropyron caninum var. *unilaterale*																x	4	1
Agropyron cristatum								x		x							4	3
Agropyron repens					x												4	3
Agropyron smithii					x			x	x		x		x				4	1
Agropyron spicatum		x	x		x	x		x			x			x			4	1
Agrostis alba var. *alba* (*A. stolonifera*)																x	4	3
Agrostis scabra var. *geminata*																x	4	1
Agrostis scabra var. *scabra*									x								4	1
Bromus carinatus var. *carinatus*				x												x	4	1
Bromus carinatus var. *linearis*													x	x	x		4	1
Bromus inermis	x			x	x		x	x	x	x	x	x	x	x	x	x	4	3
Calamagrostis stricta									x								4	1
Calamagrostis rubescens						x	x										4	1
Dactylis glomerata	x			x									x				4	3
Danthonia intermedia		x	x													x	4	1
Danthonia unispicata														x			4	1
Deschampsia caespitosa									x							x	4	1
Deschampsia sp.									x								4	1
Elymus glaucus																x	4	1
Festuca idahoensis		x	x			x			x		x					x	4	1
Festuca ovina var. *rydbergii*		x	x														4	1
Hordeum brachyantherum	x								x								4	1
Koeleria macrantha (*K. nitida*)	x	x	x		x			x	x		x		x	x		x	4	1
Melica bulbosa		x														x	4	1
Melica spectabilis											x			x			4	1
Phleum pratense	x				x				x						x	x	4	3
Poa cusickii var. *cusickii*			x											x			4	1
Poa compressa															x		4	3
Poa juncifolia						x		x									4	1
Poa nevadensis								x									4	1
Poa pratensis	x	x		x	x	x	x	x	x	x	x	x		x	x	x	4	3
Poa palustris					x				x								4	1
Poa secunda		x															4	1
Poa sp.			x														4	?
Sitanion hystrix var. *hystrix*			x											x			4	1
Stipa columbiana		x	x		x	x		x	x					x		x	4	1
Stipa comata			x		x			x									4	1
Stipa lettermanii		x	x								x			x		x	4	1
Stipa occidentalis															x		4	1
Trisetum spicatum																x	4	1
Trisetum wolfii									x								4	1

(con.)

Table 3 (Con.)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
GRASS-LIKE SPECIES:																		
Carex athrostachya	x								x							x	4	1
Carex douglasii	x																4	1
Carex geyeri																x	4	1
Carex hoodii							x										4	1
Carex lanuginosa									x						x	x	4	1
Carex petasata															x		4	1
Carex praegracilis									x						x		4	1
Carex rossii		x	x		x	x		x	x					x	x		4	1
Carex vallicola		x					x		x		x			x		x	4	1
Juncus balticus									x								4	1
Luzula campestris	x																4	1
FORBS:																		
Achillea millefolium ssp. *lanulosa*	x	x			x	x		x	x	x	x		x		x	x	4	1
Agoseris glauca		x	x			x			x						x	x	4	1
Allium geyeri var. *tenerum*									x								4	1
Androsace septentrionalis	x										x						4	1
Antennaria microphylla (*A. rosea*)	x	x	x		x	x	x	x			x		x	x	x	x	4	1
Arabis cobrensis											x		x	x			4	1
Arabis drummondii		x	x		x						x			x	x	x	4	1
Arabis holboellii var. *retrofacta*		x	x		x	x		x			x		x		x	x	3	1
Arabis sp.			x														?	?
Arenaria congesta		x	x										x	x		x	4	1
Arnica chamissonis ssp. *foliosa*	x								x								4	1
Artemisia ludoviciana var. *ludoviciana*										x					x		4	1
Aster campestris									x						x		4	1
Aster chilensis ssp. *adscendens*				x	x	x	x	x		x	x	x	x				4	1
Aster hesperius var. *laetevirens*									x						x	x	4	1
Aster integrifolius									x		x		x			x	4	1
Aster perelegans						x											4	1
Astragalus agrestis (*A. dasyglottis*)															x		4	1
Astragalus convallarius						x											4	1
Astragalus miser						x					x						4	1
Astragalus miser var. *hylophilus*					x												4	1
Balsamorhiza sagittata			x		x						x			x			4	1
Camissonia subacaulis									x								4	1
Campanula rotundifolia		x	x												x	x	4	1
Capsella bursa-pastoris																x	1	3
Carduus nutans							x										2	3
Castilleja flava						x								x			4	1
Castilleja pilosa (*C. longispica*)		x	x												x		4	1
Cerastium arvense			x						x					x		x	4	1
Cerastium vulgatum	x																3	3
Chenopodium album	x			x			x				x		x				1	3
Cirsium arvense				x			x			x						x	4	3
Cirsium scariosum (*C. foliosum*)									x						x	x	4	1
Collinsia parviflora	x																1	1
Collomia linearis	x	x	x	x					x				x	x	x	x	1	1
Comandra umbellata var. *pallida*		x	x		x	x					x			x			4	1
Cordylanthus ramosus					x	x											1	1
Crepis acuminata		x	x								x				x	x	4	1
Delphinium nuttallianum		x			x				x								4	1
Delphinium occidentale									x								4	1
Draba crassifolia																x	3	1
Dracocephalum parviflorum (*D. nuttallii*)				x													4	1
Epilobium angustifolium																x	4	1
Epilobium glandulosum																x	4	1
Epilobium minutum													x				1	1
Epilobium paniculatum													x		x	x	1	1
Epilobium watsonii									x								4	1

(con.)

Table 3 (Con.)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FORBS:																		
Equisetum laevigatum	x								x						x	x	4	1
Erigeron divergens											x						3	1
Erigeron eatonii		x	x												x		4	1
Erigeron glabellus	x																3	1
Erigeron pumilus ssp. *intermedius*			x														4	1
Erigeron pumilus		x			x		x	x			x						4	1
Erigeron speciosus var. *macranthus*															x		4	1
Eriogonum caespitosum								x									4	1
Eriogonum umbellatum		x	x		x	x		x		x	x		x	x	x	x	4	1
Eriophyllum lanatum var. *integrifolium*		x	x						x								4	1
Erysimum cheiranthoides									x								1	1
Fragaria vesca var. *bracteata*											x						4	1
Fragaria virginiana var. *glauca*									x							x	4	1
Frasera speciosa						x											2	1
Fritillaria pudica		x											x	x			4	1
Galium boreale											x						4	1
Galium trifidum									x						x		4	1
Galium triflorum																x	4	1
Gayophytum nuttallii													x	x	x	x	1	1
Geranium richardsonii						x											4	1
Geranium viscosissimum var. *viscosissimum*						x			x						x	x	4	1
Geum macrophyllum var. *perincisum*									x							x	4	1
Geum triflorum		x				x											4	1
Geum triflorum var. *ciliatum*			x														4	1
Gilia aggregata var. *aggregata*											x						3	1
Helianthella quinquenervis									x								4	1
Lactuca pulchella						x									x		4	1
Lactuca serriola							x										2	3
Lappula redowskii								x									1	2
Lepidium campestre	x														x		1	3
Lepidium densiflorum var. *densiflorum*											x		x				1	1
Lepidium densiflorum var. *pubicarpum*	x												x			x	1	1
Lepidium virginicum var. *pubescens*																x	1	1
Linanthus harknessii	x	x	x					x	x	x	x		x	x	x	x	1	1
Linaria vulgaris													x				4	3
Linum perenne var. *lewisii*		x			x						x						4	1
Lithospermum ruderale					x	x											4	1
Lomatium ambiguum			x														4	1
Lupinus polyphyllus															x	x	4	1
Lupinus sericeus var. *sericeus*		x	x		x	x		x			x	x	x	x		x	4	1
Lychnis alba													x				3	3
Machaeranthera canescens			x											x	x		3	1
Madia glomerata													x				1	1
Medicago lupulina											x					x	1	3
Medicago sativa	x			x			x					x					4	3
Melilotus officinalis						x											2	3
Mertensia oblongifolia								x									4	1
Microseris nutans		x	x											x			4	1
Orobanche fasciculata														x			4	1
Orthocarpus luteus		x															4	1
Penstemon procerus								x	x								4	1
Perideridia bolanderi													x	x			4	1
Perideridia gairdneri		x	x						x						x	x	4	1
Phlox hoodii			x		x			x			x						4	1
Phlox longifolia				x	x	x					x		x				4	1
Phlox multiflora																x	4	1
Polygonum aviculare																x	1	3
Polygonum bistortoides									x								4	1
Polygonum douglasii	x	x	x		x	x			x	x	x		x	x	x	x	1	1
Potentilla arguta var. *convallaria*					x	x	x		x						x		4	1
Potentilla gracilis var. *elmeri*	x								x						x		4	1

(con.)

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Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FORBS:																		
Potentilla gracilis var. *glabrata*									x	x	x				x	x	4	1
Ranunculus inamoenus	x																4	1
Rorippa curvisiliqua	x								x								2	1
Rorippa palustris (*R. islandica*)									x								2	1
Rumex salicifolius	x																4	1
Rumex acetosella	x												x				4	3
Rumex occidentalis									x								4	1
Rumex venosus		x															4	1
Sedum lanceolatum			x		x						x			x			4	1
Sedum stenopetalum			x														4	1
Selaginella densa		x	x														4	1
Senecio integerrimus		x															4	1
Senecio sphaerocephalus																x	4	1
Senecio streptanthifolius (*S. cymbalariodies*)						x											4	1
Smilicina stellata																x	4	1
Solidago canadensis var. *salebrosa*																x	4	1
Solidago spathulata								x								x	4	1
Spergularia rubra																x	1	3
Stellaria calycantha									x								4	1
Stellaria crassifolia																x	4	1
Stellaria sp.		x	x														?	?
Taraxacum officinale	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	4	3
Thalictrum occidentale									x								4	1
Thlaspi arvense	x			x			x		x						x		1	3
Tragopogon dubius	x			x	x		x				x		x		x	x	2	3
Trifolium hybridum	x								x								4	3
Trifolium longipes var. *reflexum*									x						x	x	4	1
Trifolium praetense	x																4	3
Trifolium repens	x															x	4	3
Valeriana edulis									x								4	1
Valeriana occidentalis									x							x	4	1
Veronica serpyllifolia var. *huifusca*	x															x	4	1
Vicia americana				x													4	1
Viguiera multiflora var. *multiflora*					x	x					x		x				4	1
Viola adunca																x	4	1
Viola nuttallii var. *praemorsa*		x															4	1
Zigadenus paniculatus			x														4	1
Unidentified annuals and seedlings	x	x	x		x	x	x		x		x	x	x	x	x		?	?
Avascular cryptogams	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	?	?
SHRUBS:																		
Artemisia arbuscula ssp. *arbuscula*														x			4	1
Artemisia cana ssp. *viscidula*									x						x		4	1
Artemisia frigida								x									4	1
Artemisia tridentata ssp. *vaseyana*		x	x		x	x	x	x		x	x			x	x		4	1
Artemisia tripartita			x			x		x									4	1
Berberis repens					x						x					x	4	1
Chrysothamnus nauseosus ssp. *graveolens*[2]						x		x									4	1
Chrysothamnus viscidiflorus						x											4	1
Chrysothamnus viscidiflorus ssp.*puberulus*			x		x			x			x						4	1
Pachystima myrsinites																x	4	1
Prunus virginiana var. *melanocarpa*											x						4	1
Purshia tridentata					x						x						4	1
Rosa woodsii						x											4	1
Symphoricarpos oreophilus var. *utahensis*					x	x					x						4	1
Tetradymia canescens								x									4	1
TREES:																		
Pinus contorta																x	4	1

[1]Cronquist and others, 1972, 1977, 1984.
[2]Anderson (1986) lists *C. n.* ssp. *glabratus* as a synonym of ssp. *graveolens*.

was estimated visually into the following cover classes: 1 = 1 - 5 percent, 2 = >5 - 25 percent, 3 = >25 - 50 percent, 4 = >50 - 75 percent, 5 = >75 - 95 percent, and 6 >95 percent, modified from Daubenmire (1959). Photographs were also taken of each transect (fig. 2).

Soils at the sites were characterized by bulked soil samples that were analyzed for pH, cation exchange capacity (CEC), percent organic matter, electrical conductivity (EC), sodium adsorption ratio (SAR), nitrate nitrogen, phosphorus, potassium, zinc, iron, manganese, copper, calcium, magnesium, and sodium (Black 1968; Page 1982) and by reference to Young (1982).

Plant specimens collected in the Park were identified and curated. Specimens were deposited in the herbaria of Snow College, the Shrub Sciences Laboratory (SSLP), and Grand Teton National Park.

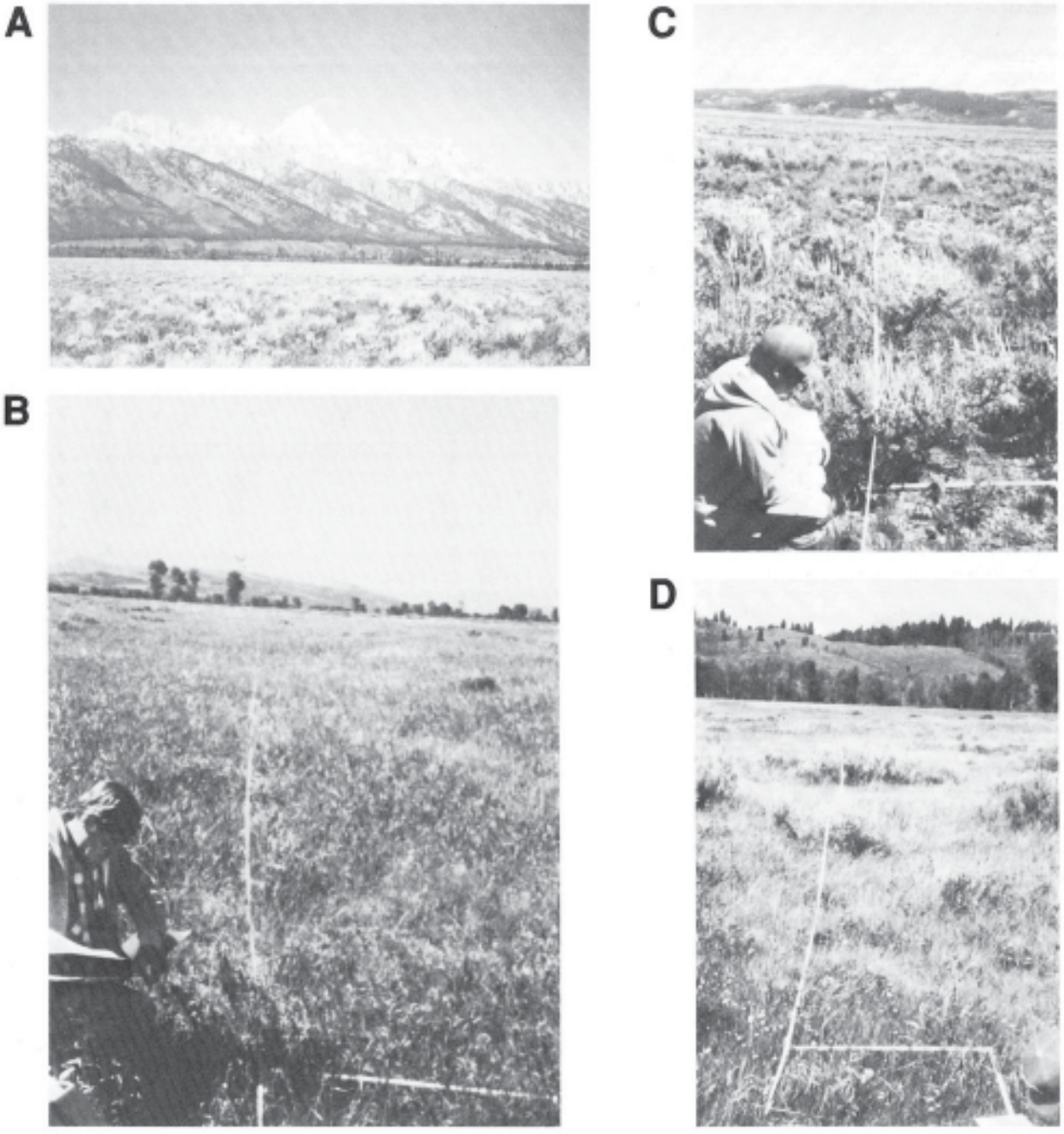

Figure 2—Photographs of Grand Teton National Park Study Areas.

A. Jackson Hole with Teton Range in the background. Note mountain big sagebrush in the immediate foreground, the Snake River channel in the mid foreground, and lodgepole pine on the terraces at the base of the Teton uplift.
B. Transect on Study Area 12, Heim Hayfield.
C. Transect on Study Area 14, Cottonwood Creek Sagebrush.
D. Transect on Study Area 15, Oxbow Bend Horse Pasture.

A site disturbance value was determined by the formula:

$$\text{Disturbance Value (D)} = \frac{\text{Sum [Cover} * \text{(Longevity - Origin Scores)]}}{\text{Number of Species}}$$

Where longevity scores are 1 = annual, 2 = biennial, 3 = biennial to perennial, and 4 = perennial. Origin scores are 1 = native to Grand Teton National Park, 2 = exotic to the Park but native to North America, and 3 = exotic to North America (see table 3). Disturbance values were arcsine transformed and subjected to one way analysis of variance (SAS 1988). Differences between mean values of study areas were determined by the SNK multiple means comparison test.

Under this formulation, original with us, disturbance values rise with increasing frequency of short-lived and exotic plants and with declining cover values and fewer species.

Possible rehabilitation options for each site were determined by reconnaissance visits to the sites and consideration of actions based on our previous experience (McArthur 1988; McArthur and others 1987; Monsen and Shaw 1983; Monsen and Stevens in review; Plummer and others 1968).

Results and Discussion

Our results and discussion focus on: 1) the vascular plants and their distribution in relation to plant community composition, disturbance, and soil factors, and 2) options for restoration to more natural plant communities on the disturbed sites.

Community Types, Disturbance, and Succession

The principal community types of the Jackson Hole valley floor are sagebrush-grass, meadow, and riparian. We did not work in the riparian communities and did only minimal work in upland communities above the valley floor. Our charge was to characterize larger areas, disturbed by human activities; these were in sagebrush-grass, meadow, and lodgepole pine communities. Twelve of our study areas were in sagebrush-grass (study areas 2 - 8, 10 - 14 of table 1), three in meadows (1, 9, 15), and one in lodgepole pine (16). The type of disturbances, years of natural recovery, and disturbance values are given in table 4. The disturbance values

Table 4—Study area disturbance history with disturbance values

Site		Species[1]			Cover[2]		Disturbance	Recovery	Disturbance
No.	Name	No.	Ave.	Intro.	Sum	Sum/spp.	value[3]	years to 1985	type
2	Cow Lake	45	17.5	2	31.3	1.76	0.10 A	28	Grazing
3	Pot Holes	48	11.6	1	22.5	1.93	0.21 A,B	28	Grazing
14	Cottonwood Creek Sagebrush	38	11.1	3	20.7	1.87	0.30 A,B,C	35	Grazing
11	Rocky Mountain Energy	49	12.4	6	25.5	2.05	0.34 A,B,C	15	Grazing
9	Buffalo Pasture	64	12.5	6	28.5	2.27	0.53 B,C,D	15	Grazing, fencing
5	Mormon Row Sagebrush	41	7.6	7	19.9	2.62	0.57 B,C,D	35	Grazing
6	Clark Moulton Sagebrush	41	7.4	2	19.6	2.65	0.71 C,D	55	Grazing
15	Oxbow Bend Horse Pasture	50	6.6	8	15.2	2.31	0.93 D	11	Grazing, fencing
16	Huckleberry Hot Springs	74	9.5	12	19.1	2.00	0.94 D	2	Campground
8	Abercrombie Warm Springs	33	5.6	5	14.1	2.52	1.53 E	10	Hayfield, pasture
13	Cottonwood Creek Hayfield	35	5.5	8	11.0	2.02	1.66 E,F	55	Hayfield
1	Three Rivers Ranch	36	6.4	12	13.4	2.09	1.98 F	36	Cleared, grazing
10	Aspen Ranch	13	3.8	5	10.2	2.68	2.00 F	16	Pasture, grazing
4	Mormon Row Hayfield	16	3.2	9	10.1	3.16	2.64 G	11	Hayfield
12	Heim Hayfield	8	2.2	4	7.9	3.58	3.54 H	36	Hayfield
7	Clark Moulton Dry Farm	20	3.3	10	9.3	2.82	3.60 H	6	Hayfield, dry farm

[1]No. = total number of species on the study area quadrats. Ave. = the average number of species per quadrat. Intro. = number of introduced species on the study area quadrats.

[2]Sum = total average cover class value per quadrat summed for all species. Both high cover class values and number of species contribute to this number, which therefore is not meaningful by itself. Sum/spp. = total average cover class per quadrat summed for all species divided by average number of species per quadrat. This number reflects relative cover per quadrat.

[3]Different letters in this column among study areas indicate significant differences ($P < 0.05$) in disturbance values by the SNK means comparison test.

were highest where the land had been cleared and hayfields and pastures were established. Values were much lower where grazing was the principal disturbance. Length of natural recovery time (= secondary succession) did not provide apparent compensation for the severity of the type of disturbance in all cases, for example, study areas 1, 12, 13, but did appear to be important in study areas 2, 3, 14 (table 4). Disturbance values ranged from 0.10 for Cow Lakes (grazing disturbance only and protected since 1950 to 3.60 for Clark Moulton Dry Farm (converted to a hayfield and dry farm and protected from disturbance since 1979).

The 16 study sites included eight classes of significant difference in disturbance values. Study areas that were grazed only, grazed and fenced, or grazed, fenced, and seeded without being completely cleared of preexisting vegetation composed the first four disturbance classes (A-D of table 4). The campground disturbance (Huckleberry Hot Springs, study area 16) was also in this group (disturbance class D). This area was mechanically disturbed during construction and maintenance of roadways, ditches, and camp spaces but was not artificially planted. Disturbance values A-D were all lower than 1 (0.10 - 0.94). The study areas with more interventive disturbances (land clearing and planting) had disturbance values above 1.5 (1.53 - 3.60, disturbance value classes E-H).

Plant Species Distribution—Table 3 lists the 215 species that we encountered in our study plots. These included 42 grasses (9 exotics, 0 annuals), 11 grass-likes (0 exotics, 0 annuals), 146 forbs (23 exotics, 23 annuals), 15 shrubs (0 exotics), and one tree (0 exotics). We documented the presence of 7 taxa that had not been previously recorded in Grand Teton National Park or the Rockefeller Parkway (table 5). Two of these were of European origin [mountain bluet (*Centaurea montana*) and sow thistle (*Sonchus uliqinosus*)]. The other five [water plantain (*Alisma graminium* var. *angustissimum*), timber poisonvetch (*Astragalus convallarius*), hairy low rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *publerulus*), western dock (*Rumex occidentalis*), and Virginia pepperweed (*Lepidium virginicum* var. *pubescens*)] are widely distributed in western North American and therefore were not unexpected in the Park area.

Thirty-six species occurred on at least five of the 16 study sites (table 6). Ten of these were grasses, including the introduced forage grasses, Kentucky bluegrass (*Poa pratensis*) (14 sites), smooth brome (*Bromus inermis*) (13 sites), and Timothy (*Phleum pratense*) (5 sites). Slender wheatgrass (*Agropyron trachycaulum*) (12 sites) and June grass (*Koeleria macrantha*) (10 sites) were the most widely distributed native grasses. Two native, grass-like plants, Ross sedge (*Carex rossii*) (8 sites) and valley sedge (*C. vallicola*) (5 sites), were common. Twenty-two forbs occurred on at least five sites (table 6). The most common forbs were common dandelion (*Taraxacum officinale*) (all 16 sites), Douglas knotweed (*Polygonum douglasii*) and rosy pussytoes (*Antennaria microphylla*) (12 sites each), western yarrow (*Achillea millefolium*), sulphur buckwheat (*Eriogonum umbellatum*), and three seeded linanthus (*Linanthus harknessii*) (11 sites each), and silky lupine (*Lupinus sericeus*) (10 sites). All of these common forbs are native except dandelion. Plant densities reflect the commonality of the species (table 7). It should be kept in mind, however, that rhizomatous plant density was determined on a per stem rather than a per plant basis.

Sagebrush-Grass Communities—Our study areas in the large sagebrush-grass communities were conveniently divided into six areas that have been drastically disturbed (study areas 4, 7, 8, 10, 12, 13) and six areas disturbed mainly by livestock grazing (study areas 2, 3, 5, 6, 11, 14) (table 4). The species richness and relative abundance of native plants were dramatically lower in the more highly disturbed study areas than in the less disturbed study areas. Common plants in the less disturbed area included sulphur buckwheat (present in 81.7 percent of quadrats), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) (70 percent of quadrats), June grass (58.5 percent of quadrats), silky lupine (55.6 percent of quadrats), and bluebunch wheatgrass (*Agropyron spicatum*) (49.3 percent of quadrats).

The more drastically disturbed study areas that had been sagebrush-grass prior to disturbance were dominated by smooth brome and Kentucky bluegrass. These grasses occurred in 80 and 65 percent of the quadrats, respectively, mostly as the dominant vegetation. Other common plants

Table 5—Species recently found at Grand Teton National Park (not listed in Shaw 1976)

Blauer, Sanderson & McArthur collection #	Species, location, and date
GTNP-138	*Centaurea montana* L. (mountain bluet). Alien from Europe growing in old ditch near disturbed lodgepole area, 3-Rivers Ranch. 13 July 1985.
GTNP-155	*Alisma graminium* Gmel. var. *angustissimum* (D. C.) Hendricks (water-plantain). Growing on exposed bed of Jackson Lake in mud. North of Leek's Marina. 15 July 1985.
GTNP-174	*Sonchus uliginosus* Bieb. (sow thistle). Roadside weed along Gros Ventre Rd. in south end of Mormon Row. Alien from Europe. 25 July 1985.
GTNP-212	*Astragalus convallarius* Greene (timber poisonvetch). Former dry farm now reverted to sagebrush. North side of section 35 next to Clark Moulton Dry Farm. 26 July 1985.
GTNP-228	*Chrysothamnus viscidiflorus* (Hook.) Nutt. ssp. *puberulus* Hall and Clements (hairy low rabbitbrush). Sagebrush flat in section 34 of Mormon Row. 29 July 1985.
GTNP-280	*Rumex occidentalis* Wats. (western dock). Grass/sedge meadow of Buffalo Pasture in Jackson Wildlife Park, National Environmental Study Area. 29 July 1985.
GTNP-362	*Lepidium virginicum* L. var. *pubescens* (Greene) C. L. Hitchcock (Virginia pepperweed). Lodgepole pine forest Huckleberry Hot Springs, Rockefeller Parkway. 16 August 1985.

Table 6—Common plants with number of study areas of occurrence listed by life form (minimum of 5 study areas)

Plant name	No. of study areas
Grasses	
Agropyron trachycaulum— slender wheatgrass (*A. caninum* var. *majus*)	12
Agropyron smithii—western wheatgrass	5
Agropyron spicatum—bluebuch wheatgrass	7
Bromus inermis—smooth brome	13
Koeleria macrantha—June grass	10
Phleum pratense—Timothy	5
Poa pratensis—Kentucky bluegrass	14
Stipa columbiana—Columbia needlegrass	8
Stipa lettermanii—Letterman needlegrass	5
Grass-like plants	
Carex rossii—Ross sedge	8
Carex vallicola—valley sedge	5
Forbs	
Achillea millefolium—yarrow	11
Agoseris glaca—mountain dandelion	6
Antennaria microphylla—rosy pussytoes	12
Arabis drummondii—Drummond rockcress	7
Arabis holboellii—Holboell rockcress	9
Aster chilensis—Pacific aster	9
Chenopodium album—lambsquarter	5
Collomia linearis—collomia	9
Comandra umbellata—bastard toadflax	6
Crepis acuminata—tapertip hawksbeard	5
Erigeron pumilis—low fleabane daisy	6
Eriogonum umbellatum—sulphur buckwheat	11
Linanthus harknessii—three seeded linanthus	11
Lupinus sericeus—silky lupine	10
Perideridia gairdneri—common yampah or false yarrow	5
Phlox longifolia—longleaf phlox	5
Polygonum douglasii—Douglas knotweed	12
Potentilla arguta—sharptoothed cinquefoil	5
Potentilla gracilis—slender cinquefoil	6
Taraxacum officinale—common dandelion	16
Thlaspi arvense—field pennycress	5
Tragopogon dubius—yellow salsify or goatsbeard	8
Shrubs	
Artemisia tridentata ssp. *vaseyana*—mountain big sagebrush	10
Chrysothamnus viscidiflorus—low rabbitbrush	5

included alfalfa (*Medicago sativia*) (17 percent), common dandelion (25 percent), Pacific aster (*Aster chilensis*) (19 percent), and salsify (*Tragopogon dubius*) (9.3 percent). The characteristic dominant plant of the pre-disturbance community, mountain big sagebrush, was present in only 13 percent of the quadrats, despite a recovery period of up to 55 years for some of the disturbed sites (table 3). The drastically disturbed sites were dominated by healthy stands of sward-forming grasses with over 1,000 stems per m^2 (table 2) and with no mountain big sagebrush present (Mormon Row, Heim, and Cottonwood Creek hayfields). Each of these study areas was near healthy mountain big sagebrush populations (fig. 1).

The areas that had been disturbed only by grazing probably have denser stands of mountain big sagebrush than they had historically because of two primary factors.

Table 7—Density of common plants in each type of study area. There were 300 quadrats each for sagebrush-grass and sagebrush-grass treated study areas, 150 quadrats for the meadow study areas, and 50 quadrats for the lodgepole pine study area

COMMON SAGEBRUSH-GRASS PLANTS

Species	Percent of quadrats	Plants/m^2
Eriogonum umbellatum sulphur buckwheat	81.7	3
Artemisia tridentata big sagebrush	70.0	3
Koeleria macrantha June grass	58.7	4
Lupinus sericeus silky lupine	55.6	3
Agropyron spicatum bluebunch wheatgrass	49.3	2
Poa pratensis Kentucky bluegrass	43.7	140
Linanthus harknessii three seeded linanthus	36.7	6
Polygonum douglasii Douglas knotweed	36.7	4
Festuca idahoensis Idaho fescue	29.3	2
Antennaria microphylla rosy pussytoes	28.0	1

Others[1]: *Arenaria congesta*—ballhead sandwart
Selaginella densa—Rydberg spikemoss
Aster chilensis—Pacific aster
Collomia linearis—collomia
Carex rossii—Ross sedge

COMMON SAGEBRUSH-GRASS TREATED AREA PLANTS

Species	Percent of quadrats	Plants/m^2
Bromus inermis smooth brome	80.0	194
Poa pratensis Kentucky bluegrass	65.3	162
Taraxacum officinale dandelion	25.0	12
Aster chilensis Pacific aster	19.0	2
Medicago sativa alfalfa	17.0	1
Artemisia tridentata big sagebrush	13.0	1
Tragopogon dubius salsify	9.3	1

Others[1]: *Collomia linearis*—annual collomia
Agropyron trachycaulum—slender wheatgrass
Antennaria microphylla—rosy pussytoes

COMMON MEADOW PLANTS

Species	Percent of quadrats	Plants/m^2
Poa pratensis Kentucky bluegrass	94.0	382
Phleum pratense Timothy	44.7	4
Taraxacum officinale common dandelion	40.7	6

(con.)

Table 7 (Con.)

COMMON MEADOW PLANTS

Species	Percent of quadrats	Plants/m²
Potentilla gracilis cinquefoil	38.0	4
Equisetum laevigatum horsetail	36.0	11
Achillea millefolium yarrow	33.3	9
Trifolium hybridum alsike clover	28.0	3
Polygonum douglasii Douglas knotweed	25.3	2
Bromus inermis smooth brome	24.7	17
Collomia linearis collomia	17.3	1

Others[1]: *Aster hesperius*—Siskiyou aster
Trifolium longipes—longstalk clover
Cirsium scopulorum—mountain thistle
Carex praegracilis—blackcreeper sedge
Lepidium campestre—field pepperweed

COMMON LODGEPOLE PINE PLANTS

Species	Percent of quadrats	Plants/m²
Taraxacum officinale common dandelion	72.0	10
Poa pratensis Kentucky bluegrass	37.5	72
Achillea millefolium yarrow	37.5	3
Polygonum douglasii Douglas knotweed	48.0	26
Phleum pratense Timothy	40.0	2
Aster integrifolius thickstem aster	34.0	3
Elymus glaucus blue wildrye	30.0	2
Carex geyeri elk sedge	28.0	2
Bromus carinatus mountain brome	28.0	4

Others[1]: *Spergularia rubra*—red sandspurry
Collomia linearis—collomia
Agrostis alba—redtop
Geranium viscosissimum—sticky geranium
Fragaria virginiana—woodland strawberry
Arabis drummondii—Drummond rockcress
Pinus contorta—lodgepole pine

[1]Plants listed in this table were those most common across study areas within community types with average densities ≥1. The other plants listed were also relatively common. For a complete species list for each study area see table 3.

One, preferential grazing of grasses by domestic livestock provided the sagebrush with a competitive advantage that has been subsequently maintained. Two, fire suppression since Caucasian settlement has also led to more dense sagebrush stands and to the exclusion of grasses (Clark 1981).

Meadow Communities—The meadow study areas were Three Rivers Ranch (study area 1), Buffalo Pasture (study area 9), and Oxbow Bend Horse Pasture (study area 15) (tables 1, 4, fig. 1). Three Rivers Ranch was more drastically disturbed than the other two areas (tables 1, 4); land there had been cleared and planted. The two pasture sites had some forage pasture plants added but the native meadow was not completely cleared. The Buffalo Pasture, which has had 4 years longer for recovery, appears to be in a more natural condition than the Oxbow Bend Horse Pasture. The seeded forage plants Kentucky bluegrass, Timothy, alsike clover (*Trifolium hybridum*), and smooth brome, and the weedy plants common dandelion and Douglas knotweed were among the most common plants in the meadow communities (table 7). However, especially in the two pasture sites, natural healing seems to be taking place with a rich array of native plants intermixed with the seeded forage plants.

Lodgepole Pine Community—The only lodgepole pine community was Huckleberry Hot Springs (study area 16) in the John D. Rockefeller Memorial Parkway. This area is a former campground that was closed in 1983 when the protozoan *Giardia lamblia*, the causative agent for giardiasis, was discovered in the hot springs. It was the smallest of our study areas, yet included the most species (tables 1, 3). Even though it had been abandoned for only 2 years, its disturbance value was intermediate and was significantly lower than that of study areas that had been cleared and seeded with recovery times of up to 55 years (table 4). The visually dominant plant at this site was, of course, lodgepole pine (*Pinus contorta*). However because of the large size of that tree in comparison to other species present and the clearings created for the establishment of the now abandoned campground, the density of lodgepole pine was 0.26 per m^2—less than several other plant species in the study area (table 7). Young lodgepole pine seedlings had established in the campground clearings. The most common plants in the study area included common dandelion, Kentucky bluegrass, yarrow, Douglas knotweed, and Timothy. These plants are all common in disturbed areas and are weedy (common dandelion, yarrow, Douglas knotweed) or had been commonly planted for forage or restoration purposes in the Jackson Hole area (Kentucky bluegrass, Timothy). Several of the common plants were native components of the lodgepole pine ecosystem (table 7), including thick stem aster (*Aster integrifolius*), blue wildrye (*Elymus glacus*), elk sedge (*Carex geyeri*), mountain brome (*Bromus carinatus*), sticky geranium (*Geranium viscossimum*), and woodland strawberry (*Fragaria virginiana*).

Soils—The soils of the study areas were soils of terraces and alluvial fans—Tieneman-Bearmouth-Greyback (study areas 2-7, 10-14), soils of the mountains and foothills—Buffork-Perceton-Tongue River (study area 1) and Hechtman-Rock outcrop (study area 16), soils of floodplains—Tetonville-Wilsonville-Tineman (study area 9) and Cryaquolis-Cryofibrists (study area 15) and soils of foothills, buttes, and glacial moraines—Turnerville-Tetonia-Greyback (study area 8) (Young 1982). These soils are deep and well drained except for the floodplain soils, which are poorly drained. The soils are gravelly and sandy loams. All of the soil profiles we examined were at least 0.5 m (table 8). Soil pH

values were generally in the neutral range but varied from 4.9 to 7.7 (table 8). Values for soil organic matter were in the normal range for western rangeland soils (Webb 1994). Values for CEC and SAR were lower than is typical for western rangeland sites (McArthur and others 1994; Woodward and others 1984) except for the Huckleberry Hot Springs study area, which had higher than normal SAR values (table 8). Electrical conductivity (EC) values demonstrated that the soils are non-saline, less than 4×10^3. Values for the other soil minerals assayed were (all in ppm, N = 28, means ± standard deviation):

Nitrate nitrogen (NO_3-N)	5.56 ± 5.21
Phosphorus (P)	22.22 ± 14.85
Potassium (K)	262.03 ± 166.07
Zinc (Zn)	1.87 ± 1.96
Iron (Fe)	65.52 ± 53.18
Manganese (Mn)	28.55 ± 48.42
Copper (Cu)	0.96 ± 0.44
Calcium (Ca)	65.74 ± 34.04
Magnesium (Mg)	16.79 ± 7.75
Sodium (Na)	21.28 ± 45.60

These values are unremarkable except for the high variation in the sodium, manganese, and zinc values. This variation is attributable to Huckleberry Hot Springs study area. Sodium values there were as high as 145 ppm, manganese as high as 243 ppm, and zinc as high as 8 ppm (data on file at the Shrub Sciences Laboratory). The high mineral and SAR values for the Huckleberry Hot Springs study area are not unexpected; this is an area of geothermal venting. The values for phosphorus and iron are relatively high for western rangeland sites (Webb 1994). The values for the more drastically disturbed sites were not different in any systematic way than those for the less drastically disturbed sites.

Restoration Options

Treatment alternatives by general study area community type (drastically disturbed sagebrush-grass, meadow, lodgepole pine) were developed for those study areas with disturbance values above 0.9 (table 4). We believe those areas with disturbance values below 0.9 will naturally heal. Recommendations for each study area were discussed elsewhere (McArthur and others 1986).

The study areas were once grazing lands, pastures, farmland, and in one case, a campground (table 4). The sagebrush-grass and converted sagebrush-grass sites (study areas 2-8, 10-14) occur under somewhat similar conditions. The soils and potential natural plant communities are quite similar. The more drastically disturbed of these sites (one-time farms and ranches) have been seeded for production purposes and support more or less similar mixtures of native and exotic species (table 3). Many disturbance sites

Table 8—Summary of soil characteristics at study areas

Site name	Horizons	Depth (cm)	pH	CEC	%OM	ECx10³	SAR
Sagebrush-Grass, Grazed							
Cow Lake	A	0-15	5.50	20.30	3.89	0.33	0.12
"	B	15-61	5.10	14.90	1.24	0.20	0.08
Pot Holes	A,B	0-33	5.70	31.60	5.29	0.31	0.02
"	C	33-71	6.12	22.87	4.60	0.28	0.04
Mormon Row Sagebrush	A	0-61	6.30	18.10	5.43	0.39	0.08
Clark Moulton Sagebrush	A	0-71	6.70	16.30	2.11	0.58	0.03
Rocky Mountain Energy	A	0-10	6.10	16.10	5.28	0.38	0.04
"	B	10-51	5.80	14.40	2.92	0.23	0.06
Cottonwood Creek Sagebrush	A	0-30	5.60	22.30	4.60	0.43	0.03
"	B	30-66	7.40	14.50	4.66	0.35	0.05
Sagebrush-Grass, Radically Disturbed							
Mormon Row Hayfields	A	0-61	6.50	24.40	2.68	0.87	0.04
Clark Moulton Dry Farm	A	0-71	7.10	18.60	2.53	0.68	0.02
Abercrombie Warm Springs Ranch	A	0-71	7.50	17.20	1.52	0.71	0.05
Aspen Ranch Corp.	A	0-8	7.00	20.40	5.20	0.63	0.02
"	A,B	8-20	7.30	19.20	3.53	0.57	0.03
"	B	20-61	7.70	16.00	2.06	0.68	0.02
Heim Hayfields	A	0-71	7.30	14.60	1.75	0.44	0.09
Cottonwood Creek Hayfield	A	0-15	6.20	13.70	4.40	0.96	0.08
"	B	15-76	4.90	9.78	3.17	0.40	0.09
Meadows							
Three Rivers Ranch	A,C	0-61	7.10	21.00	1.55	0.56	0.07
Buffalo Pasture	A	0-46	5.90	32.70	5.36	0.24	0.17
"	C	46-81	6.80	23.10	1.38	0.46	0.11
Oxbow Bend Horse Pasture	A	0-56	5.70	31.60	5.27	0.21	0.14
"	C	56-81	5.90	26.70	1.40	0.30	0.17
Lodgepole Pine							
Huckleberry Hot Springs	C	0-8	7.00	25.90	5.51	1.20	2.01
"	C	8-25	7.60	9.61	1.13	1.11	8.20
"	C	25-33	7.00	22.90	1.30	1.08	4.84
"	C	33-66	7.20	14.00	1.00	1.12	6.54

are dominated by smooth brome and Kentucky bluegrass. These species are well adapted to the sites they occupy. They are competitive and persistent and restrict the entry of native herbs and shrubs into their sward-like stands in a manner described by del Moral (1985) and Goldberg and Gross (1988). The meadow study areas (1,9,15), like the drastically disturbed sagebrush-grass sites, are dominated by persistent, competitive species, such as Kentucky bluegrass, Timothy, and smooth brome.

Cotts and others (1991) in their work on restoration of abandoned roads in the lower elevations of Grand Teton National Park concluded that natural succession to native plant communities without seeding will occur on these areas but that community development is accelerated best with seeding of site indigenous plant materials and almost as well with non-site indigenous, but native, plant materials purchased from commercial seed dealers. Our study differs from that of Cotts and others (1991) in that many of our study areas had been previously planted to and managed for aggressive, competitive agricultural pasture and hayfield plants.

In management and restoration of these sites some limitations or constraints can influence the reestablishment of native plants.

1. Smooth brome and Kentucky bluegrass are well suited to this region. If present, these grasses, especially smooth brome, will prevent the reestablishment of natives. These grasses are rhizomatous and increase to attain dominance of seeded areas. They may attain impressive stem densities (table 2). Seeds of these grasses are easily spread and consequently they are found throughout the major lowland Park plant communities (table 3). If their presence and abundance are not acceptable to Park management, the plants must be removed by physical or chemical treatments.

2. If smooth brome is to be removed from the disturbed sites, plowing, disking, and spraying with herbicides are the only available treatments. Each of these treatments has management drawbacks. Plowing or disking would have to be repeated over a 2- to 3-year period. Plowing would not be effective unless the plants were repeatedly uprooted. This treatment eventually weakens and ultimately kills the roots. Sites would require plowing or disking three to four times each year until success is obtained. Areas would need to be summer-fallowed similar to "dry farming" operation. If areas were not treated correctly, re-rooting would occur. Selective spraying could be used to remove the introduced grasses without complete elimination of associated plants. Several applications may be required. The grasses cannot be eliminated or significantly reduced through natural succession alone. These species are more competitive than most of the natives.

Partial restoration (= substantive residue of exotic grasses) could be achieved by interseeding or interplanting into existing cover. Small clearings within the existing cover must be created to reduce competition to the new transplants and especially to the new seedlings.

3. Seed and planting stock quantities of many native herbs and shrubs are limited. Planting stock should be grown from seed collected near the study areas. This would require planning and time to acquire seed or propagate transplant stock, thus limiting the ability to plant large areas at one time. Some species are difficult to establish by artificial plantings even if seed or transplant stock is available. Therefore, natural succession must be relied on to accomplish reestablishment of these species. Plantings must be designed to allow entry and spread of these species. Some species will be extremely slow to fully recover and time must be provided to attain a natural plant composition. Seed mixtures proposed for treatment include native species that are compatible, can be established together, and for which seed can be acquired in large enough quantities to complete reasonably scaled projects.

4. Areas occupied by exotic grasses can be interseeded or inter-transplanted with shrubs. Small clearings need to be created to allow the small shrub seedlings to become established. Once shrubs have reached maturity, the understory grasses can be removed by selective spraying or plowing. Native herbs could be seeded as the grasses are removed. This sequence and combined methods of treatment could be employed on sites naturally dominated by shrubs. Once shrubs are established, removal of the understory herbs could be accomplished without exposing obvious bare ground patches. Treatment could be confined to small areas, and conversion of the vegetation could be completed by natural plant succession.

Drastically Disturbed Sagebrush-Grass Communities (Study Areas 4, 7, 8, 10, 12, 13)—Each study area has its own peculiarities (McArthur and others 1986) so the following treatment alternatives will need to be considered in light of those differences:

1. Leave in present condition recognizing that smooth brome, Kentucky bluegrass, and other exotic species are well adapted and may remain in situ indefinitely. Some of the pasture and hayfield lands such as Heim Hayfield, are esthetically pleasing to many visitors; this factor needs to be considered in management decisions.

2. Close existing roads and ditches as individual study areas may require. As possible, recreate natural drainage ways. Spray, plow, or disk to remove noxious weeds. Reduce existing vegetation by these same methods on mosaics that include approximately 20 to 30 percent of the areas under consideration, and interseed or transplant native species. Allow treatments to create a natural mosaic of plant communities. Selectively treat areas to remove dominant stands or patches of smooth brome and Kentucky bluegrass. Plants to consider seeding or transplanting, depending on the particular study area (table 3, McArthur and others 1986), include mountain big sagebrush, antelope bitterbrush (*Purshia tridentata*), Woods rose (*Rosa woodsii*), three tip sagebrush (*Artemisia tripartita*), rubber rabbitbrush (*Chrysothamnus nauseosus*), low rabbitbrush (*C. viscidiflorus*), mountain snowberry (*Symphoricarpos oreophilous*), and Saskatoon serviceberry (*Amelanchier alnifolia*) as the shrub component. Antelope bitterbrush, the sagebrushes, and rabbitbrushes can be seeded but the other shrubs should be established as transplants. Interseed a mixture of native grasses and broadleaf herbs with the shrubs. Some possible species, depending on the study area, include western wheatgrass (*Agropyron smithii*), bluebunch wheatgrass (*A. spicatum*), alpine Timothy (*Phleum alpinum*), needle and thread grass (*Stipa comata*), green needlegrass (*S. viridula*), Pacific aster (*Aster chilensis*), sulfur buckwheat (*Eriogonum umbellatum*), Lewis flax (*Linum*

lewisii), silky lupine, and arrowleaf balsamroot (*Balsamorhiza sagittata*). As plantings attain maturity, interplant additional segments until entire study areas have been restored. Individual segments or plantings will require approximately 5 years to attain maturity. Treating small segments at various times will diminish aesthetic impacts, and yet allow for the initial establishment and natural invasion of native species.

3. Remove existing grasses by plowing or spraying entire study areas (sites) in one operation. Seed mixture of native herbs described in alternative 2. Interseed or inter-transplant mountain big sagebrush through areas in random patterns. Inter-transplanting 1- to 3-year-old nursery stock would produce an immediate woody cover. Shrubs will develop rapidly and reach a mature stature similar to surrounding area within 3 to 5 years.

4. Interseed or inter-transplant shrubs throughout the study areas by making small clearings in existing vegetation to reduce grass competition. Allow seeded exotic grass to remain as an understory.

Meadows (Study Areas 1, 15)—Three Rivers Ranch (study area 1) and Oxbow Bend Horse Pasture (study area 15) are quite different. The Oxbow Bend Horse Pasture (study area 15) and the Buffalo Pasture (study area 9), however, are quite similar. The Buffalo Pasture shows less quantitative evidence of disturbance than the Oxbow Bend Horse Pasture (table 4) but recommendations for restorative techniques for the two are similar. We omit more specific reference to the Buffalo Pasture because its disturbance value was < 0.9 (0.53, table 4).

Treatment alternatives for Three Rivers Ranch:

1. Control trespass livestock grazing; allow vegetation to recover by natural succession. Cover portions of irrigation system; close access road.

2. Plow or disk major portions of abandoned fields to remove principal exotics. Seed with a complement of native herbs including slender wheatgrass (*Agropyron trachycaulum*), mountain brome, Idaho fescue (*Festuca idahoensis*), and western yarrow. Define natural ephemeral stream routes and transplant willow (*Salix* spp.), currant (*Ribes* spp.), bush cinquefoil (*Potentilla fruticosa*), and mountain snowberry (*Symphoricarpos oreophilus*). Transplant or seed upper benches with mountain big sagebrush and lodgepole pine. Allow for natural recovery of the herbs.

3. Remove exotics by disking, plowing, or spraying entire fields. Treat as described in alternative 2, but include additional herbs—sticky geranium, cinquefoil (*Potentilla gracilis*), and Pacific aster (*Aster chilensis*)—in seed mixture.

Treatment alternatives for Oxbow Bend Horse Pasture:

1. Treat by spraying, plowing, or uprooting to remove noxious weeds. If selective herbicides are used and the existing mix of perennial grasses is acceptable to Park management, seeding is not required. If sites are plowed, seed with mountain brome and tufted hairgrass (*Deschampsia caespitosa*). Manage remaining areas to allow natural recovery.

2. This area is occupied by extensive and solid stands of smooth brome. Kentucky bluegrass is also abundant and widespread. Intermixed with both grasses are many native grasses and broadleaf herbs. The area consists of semi-wet and wet meadows. Many species native to these conditions are extremely difficult to reestablish. Treatments such as plowing or disking should not be conducted in areas where these native herbs occur. The large stands of smooth brome should be mapped and considered for treatment. These could be sprayed or plowed; spraying would be best over the areas of irregular terrain. The study area is highly visible. Artificial treatment will have a major impact on esthetics. The smooth brome areas could be treated segmentally over a number of years to reduce the visual impact. Seeding (after the spraying or plowing preparatory work) should consist of mountain brome, tufted hairgrass, Columbia needlegrass (*Stipa columbiana*), western yarrow, and slender cinquefoil. If sites are planted with this mixture, natural invasion of adapted natives will occur. Riparian sites should not be treated unless wilding transplants of sedge (*Carex*) and rush (*Junceus*) are available for use. Species of *Carex rossi*, *C. lanuginosa*, and *C. praegracilis* transplant well and can be used along streambanks. This is a very difficult area to restore. Where smooth brome is present natives will not establish. Artificial treatment will be required for rehabilitation where smooth brome is removed.

Lodgepole Pine (Study Area 16)—Only one study area was evaluated. We present a single treatment alternative.

1. Remove existing structures as determined necessary. Spray, plow, or uproot noxious weeds. Remove pathways and roads. Excavate asphalt surfaces and aggregates. Rip and plow compacted areas. Allow for recovery of native species throughout the small disturbances. Control further spread of weeds. Seed or transplant native herbs, shrubs, and lodgepole pine into larger disturbances (table 3). Natural invasion of native plants would be slow to develop in the larger disturbances. We recommend that lodgepole pine, bush cinquefoil, and mountain lover (*Pachystima myrsinites*) be amply transplanted to speed up the recovery time by providing larger plants early in the successional process. Transplant different ages and sizes of stock to provide a more natural appearance. Seed mountain brome and slender wheatgrass. Both of these grasses will provide initial cover, yet allow natural entry of adapted herbs.

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