Collection and Production of Indigenous Plant Material for National Park Restoration

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Abstract—The National Park Service is taking the "Restoration" approach to reestablishing native plant communities by salvaging topsoil and by seeding and planting native indigenous plant materials. In this way, they are making every effort to protect the genetic integrity of the often unique native plant resource. Since 1985, Yellowstone and Glacier National Parks have been working with the USDA Natural Resources Conservation Service, Plant Materials Center in Bridger, MT, to identify native plant species from which seed can be readily collected, propagated on a large scale, and successfully reestablished on disturbed roadsides. Early colonizers are utilized for initial protection and stabilization, but late seral dominant species are added to mixtures to add longevity to resulting plant communities.

Revegetation, reclamation, and restoration all imply the reestablishment of plant cover on a disturbed site, but if taken literally may imply three levels or intensities of site mitigation. "Revegetation" is simply the reestablishment of plant cover, often a monoculture of an introduced plant species. Although relatively inexpensive, revegetation may not offer permanence or ecological stability. "Reclamation" has been defined historically as the process of returning disturbed land to a condition that approximates the original site conditions and is habitable by the same or similar plants and animals that existed on the site before disturbance (Redente and others 1994). Restoration strives to emulate the structure, function, diversity, and dynamics of a specific ecosystem. Topsoil salvage can preserve the soil biota along with viable propagules in indigenous plant materials. By utilizing native indigenous materials (seed, cuttings, transplants), the genetic integrity and diversity of the native plant communities may be maintained. Even with soil salvage and the use of native indigenous plants, restoration must not be interpreted as a discrete event, but rather as an ongoing process involving the reestablishment of nutrient cycling, plant succession, and plant community dynamics.

The U.S. Department of the Interior, National Park Service has adopted a policy of restoration of all disturbed sites related to road construction, visitor impact, and facility maintenance. The National Park Service is committed to maintaining the genetic integrity of the unique native flora, with secondary goals of erosion control, competition with exotic and noxious invasive plants, and improving overall aesthetics of a disturbed site. In 1985, with the financial support of the Federal Highway Administration, both Yellowstone National Park (northwestern Wyoming) and Glacier National Park (northwestern Montana) initiated restoration programs that involved topsoil salvage and plant salvage, native indigenous seed collection and production, plant propagation from seed and cuttings, and extensive seeding and planting of disturbed sites. A nationwide cooperative agreement between the National Park Service and the U.S. Department of Agriculture's Natural Resources Conservation Service Plant Materials Centers was established in 1986 to assist in the determination of which native species could be readily collected, increased, and successfully reestablished on disturbed sites. The decision by the National Park Service to adopt a restoration policy has generated many unanswered questions and much controversy concerning the protection and preservation of the indigenous gene pools, such as:

- What plant species can be considered indigenous to an open disturbance in a forest community?
- What constitutes the limits of a genotype? How far away from the project area can plant propagules be collected and still be within these limits?
- What species can be readily collected and produced using standard agricultural techniques?
- By taking seed outside of the Parks to a dissimilar environment to increase seed or plants, is genetic drift or natural selection going to impact the genetic integrity of the plant material?
- What type of plant community is an acceptable restoration goal?

Species Selection

Once the National Park Service made the decision to use native indigenous plant materials in its restoration efforts, its next decision was to determine what species would naturally colonize on open disturbances within forest communities. In Yellowstone National Park, the first road project (Old Faithful to West Thumb) was through lodgepole pine (*Pinus contorta*) habitat types, whereas in Glacier National Park, the first project was along Lake McDonald through a cedar-hemlock (*Thuja plicata*/*Tsuga heterophylla*) habitat type. The open road corridors would not support the understory species of the forest communities. By examining abandoned roads, burns, old disturbance areas (both man-made and natural), and open parks and meadows it was possible to identify early colonizing species. Chambers and others (1984), working in the alpine zone of the Beartooth Mountains of south-central Montana, found early colonizing species to have characteristics most desirable for

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reclamation of alpine disturbances. These species exhibited an ability to establish and grow on harsh phytotoxic sites, frequently have larger ecological amplitudes, and are distributed over wide geographic areas. Harper (1977) stated that early colonizing species usually had abundant and consistent seed production, effective seed dissemination, higher germination percentages, and broad tolerance for establishment on disturbed sites. Late seral dominants, on the other hand, as defined by Johnson and Billings (1962), are found on older and less severely disturbed sites. These species are often included in seed mixtures to accelerate succession, but may not be completely successful because of competition from early colonizers, or simply may not be suited to the edaphic conditions of the disturbed site. Both Yellowstone and Glacier Parks are creating mixtures for each specific project that include both early colonizing and late seral dominant species (table 1). Mixtures are relatively simple, relying somewhat on existing propagules in the salvaged topsoil and seed rain from adjacent areas to compliment the seeded material.

Genotype Determination

The genetic variability within and among plant populations vary by species as a function of geographic range, reproduction mode, mating system, seed dispersal mechanism, and stage of succession (Hamrick 1983). Whether a species is self-pollinating or outcrossing makes a difference in genetic variability. The self-pollinating mode of reproduction limits the movement of alleles from one population to another, so these species are found in small disjunct populations with little variation within populations, but distinct variation among populations. Outbreeding plants have widely dispersed pollen and seed, and tend to exhibit significant variation among individuals but less variation among populations. Species with winged or plumose seeds have the greatest potential for gene movement and subsequently have less variability among populations.

To capture the genetic diversity of early successional stage (primarily selfed) plants, seed would have to be sampled from several populations within a project area. With late seral dominants (primarily outcrossed), however, the number of populations that would need to be harvested is significantly less. When a disturbed site is planted with seed from an adjacent or close-proximity site, there is a possibility that a distinct new genotype may develop. Jain and Bradshaw (1966) found that those species that evolve on a disturbed site may actually be genetically different from individuals of the same species on adjacent undisturbed sites. Antonovics (1968) found that on harsh sites characterized by low pH and heavy metals, grass species had the ability to change from an outcrossing to a self-pollinating mode of reproduction to prevent dilution of the gene pool by adjacent unadapted populations. This raises the question of the need to harvest from many sites if a new distinct genotype will evolve on disturbed sites as it is influenced by the harshness and edaphic conditions of the site.

Table 1—Native plant species found to reestablish naturally on disturbed sites in Yellowstone and Glacier National Parks.

Scientific name	Common name
Colonizers	
Short-lived perennial grasses	**Perennial forbs**
Elymus tracycaulus	Slender wheatgrass
Bromus marginatus	Mountain brome
Elymus elymoides	Bottlebrush squirreltail
Elymus glaucus	Blue wildrye
Achillea millefolium	Western yarrow
Anaphalis margaritacea	Pearlyeverlasting
Phacelia hastata	Silverleaf phacelia
Aster integrifolius	Thickstem aster
Solidago elongata	Goldenrod
Viguiera multiflora	Showy goldeneye
Late seral dominants	
Long-lived perennial grasses	**Perennial forbs**
Poa ampla	Big bluegrass
Deschampsia cespitosa	Tufted hairgrass
Pseudoroegneria spicata	Bluebunch wheatgrass
Festuca idahoensis	Idaho fescue
Poa alpina	Alpine bluegrass
Phleum alpinum	Alpine timothy
Agrostis scabra	Rough bentgrass
Lupinus argenteus	Silvery lupine
Eriogonum umbellatum	Sulfur eriogonum
Penstemon confertus	Yellow penstemon
Geranium viscosissimum	Sticky geranium
Potentilla gracilis	Cinquefoil

Seed Collection

Seed collection within National Park boundaries can only be done by hand or by using backpack vacuums. Collection outside of the Park is also done by hand because of the rough terrain or small plant communities that are harvested. Hand collection consists of hand stripping or cutting off seedheads—a time consuming task however it is performed. The National Park Service uses a variety of permanent and seasonal employees and volunteers to collect most of the seed. After drying the seed, they send the harvested material to the Bridger Plant Materials Center for cleaning and storage. The amount of seed that can be harvested per person-hour varies with species, density of the plant population, yearly climate, degree of seed set, and the individuals collecting the seed (table 2).

The easiest species to collect are the short-lived pioneer species such as mountain brome and slender wheatgrass. Collection of seed from forbs such as pussytoes (*Antennaria* sp.) and broadleaf arnica (*Arnica latifolia*) is very time consuming and often not worth the effort. Seeds of a majority of the composites (Asteraceae Family) are difficult to collect because there is usually poor fill, the plumose seed has a very short time period between maturity and shattering, and there is significant insect predation on the seedheads. Those species that are easiest to collect are generally the easiest to produce because of their seed production potential and generally high level of seed viability.

Since 1985, seed of 47 species of grasses and sedges, 75 species of forbs, and 33 species of trees and shrubs have been collected from 137 different sites in Yellowstone National Park. During the same period, seed of 42 species of grasses,

Table 2—Seed collection rates of the primary plant species being used for restoration projects in Yellowstone National Park.

Common name	Scientific name	Number of collections	Time ratio Range	Time ratio Average
			grams per person-hour	
Grasses				
Mountain brome	*Bromus marginatus*	61	30 - 1008	269
Slender wheatgrass	*Elymus trachycaulus*	91	35 - 976	235
Bluegrasses	*Poa* spp.	17	8 - 514	149
Blue wildrye	*Elymus glaucus*	49	23 - 465	147
Bluebunch wheatgrass	*Pseudoroegneria spicata*	29	10 - 433	122
Rough bentgrass	*Agrostis scabra*	20	29 - 197	94
Tufted hairgrass	*Deschampsia cespitosa*	28	3 - 318	89
Bottlebrush squirreltail	*Elymus elymoides*	23	12 - 195	77
Richardson needlegrass	*Stipa richardsonii*	10	23 - 118	67
Idaho fescue	*Festuca idahoensis*	38	13 - 234	63
Subalpine needlegrass	*Stipa nelsonii*	28	9 - 96	43
Forbs				
Showy goldeneye	*Viguiera multiflora*	8	28 - 332	126
Penstemons	*Penstemon* spp.	48	14 - 1583	122
Helianthella	*Helianthella uniflora*	15	9 - 339	88
Western yarrow	*Achillea millefolium*	82	3 - 188	53
Thickstem aster	*Aster integrifolius*	34	3 - 136	52
Lupines	*Lupinus* spp.	39	5 - 222	49
Silverleaf phacelia	*Phacelia hastata*	25	4 - 300	46
Pearlyeverlasting	*Anaphalis margaritacea*	23	3 - 149	41
Goldenrod	*Solidago* spp.	22	2 - 78	41
Cinquefoils	*Potentilla* spp.	55	9 - 110	39
Hairy goldenaster	*Heterotheca villosa*	11	4 - 57	29
Sticky geranium	*Geranium viscosissimum*	19	5 - 62	16

sedges, and rushes, 84 species of forbs, and 37 species of trees and shrubs were collected from 104 sites in and around Glacier National Park. The cost of collection varies from about $40 per kg for large-seeded grasses to well over $200 per kg for some of the forbs.

Seed and Plant Production

The Bridger Plant Materials Center is located approximately 160 km northeast of Yellowstone National Park and 560 km southeast of Glacier National Park. The elevation at Bridger is 1,128 m and the average growing season is 130 days. Seed is collected from sites at 1,800 m to 2,400 m in Yellowstone and from elevations of 970 m to 2,050 m in Glacier—most sites have less than 100-day growing seasons. The most significant shortcoming at Bridger, for seed production of mountainous species, has been the hot dry spring weather. Species that mature early and set seed in August and September in the mountains will mature as early as late June or early July in Bridger. Hot weather during anthesis will significantly reduce pollination and subsequent seed set.

Seed production fields are established by seeding a 1 m spaced row at a rate of 90 pure-live-seeds per linear meter of row. Fields are furrow-irrigated, fall-fertilized (80 kg nitrogen and 30 kg phosphorus per ha), and cultivated and sprayed following standard procedures used by most commercial seed growers. Extensive hand-roguing is required to minimize weed and off-type invasion. Depending on the size of the seed increase field, seed is harvested by hand, head-harvested with a swather equipped with a canvas catch basin, or harvested with one of two small plot combines. All harvesting equipment is thoroughly cleaned between harvesting of each individual ecotype.

There is some question as to how much natural selection and genetic drift will occur when seed is grown at a site remote from the original source. Merrell (1981) stated that individuals developing at the same time, but under different environmental regimes, may develop different phenotypes, even though their genotype is essentially the same. Seed production at a site remote from and dissimilar to the original collection site has the potential for natural selection and genetic drift. There is a potential for a decrease in genetic diversity at several stages of production, for example: (1) The sizing nature of the cleaning process may exclude the largest and smallest seeds; (2) harsh conditions at the time of germination and emergence may limit the survival to only the most viable seeds; (3) as individual plants compete for space and nutrients in the seed production field, some individuals may succumb to others; and (4) during the harvesting process only the seeds that are mature at the time of harvest will be represented—early and late maturing individuals will be excluded.

Samples of three generations of mountain brome were evaluated both phenotypically and genotypically by Dr. Thomas Mitchell-Olds and Dianne Pavek at the University of Montana-Missoula. The original collection (G_0) was collected in the Dickie Creek drainage along the southern border of Glacier Park (1987), the second generation (G_1)

was produced at the Bridger Plant Materials Center (1990) in a field established with G_0 seed, and the third generation (G_2) was produced at the Bridger Plant Materials Center (1992) from a stand established with G_1 seed. Mitchell-Olds (1993) found the phenotype variation (comparing morphological characteristics at three common garden sites in Glacier National Park) and genotypic variation (isozyme electrophoretic analysis utilizing 25 scorable bands) was not significant among the three generations of mountain brome. The distance coefficients (after Johnson and Wischern 1982) and the similarity coefficients (after Gottlieb 1977) indicated that there was very little difference among the original mountain brome collection and the two subsequent generations grown at the Bridger Plant Materials Center. Although this data is for only one species, it supports the potential for producing native indigenous plant materials at sites remote from their source with minimal impact on the genetic integrity of the original gene pool.

If increased seed is to be used on restoration sites, the planning process must allow for at least 3 years—the first to collect and clean the seed, the second to plant and establish a seed production field, and the third year to make the first harvest. Three to four harvests can be taken from a field before production drops to an uneconomical level. The cost of producing seed under commercial conditions varies greatly with species, size of field, yearly environmental conditions, and the timing of harvest. However, seed production under cultivated conditions produces a more reliable quality and quantity of seed than under natural conditions.

To date, there are only a few private growers that are attempting to grow native indigenous ecotypes under contract with the National Park Service and the U.S. Forest Service (table 3). Contracts with private growers include stipulations to guarantee genetic purity and usually a set price as well as the maximum and minimum amount of seed that will be purchased.

Both Yellowstone and Glacier National Parks are using multiple sources of plant materials for their restoration projects: (1) salvaged plant material is either directly transplanted or potted for later use; (2) seed of native indigenous plants is collected for direct seeding, seeding of flats or containers, or for seed increase at the Bridger Plant Materials Center; (3) cuttings are propagated at each Park's own nursery facilities; and (4) containerized material is grown at their nurseries or contracted to commercial nurseries.

Table 3—Estimated cost of production of native ecotypes by commercial growers.

	Asking price[a]	
Scientific name	**Dollars per pound**	**Dollars per kilogram**
Bromus marginatus	3-10	6-22
Deschampsia cespitosa	10-30	22-66
Elymus glaucus	8-28	18-62
Agrostis idahoensis	9	20
Glyceria elata	8	18
Elymus elymoides	17	37
Stipa comata	75	165
Stipa columbiana	46	101

[a]Source: contracts between U.S. Forest Service and private seed growers in Oregon.

Planting and Monitoring

To maximize species diversity and compatibility, plant mixtures are designed to minimize competitive interactions. The goal of the restoration effort is to produce a plant community that is as stable as the adjacent undisturbed area, which can sustain itself as it progresses through successional stages. The nature of the disturbance may place constraints on both the ability to restore the site and the subsequent success that occurs on that site (Chambers and others 1990). To minimize competition, seed mixtures should not be too complex. With linear disturbances in particular, seed rain from adjacent areas will provide added species diversity to a seeded plant community.

Restoration within Yellowstone and Glacier National Parks begins with the salvage of topsoil. The topsoil is carefully stripped and stored in windrows along the upper edge of the road project and redistributed on the prepared cuts and fills during the same growing season. The surface is left rough, and downfall logs and rocks are strategically placed to create micro-niches. Most of the seeding is done by hand broadcasting, followed by mulching with wood chips, extruded aspen fiber, or straw to protect against surface soil erosion and reduce soil surface drying during germination and emergence. Seed mixtures are a combination of short-lived perennials (colonizers) and long-lived perennials (late seral dominants). The seed mixtures are relatively simple, consisting of four to six grasses and three to five forbs (table 4). Shrubs and some forbs are planted as transplants, containerized material, or as bareroot stock.

Monitoring is an integral part of the restoration process—providing information on the success of establishment and survival, species compatibility, and long-range stability of the established plant communities. Glacier National Park's monitoring program is loosely based on the U.S. Forest Service ECODATA (Jensen and others 1992) ocular plot methodology. This technique uses both microplot and ocular surveys of ground cover, species cover, species composition, erosion status, plant mortality, plant growth, and invasion of exotics. Both Parks utilize varying intensities of monitoring:

Level I is basic documentation of ground cover and the presence of exotics (often used to document conditions on small backcountry projects).

Level II is general evaluation of surface status and total vegetation cover including species lists, mortality, plant density, and overall plant vigor (most commonly used along road shoulders).

Level III involves microplots and shrub transects to collect data suitable for statistical analysis (utilized on large obliterated turnouts and larger cut-and-fill slopes).

Level IV uses replicated plot designs to evaluate the effectiveness of various combinations of restoration treatments (seeded versus unseeded, mulched versus unmulched, fertilized versus unfertilized, chemical weed control treatments of weeds and exotics, and nurse and cover crop alternatives).

The restoration attempts in Yellowstone and Glacier National Parks have made every effort to maintain the genetic integrity of the plant material, to salvage and protect the viability of the soil biota (micro-organisms, mycorrhizae, and plant propagules), and to create stable self-sustaining plant communities on disturbed sites. These new plant communities continue to change as some of the colonizer species give way to the late seral species and as additional species appear as a result of seed rain from adjacent sites and soil-borne plant propagules. Research results indicate that seeding and associated mulching practices provide erosion control, but do not totally restrict the encroachment of exotics without additional weed control measures.

Table 4—Basic seed mixtures developed for different vegetation types in Glacier and Yellowstone National Parks (other species are used as available).

Glacier National Park	Yellowstone National Park
Alpine	**Lodgepole pine forest**
Poa alpina[a]	*Bromus marginatus*[a]
Phleum alpinum[a]	*Elymus trachycaulus*[a]
Poa gracilima[a]	*Elymus elymoides*[a]
Deschampsia atropurpurea[a]	*Agrostis scabra*[a]
Carex haydeniana	*Poa ampla*[a]
Aster laevis	*Achillea millefolium*[a]
Sibbaldia procumbens	*Lupinus sericeus*[a]
Senecio triangularis	*Phacelia hastata*[a]
Epilobium alpinum	*Potentilla gracilis*
Hypericum formosum	*Eriogonum umbellatum*
	Viguiera multiflora[a]
Fescue grassland	
Bromus marginatus[a]	**Northern grasslands**
Pseudoroegneria spicata[a]	*Stipa comata*[a]
Festuca idahoensis[a]	*Pascopyrum smithii*[a]
Festuca compestris[a]	*Leymus cinereus*[a]
Koeleria macrantha[a]	*Nassella viridula*[a]
Elymus elymoides	*Bromus anomalus*[a]
Gaillardia aristata[a]	*Achillea millefolium*[a]
Hedysarum boreale[a]	*Linum lewisii*[a]
Geranium viscosissimum	*Potentilla fruticosa*
Huechera cylindrica[a]	
Potentilla gracilis[a]	**Wetlands**
	Deschampsia cespitosa[a]
Cedar Hemlock	*Agrostis scabra*[a]
Bromus marginatus[a]	*Elymus trachycaulus*[a]
Elymus glaucus[a]	*Pedicularis groenlandica*
Deschampsia cespitosa[a]	*Gentiana dentosa*
Calamagrostis rubescens	
Achillea millefolium[a]	
Penstemon confertus[a]	
Penstemon albertinus	
Aster laevis	
Antennaria neglecta	

[a]Species of seeds or plants that have been successfully produced at the Bridger Plant Materials Center.

Both Parks are satisfied that the seeding and planting of native indigenous plant material on major disturbances, rather than letting nature take its course, is the proper procedure for the preservation and protection of native gene pools.

References

Antonovics, J. 1968. Evolution in closely adjacent plant populations. V. Evolution of self-fertility. Heredity. 23: 219-238.

Chambers, J. C.; Brown, R. W.; Johnston, R. S. 1984. Examination of plant successional stages in disturbed alpine ecosystems: a method of selecting revegetation species. In: Colbert, T. A.; Cuany, R. L., eds. Proceedings: high altitude revegetation workshop, No. 6. Information Series No. 53. Colorado State University. Water Resources Research Institute: 215-224.

Chambers, J. C.; McMahon, J. A.; Wade, G. L. 1990. Difference in successional processes among biomes: importance in obtaining and evaluating reclamation success. In: Chambers, J. C.; Wade, G. L., eds. Evaluating reclamation success: the ecological consideration—proceedings of a symposium; April 23-26; Charleston, WV: Gen. Tech. Rep. NE-164. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Gottlieb, L. 1977. Electrophoretic evidence and applied systematics. Annals of the Missouri Botanical Garden. 64: 161-180.

Hamrick, J. L. 1983. The distribution of genetic variation within and among natural plant populations. In: Schonewald-Cox, C. M.; Chambers, S. M.; MacBryde, G.; Thomas, L., eds. Genetics and conservation—a reference for managing wild animals and plant populations. Menlo Park, CA: Benjamin Cummings Publishing Co., Inc.: 335-348.

Harper, J. L. 1977. Population biology of plants. New York: Academic Press.

Jain, S. K.; Bradshaw, A. D. 1966. Evolutionary divergence among adjacent plant populations. I. The evidence and its theoretical analysis. Heredity. 21: 407-441.

Jensen, M. E.; Hann, W.; Keane, R. E. 1992. Ecosystem inventory and analysis guide. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region.

Johnson, P. L.; Billings, W. D. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. Ecological Monographs. 32: 105-135.

Johnson, R. A.; Wischern, D. W. 1982. Applied multivariate statistical analysis. Englewood Cliffs, NJ: Prentice Hall, Inc.

Mitchell-Olds, T. 1993. Genetic diversity of plant species in Glacier National Park: implications in management. Annual report—National Park Service Contract No. CA-1463-5-0001.

Merrell, D. 1981. Ecological genetics. Minneapolis: University of Minnesota.

Redente, E.; Cotts, N.; Schuller, R. 1994. Abandoned road restoration methods tested at Grand Teton National Park. Park Service. Vol. 14, No. 2. U.S. Department of the Interior, National Park Service.