Biodiversity: Aspen Stands Have the Lead, But Will Nonnative Species Take Over?

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Abstract—*We investigated vascular plant and butterfly diversity in Rocky Mountain National Park. We identified 188 vascular plant species unique to the aspen vegetation type. The slope of the mean species-area curve for the aspen vegetation type was the steepest of the 10 types sampled, thus, an increase in aspen area could have much greater positive impacts on plant species richness than other vegetation types. Aspen plots contained the greatest number of butterfly species and ranked highest with all diversity indices tested. However, aspen plots were the most heavily invaded by nonnative plant species, which could have negative effects on native plant and butterfly species diversity.*

The importance of aspen (*Populus tremuloides* Michaux) for maintaining biodiversity in western landscapes is well introduced in DeByle et al. (1985), where aspen stands are noted for their own genetic diversity, as well as providing habitat for insects, birds, and mammals. Stohlgren et al. (1997a,b) found a disproportionately high number of vascular plant species in aspen stands in relation to their coverage in the Beaver Meadows area (750 ha) of Rocky Mountain National Park, Colorado. There, aspen covered only 1.2% of the landscape, but it contained 45% of the plant species sampled.

Resource managers in Rocky Mountain National Park (the Park) are concerned that elk (*Cervus elaphus* Nelsoni) may be harming vegetation in portions of the Park (Berry et al. 1997). Localized studies have reported little or no aspen regeneration in elk winter range (Baker et al. 1997; Olmstead 1997), while a more extensive study did find successful regeneration at landscape scales in areas of low elk use (Suzuki et al. 1999). Similar concern and controversy over regeneration exists in the Greater Yellowstone Ecosystem (Barnett and Stohlgren 2000; Bartos et al. 1991; Gruell and Loope 1974; Krebill 1972; Romme et al. 1995; Weinstein 1979). Another potential harmful effect on aspen stands and the diversity that they support is invasion by nonnative plant species. Work in other species-rich habitat types has found that hotspots of native plant diversity are being invaded by nonnative plant species (Stohlgren et al. 1998b, 1999a,b,c). These invasions may have long-term, negative consequences for native diversity, especially in vegetation types such as aspen that are small, scattered, and rare on the landscape in parts of their range.

Our objective was to assess a variety of vegetation types' contributions to plant and butterfly species richness. We used species-log(area) curves (Gleason 1925; Rejmanek and Ejvind 1992; Shmida 1984) to compare the relative contributions to vascular plant species richness made by 10 different vegetation types in the Park. Species-area curves allow comparisons across vegetation types, and even other studies, because the slopes of the curves can be calculated and compared without the difficulties posed by other diversity indices that often require abundance data (for evenness) and vary greatly depending on study design (Ludwig and Reynolds 1988). In addition, species-area models allow one to estimate the number of species expected in an area larger than the area

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sampled. These estimates may also be used as an index of diversity (richness). We also examine the number of species that only occur in one vegetation type (unique to a vegetation type) and the number of nonnative plant species found in a set of vegetation plots.

To test the use of plant richness to predict the diversity of other taxonomic groups, we investigated the significant contributions of aspen to butterfly species diversity and the relations between butterfly species richness and plants in the Beaver Meadows area (Simonson et al. 2000).

Our results should place renewed emphasis on the need to maintain aspen on the landscape to maintain landscape-scale biodiversity. In addition to managing natural processes such as elk herbivory and fire, resource managers may need to detect invasive species early, monitor their effects, and control nonnative plant invasions to maintain the native diversity supported by aspen.

Methods

Study Sites

From 1995 through 1998, 104 Modified-Whittaker plots (20 m x 50 m or 10 m x 25 m; figure 1) were established (using stratified, random sampling) in 10 vegetation types in a 54,000 ha portion of Rocky Mountain National Park, Colorado (after Stohlgren et al. 1997b). Vegetation cover types were identified on aerial photos (1987, color; 1:15840 scale) and included aspen (*Populus tremuloides* Michaux), willow (*Salix* spp.), dry meadow (various species), wet meadow (various species), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), lodgepole pine (*Pinus contorta* Dougl.), mixed conifer (various species), subalpine (various species), alpine tundra (various species), and spruce/fir (*Picea engelmannii* Parry ex Engelm. and *Abies lasiocarpa* (Hook.) Nutt). Twenty of the aspen plots were located based on a previous bird study (stands were similarly randomly located; Natasha Kotliar, U.S. Geological Survey, personal communication). Butterfly data were collected in 1996 on the 24 Modified-Whittaker plots (four plots in each of six vegetation types: aspen, burned ponderosa, dry meadow, lodgepole pine, ponderosa pine, and wet meadow) in the 750 ha Beaver Meadows study area (Simonson et al. 2000).

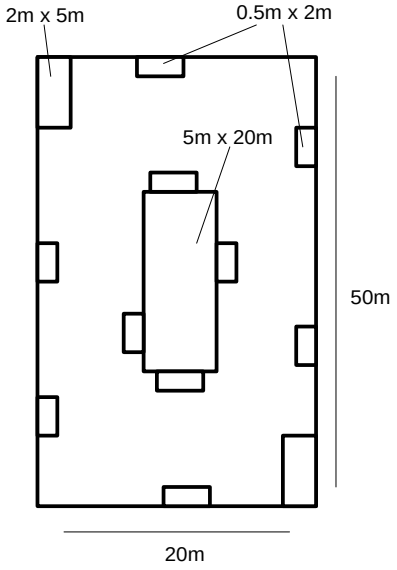

Figure 1—The Modified-Whittaker plot (not to scale). The main plot is 20 m x 50 m and contains ten 1-m^2 subplots (0.5 m x 2 m, six inside the perimeter of the main plot and four outside the perimeter of the 100-m^2 subplot), two 10-m^2 subplots (2 m x 5 m, in opposite corners of the main plot), and one 100-m^2 subplot (5 m x 20 m in plot center). Sampling at multiple spatial scales (1-m^2, 10-m^2, 100-m^2, and 1000-m^2) allows the construction of a species-area curve (figure 2). Plots that measured 10 m x 25 m (four vegetation plots) had the same plot design, but all dimensions were halved.

Plot Designs

The Modified-Whittaker plot for vegetation sampling consists of ten 1-m^2 subplots, two 10-m^2 subplots (in opposite corners), and one 100-m^2 subplot (in plot center) all contained within the 20 m x 50 m plot (figure 1). The original plot design placed the ten 1-m^2 subplots around the inside of the plot perimeter (Stohlgren et al. 1995). However, after 1996, four of the 1-m^2 subplots were moved to the outside perimeter of the 100-m^2 subplot to decrease the linearity of the 1-m^2 subplots. The 1-m^2 subplots were placed to maximize the distance between them while allowing for easy relocation where long-term monitoring was an objective (Stohlgren et al. 1998a). Within each 1-m^2 subplot, we identified all vascular plant species, recorded their average height, and estimated their cover to the nearest percent. In the 10-m^2 subplots and the 100-m^2 subplot we recorded species presence. Finally, the entire 1,000-m^2 plot was surveyed and any previously unrecorded (in the subplots) species were recorded.

For butterfly sampling, the 20 m x 50 m plot contained six 10-m^2 subplots around the inside of the plot perimeter and one 100-m^2 subplot in the plot center (Simonson 1998). The butterfly plot was overlain directly on the vegetation plot. Butterfly diversity was measured based on systematic surveys of the subplots and plot, under minimum weather conditions (Simonson 1998). Butterflies were identified to species, and abundances were also recorded.

Analyses

Species lists were compiled for plants and butterflies to determine the total numbers of species found in each vegetation type as well as the species unique to a vegetation type. Nonnative plant species were noted. All plant specimens identified to species follow the National Plants Database nomenclature (USDA NRCS 1999). Some plants could not be identified to species because of phenology or condition, so they were labeled with a unique identifier. If these "unknowns" could be identified to genus, then the genus was included in the descriptive name. For analyses, we erred on the side of caution by lumping difficult unknown species together (e.g., many grasses and small, basal rosettes of composites).

Species-log(plot size) curves, hereafter called species-area curves, were constructed using the mean number of plant species found in each subplot for the 1-m^2 and 10-m^2 subplots and the total number of plant species found in the 100-m^2 subplot and the full 1,000-m^2 plot. These curves are the result of linear regression where the number of species is dependent on the area sampled (figure 2). Thus, the curve rises more rapidly in species-rich habitat types because more species are encountered as area is increased (the slope of the line is steeper). Species-area curves were developed for each vegetation type based on all the plots sampled in that type. Butterfly data were analyzed using rarefaction curves, analysis of variance, diversity and evenness indices, and regression (Simonson et al. 2000).

Results

We identified 188 vascular plant species that occurred only in aspen plots (N = 32 plots) (appendix A). The remaining vegetation types (N = 72 plots) combined contained 264 species that only occurred in one vegetation type. The slope of the mean species-area curve for the aspen vegetation type was the steepest of the nine vegetation types sampled (table 1, figure 2). The slope indicates the rate of accumulation of new species as the area sampled is increased.

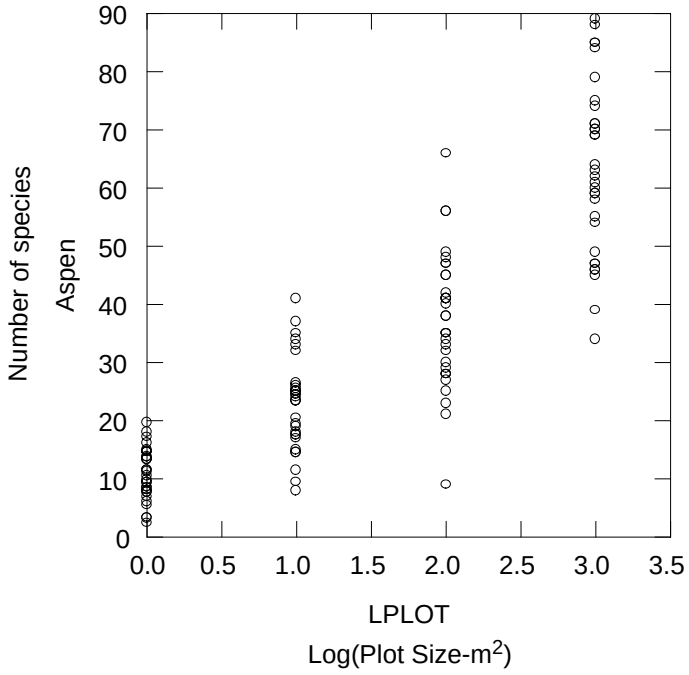

Figure 2—An example species-log(area) curve. Data are from 32 Modified-Whittaker plots placed in 32 aspen stands. The slope of the regression line is an index of species richness: the steeper the slope, the more new species are expected to be added as the area sampled increases. We used plot size (m^2) for area. The equation of the aspen regression is: N = 17.18(log(area)) + 7.85 (adjusted r^2 = 0.76, $p < 0.01$), where N is the predicted number of species for a given area, the slope is 17.18, and the constant (i.e., intercept) is 7.85.

Aspen plots contained 38 of the 42 nonnative species identified in all plots, and 15 of the 38 were not found in any other vegetation type (appendix A).

In the Beaver Meadows portion of the Park, four plots were sampled for plant and butterfly diversity in each of six vegetation types. Aspen covered the smallest area with a total of 8.8 ha scattered throughout the 750-ha area. Thirty-three butterfly species, a total of 252 individuals, were recorded in aspen stands, and seven of those species were found only in aspen (Simonson 1998; appendix B). For both richness and diversity indices, aspen consistently ranked the highest of the vegetation types sampled for butterfly diversity (Simonson et al. 2000; table 2). Butterfly species richness was strongly positively correlated with native plant species richness ($r = 0.64$; $p < 0.001$), but the best predictors of butterfly species richness were exotic plant species richness ($r = 0.70$; $p < 0.0001$) and exotic plant species cover ($r = 0.70$; $p < 0.001$; Simonson et al. 2000).

Table 1—Species-area curves for vascular plant species in 10 vegetation types from a 54,000-ha portion of Rocky Mountain National Park, Colorado. We used SYSTAT (SPSS, Inc., 1998) for statistical analyses. We used the mean number of species in the 1-m^2 and 10-m^2 subplots and the total number of species in the 100-m^2 subplot and 1,000-m^2 plot. We used the log(plot size) for area. The equations follow the general equation of a line: N = m(x) + b, where N = the number of species; m = the slope of the line; x = log(plot size); and b is a constant (the intercept). Larger values of the slope (m) indicate a greater accumulation of species as area is increased. In all cases $p < 0.01$.

Vegetation	Equation	Adjusted R^2	# plots
Aspen	N = 17.18(log(area)) + 7.85	0.76	32
Willow	N = 15.11(log(area)) + 6.31	0.80	9
Dry meadow	N = 13.14(log(area)) + 8.20	0.75	9
Spruce/fir	N = 12.81(log(area)) + 5.78	0.74	4
Ponderosa	N = 12.47(log(area)) + 3.70	0.85	8
Tundra	N = 11.69(log(area)) + 14.40	0.86	4
Wet meadow	N = 11.60(log(area)) + 6.55	0.71	8
Mixed conifer	N = 9.36(log(area)) + 1.33	0.48	5
Lodgepole	N = 9.23(log(area)) + 2.82	0.74	8
Subalpine	N = 9.02(log(area)) + 3.80	0.66	8

Table 2—Richness and diversity indices for butterflies in aspen (A), wet meadow (WM), Ponderosa pine (PP), dry meadow (DM), burned conifer (BC), and lodgepole pine (LP) vegetation types in the Beaver Meadows study area, Rocky Mountain National Park, Colorado (Simonson et al. 2000).

Vegetation	A	WM	PP	DM	BC	LP
Richness						
Observed species	33	27	21	19	15	13
Estimated species[a]	19	15	14	11	14	13
Diversity						
Simpson's A	0.08	0.11	0.12	0.17	0.12	0.13
Shannon's H	2.92	2.56	2.29	2.10	2.32	2.16
Hill's N1	18.60	12.89	9.83	8.13	10.21	8.71
Hill's N2	12.27	9.54	6.45	5.96	8.55	7.80

[a]Based on rarefaction, which allows the comparison of species numbers between vegetation types where sample sizes (number of individuals observed) were unequal. This estimate provides an index of richness.

Discussion

Although aspen stands cover a small proportion of Rocky Mountain National Park (2% based on one Park map or 5% based on recent work by Kaye et al., this proceedings), they contribute a disproportionate amount to plant and butterfly species richness. For example, aspen comprised only 1.2% of the vegetation cover in the Beaver Meadows study area, yet the four plots sampled in aspen contained 150 plant species (45% of the plants observed on all 24 plots). Of the plant species, 50 were unique to the aspen type (25% of the unique species observed in the six vegetation types in that study; Stohlgren et al. 1997b). Beaver Meadows aspen contained more unique butterfly species than any other vegetation type. Thirty-three of the 49 butterfly species observed were seen in aspen, and seven of those were recorded only in the aspen type. In the Beaver Meadows study area (750 ha; Stohlgren et al. 1997b) and the larger study area (54,000 ha, present study) the slopes of species-area curves for plants in aspen were steeper than those for any other vegetation type sampled. Using slope steepness as an index of a vegetation type's contribution to species richness, aspen stands are clearly important for maintaining landscape biodiversity. Resource managers are justified in their concern about aspen's persistence on the landscape.

Managers must add invasive, nonnative species to their list of potential threats to the integrity of aspen ecosystems. We observed 42 nonnative plant species in the Park; 38 of those occurred in aspen stands, and 15 of those were not found in the plots in any other vegetation type. This is partially explained by the large number of plots in aspen (N = 32 plots), but it is still extremely high compared to the 72 nonaspen plots. Especially alarming was the presence of noxious, agricultural, and urban weeds (e.g., field bindweed, *Convolvulus arvensis* L.) in seemingly remote, undisturbed aspen stands. None of our sites that appeared relatively undisturbed had high cover of nonnative species, but their presence indicates that seed sources are available. With seed available, any disturbance is likely to result in increased cover of nonnative plant species. The ability of the nonnative species to form dense stands can prevent native plants from persisting or establishing (Whitson et al. 1996).

Other potential negative effects involve pollinator interactions between native and nonnative plants. For example, we observed many butterflies on the flowers of musk thistle (*Carduus nutans* L.) and Canada thistle (*Cirsium arvense* L.). Even though these nonnative species provide nectar, they are not suitable host plants

for most butterfly larva, which often require specific native hosts. If nonnatives are being pollinated this may increase their invasion success. In addition, many native plants are believed to be pollinator-limited (Burd 1994) even without competition for pollinators from nonnatives. If pollination of natives is reduced and results in decreased reproduction, this will exacerbate their displacement and could impact butterfly diversity by reducing the populations of required host plants.

Attempts to manage for intact aspen stands as a component of forest ecosystems must consider the potential negative impacts of nonnative plant species on native species richness across taxonomic groups. Controlling invasive nonnative species in aspen stands must be carefully done because these areas contain more unique assemblages of native species. Researchers and managers must be especially attentive to processes that encourage aspen regeneration or establishment (e.g., fire, disturbance) because these processes also facilitate nonnative species establishment. Understanding the connectivity of aspen and other vegetation cover types in relation to nonnative plant species movement and establishment will be an essential component to proactive management of native species and aspen stands.

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Appendix A

Plant species listed were only found in aspen stands (32 plots), except for the nonnative species indicated by an "N*", which were found in other vegetation types as well. We only list plants that were identified to species (47 unknowns were not included). Please note that a portion of these species certainly occurs in other vegetation cover types, but they were not found in our plots in other types (N = 72). Species noted as "Rare" are listed by Spackman et al. (1997).

Status	Family	Scientific name	Common name
N*	Poaceae	*Agrostis gigantea*	Redtop
N	Poaceae	*Alopecurus pratensis*	Meadow foxtail
N*	Brassicaceae	*Alyssum alyssoides*	Pale madwort
N*	Brassicaceae	*Arabis glabra*	Tower mustard
N	Brassicaceae	*Brassica juncea*	India mustard
N*	Poaceae	*Bromus tectorum*	Cheatgrass
N*	Brassicaceae	*Camelina microcarpa*	False flax
N	Apiaceae	*Carum carvi*	Caraway
N	Asteraceae	*Carduus nutans*	Musk thistle
N*	Chenopodiaceae	*Chenopodium album*	Lambsquarters
N*	Asteraceae	*Cirsium arvense*	Canadian thistle
N	Convolvulaceae	*Convolvulus arvensis*	Field bindweed
N*	Apiaceae	*Conium maculatum*	Poison hemlock
N	Poaceae	*Cynodon dactylon*	Bermudagrass
N	Boraginaceae	*Cynoglossum officinale*	Gypsy flower
N	Poaceae	*Dactylis glomerata*	Orchardgrass
N*	Brassicaceae	*Descurainia Sophia*	Flixweed
N	Poaceae	*Elytrigia repens* var. *repens*	Quackgrass
N*	Poaceae	*Festuca ovina*	Sheep fescue
N*	Apiaceae	*Heracleum sphondylium*	Eltrot
N	Brassicaceae	*Lepidium campestre*	Field pepperweed
N	Brassicaceae	*Lepidium perfoliatum*	Clasping pepperweed
N*	Poaceae	*Lolium pratense*	Ryegrass
N	Fabaceae	*Melilotus officinalis*	Yellow sweetclover
N*	Poaceae	*Phleum pratense*	Timothy
N	Poaceae	*Poa compressa*	Canada bluegrass
N*	Poaceae	*Poa pratensis*	Kentucky bluegrass
N*	Polygonaceae	*Rumex acetosella*	Sheep sorel
N*	Polygonaceae	*Rumex crispus*	Curly dock
N	Caryophyllaceae	*Silene vulgaris*	Maidenstears
N*	Brassicaceae	*Sisymbrium altissimum*	Tall tumblemustard
N*	Asteraceae	*Taraxacum officinale*	Common dandelion
N*	Brassicaceae	*Thlaspi arvense*	Pennycress
N*	Asteraceae	*Tragopogon dubius*	Salsify
N*	Fabaceae	*Trifolium hybridum*	Alsike clover
N*	Fabaceae	*Trifolium repens*	White Dutch clover
N	Scrophulariaceae	*Verbascum thapsus*	Common mullein
	Poaceae	*Achnatherum lettermanii*	None listed
	Asteraceae	*Achillea millefolium* var. *occidentalis*	Western yarrow
	Poaceae	*Achnatherum nelsonii* ssp. *dorei*	Needle-and-thread
	Ranunculaceae	*Actaea rubra*	Baneberry
	Rosaceae	*Amelanchier alnifolia*	Saskatoon serviceberry

Appendix A, cont'd

Status	Family	Scientific name	Common name
	Ranunculaceae	*Anemone canadensis*	Meadow anemone
	Apocynaceae	*Apocynum androsaemifolium*	Spreading dogbane
	Ranunculaceae	*Aquilegia caerulea*	Colorado blue columbine
	Araliaceae	*Aralia nudicaulis*	Wild sarsaparilla
	Asteraceae	*Artemisia ludoviciana* ssp. *Mexicana*	Mexican white sagebrush
	Fabaceae	*Astragalus alpinus*	Alpine milkvetch
	Asteraceae	*Aster foliaceus* var. *parryi*	Parry's aster
	Asteraceae	*Aster laevis*	Smooth aster
	Asteraceae	*Aster novae-angliae*	New England aster
	Fabaceae	*Astragalus parryi*	Parry's milkvetch
	Asteraceae	*Aster porteri*	Porter's aster
	Fabaceae	*Astragalus sparsiflorus*	Front range milkvetch
	Asteraceae	*Brickellia californica*	California brickellbush
	Asteraceae	*Brickellia grandiflora*	Tasselflower brickellbush
	Poaceae	*Calamagrostis montanensis*	Plains reedgrass
	Cyperaceae	*Carex canescens*	Silvery sedge
	Cyperaceae	*Carex durinscula*	Needleleaf sedge
	Cyperaceae	*Carex foenea* var. *foenea*	Dryspike sedge
	Cyperaceae	*Carex lanuginosa*	Woolly sedge
	Cyperaceae	*Carex oreocharis*	Grassyslope sedge
	Cyperaceae	*Carex rostrata*	Beaked sedge
	Scrophulariaceae	*Castilleja miniata*	Scarlet paintbrush
	Rhamnaceae	*Ceanothus velutinus*	Snowbrush ceanothus
	Chenopodiaceae	*Chenopodium fremontii*	Fremont's goosefoot
	Asteraceae	*Cirsium canescens*	Prairie thistle
	Asteraceae	*Cirsium drummondii*	Dwarf thistle
	Ranunculaceae	*Clematis occidentalis*	Western blue virginsbower
	Scrophulariaceae	*Collinsia parviflora*	Smallflower blue-eyed Mary
	Orchidaceae	*Corallorhiza* sp.	Coral root
	Fumariaceae	*Corydalis aurea*	Golden smoke
	Pteridaceae	*Cryptogramma crispa*	Crisp rockbreak
	Boraginaceae	*Cryptantha fendleri*	Sanddune catseye
	Ranunculaceae	*Delphinium ramosum*	Mountain larkspur
	Brassicaceae	*Descurainia pinnata*	Western tanseymustard
	Primulaceae	*Dodecatheon pulchellum*	Darkthroat shootingstar
	Lamiaceae	*Dracocephalum parviflorum*	American dragonhead
	Poaceae	*Elymus elymoides*	Bottlebrush squirreltail
	Poaceae	*Elymus glaucus*	Blue wildrye
	Poaceae	*Elymus lanceolatus* ssp. *Albicans*	Montana wheatgrass
	Poaceae	*Elymus subsecundus*	Bearded wheatgrass
	Poaceae	*Elymus virginicus* var. *submuticus*	Virginia wildrye
	Onagraceae	*Epilobium brachycarpum*	Autumn willowweed
	Equisetaceae	*Equisetum laevigatum*	Smooth horsetail
	Asteraceae	*Erigeron subtrinervis*	Three-nerved fleabane
	Asteraceae	*Eucephalus engelmannii*	None listed
	Poaceae	*Festuca thurberi*	Thurber's fescue
	Rosaceae	*Fragaria vesca*	Woodland strawberry
	Polemoniaceae	*Gilia pinnatifida*	Sticky gilia

Appendix A, cont'd

Status	Family	Scientific name	Common name
	Orchidaceae	*Goodyera oblongifolia*	Western rattlesnake plantain
	Dryopteridaceae	*Gymnocarpium dryopteris*	Western oakfern
	Asteraceae	*Helianthella quinquenervis*	Five-nerve helianthella
	Asteraceae	*Heterotheca fulcrata*	Rockyscree false goldenaster
	Saxifragaceae	*Heuchera bracteata*	Bracted alumroot
	Asteraceae	*Hieracium albiflorum*	White hawkweed
	Rosaceae	*Holodiscus dumosas*	Rock spirea
	Juncaceae	*Juncus balticus*	Baltic rush
	Asteraceae	*Lactuca tatarica*	Large-flowered blue lettuce
Rare	Liliaceae	*Lilium philadelphicum*	Wood lily
	Orchidaceae	*Listera convallarioides*	Broadlipped twayblade
	Fabaceae	*Lupinus argenteus*	Silvery lupine
	Asteraceae	*Machaeranthera bigelovii* var. *bigelovii*	Bigelow's tansyaster
	Asteraceae	*Machaeranthera canescens*	Hoary aster
	Lamiaceae	*Monarda fistulosa*	Wild bergamot beebalm
	Poaceae	*Muhlenbergia asperifolia*	Alkali muhly
	Onagraceae	*Oenothera villosa* ssp. *Strigosa*	Hairy evening primrose
	Orobanchaceae	*Orobanche uniflora*	One-flowered broomrape
	Poaceae	*Oryzopsis asperifolia*	Roughleaf ricegrass
	Celastraceae	*Paxistima myrsinites*	Mountain-lover boxleaf myrtle
	Scrophulariaceae	*Pedicularis procera*	Grays lousewort
	Scrophulariaceae	*Penstemon rydbergii*	Rydberg's penstemon
	Solanaceae	*Physalis heterophylla*	Clammy groundcherry
	Rosaceae	*Physocarpus monogynus*	Mountain ninebark
	Orchidaceae	*Platanthera hyperborean* var. *hyperborean*	Northern green orchid
	Polygonaceae	*Polygonum aviculare*	Devils shoestrings
	Polygonaceae	*Polygonum douglasii* ssp. *Johnstonii*	Johnston's knotweed
	Rosaceae	*Potentilla nivea*	Snow cinquefoil
	Lamiaceae	*Prunella vulgaris*	Common selfheal
	Asteraceae	*Ratibida columnifera*	Upright prairie coneflower
	Asteraceae	*Rudbeckia laciniata*	Tall cone-flower
	Salicaceae	*Salix petiolaris*	Meadow willow
	Salicaceae	*Salix scouleriana*	Scouler's willow
	Apiaceae	*Sanicula marilandica*	Maryland snakeroot
	Selaginellaceae	*Selaginella densa*	Lesser spikemoss
	Selaginellaceae	*Selaginella underwoodii*	Underwood's spikemoss
	Asteraceae	*Senecio crassulus*	Thickleaf groundsel
	Asteraceae	*Senecio eremophilus* var. *kingii*	King's groundsel
	Asteraceae	*Senecio pudicus*	Bashful ragwort
	Asteraceae	*Senecio rapifolius*	Openwoods groundsel
	Asteraceae	*Senecio serra*	Butterweed
	Caryophyllaceae	*Silene drummondii*	Drummond's campion
	Caryophyllaceae	*Silene drummondii* var. *drummondii*	Drummond's campion
	Asteraceae	*Solidago simplex* ssp. *simplex* var. *simplex*	Mt. Albert goldenrod
	Rosaceae	*Sorbus scopulina*	Greene mountain ash
	Lamiaceae	*Stachys palustris*	Marsh hedgenettle
	Caryophyllaceae	*Stellaria calycantha*	Northern starwort
	Asteraceae	*Taraxacum officinale* ssp. *ceratophorum*	Fleshy dandelion

Appendix A, cont'd

Status	Family	Scientific name	Common name
	Caprifoliaceae	*Viburnum edule*	Mooseberry viburnum
	Violaceae	*Viola canadensis*	Canadian white violet
	Vitaceae	*Vitis riparia*	Riverbank grape
	Asteraceae	*Wyethia mollis*	Woolly wyethia

Appendix B

Butterfly species found in the aspen vegetation type in the 754-ha Beaver Meadows area of Rocky Mountain National Park (four 0.1-ha plots, each sampled four times; Simonson 1998).

Scientific name and authority	Unique to aspen plots
Parnassius smintheus Doubleday	
Papilio rutulus Linnaeus	
Papilio multicaudatus Kirby	X
Pontia protodice (Boisduval and Leconte)	X
Pieris marginalis (Scudder)	X
Euchloe ausonides (Lucas)	
Colias eurytheme Boisduval	
Colias philodice Godart	
Colias alexandra Edwards	
Lycaena helloides (Boisduval)	
Lycaena rubida (Behr)	
Callophrys spinetorum (Hewitson)	
Callophrys eryphon (Boisduval)	
Everes amyntula (Boisduval)	
Celastrina ladon (Cramer)	
Plebejus acmon (Westwood and Hewitson)	
Plebejus saepiolus (Boisduval)	
Agriades glandon (De Prunner)	
Glaucopsyche lygdamus (Doubleday)	X
Speyeria atlantis (Edwards)[a]	
Speyeria aphrodite (Fabricus)	
Speyeria edwardsii (Reakirt)	
Phyciodes pratensis (Behr)	
Polygonia faunus (Edwards)	X
Polygonia gracilis (Grote and Robinson)	
Nymphalis antiopa (Linnaeus)	
Limentis weidemeyerii (Edwards)	X
Coenonympha tullia (Edwards)	
Cercyonis oetus (Boisduval)	
Oeneis chryxus (Doubleday and Hewitson)	
Erynnis persius (Scudder)	
Oarisma garita (Reakirt)	
Polites draco (Edwards)	

[a]Complex, including *Speyeria hesperis* (Edwards).