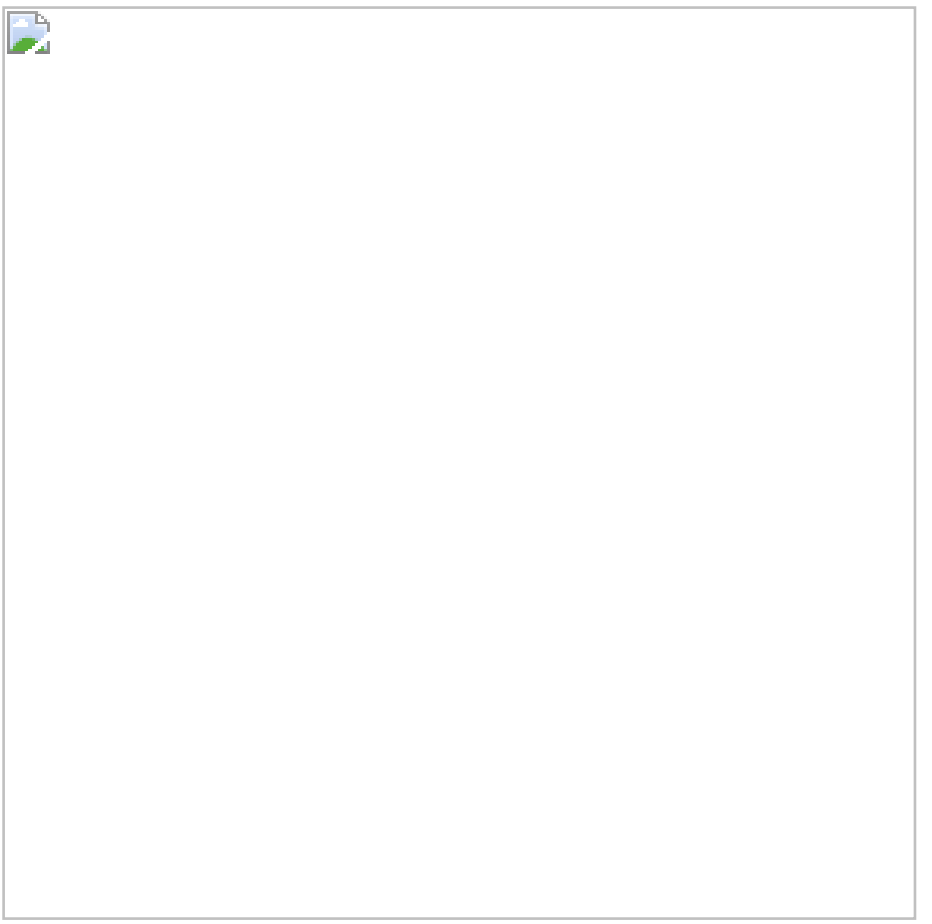

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PLANT SPECIES COALITION GROUPS OF ZION NATIONAL PARK: AN INDIVIDUALISTIC, FLORISTIC ALTERNATIVE TO VEGETATION CLASSIFICATION

Jeffrey E. Ott[1], Stewart C. Sanderson[2] and E. Durant McArthur[2]

ABSTRACT.—Vegetation surveys at Zion National Park (Zion), Utah, have contributed to our understanding of plant community patterns and their relationship to environmental factors. Previous authors used vegetation plot data to characterize vegetation types at Zion following conventional procedures that emphasize spatial discreteness and dominant species. We developed and applied an alternative approach for community characterization that emphasizes nondiscrete presence-absence patterns and is compatible with the individualistic concept. We reanalyzed existing plot data from Zion using coalition clustering, an algorithm that identifies groups of positively-associated species referred to as coalition groups. Each species and plot in the data set was linked to each coalition group via an "affinity" value obtained through weighted averaging. Affinity values were used to characterize environmental affinities of coalition groups through regression tree modeling and predictive mapping. We also identified species that frequently co-occurred with coalition groups (affiliate species) and those that frequently co-occurred with high cover (dominant-affiliates), viewing these as alternatives to conventional prevalent and dominant species. Following this approach, we identified 10 coalition groups at Zion that overlapped compositionally and spatially to differing degrees. Mesic environments on a gradient from low-elevation riparian zones through mid-elevation narrow canyons to high-elevation plateaus were represented by 3 overlapping groups. Two groups occupying slickrock and sand environments were detected on the Navajo Sandstone, as well as 2 on mesa tops above it. At lower elevations, 3 intergrading xeric coalition groups were distinguished. When previously classified associations of the National Vegetation Classification were clustered based on shared affinities to coalition groups, the arrangement differed from existing classification schemes but was environmentally interpretable. Although these patterns are contingent on conditions at the time of data collection, they provide a baseline that could be used for evaluating and predicting plant community change in the park. With proper attention to sampling and analysis issues, our community characterization approach could be applied in other settings as an alternative or supplement to conventional vegetation classification.

RESUMEN.—Monitoreos de la vegetación en el Parque Nacional Zion (Zion), Utah, han contribuido a nuestro entendimiento de los patrones de las comunidades de plantas y su relación con factores ambientales. En estudios anteriores, los autores utilizaron datos de terrenos con vegetación para caracterizar tipos de vegetación en Zion, siguiendo procedimientos convencionales que enfatizan estados discretos espaciales y especies dominantes. Desarrollamos y aplicamos un enfoque alternativo para la caracterización de la comunidad que enfatiza los patrones de presencia-ausencia no-discreta y es compatible con el concepto individualista. Reanalizamos datos gráficos de vegetación de Zion utilizando agrupamiento de coalición, un algoritmo que identifica grupos de especies positivamente asociadas, llamados grupos de coalición. Cada especie y terreno en el conjunto de datos estaba unido a cada grupo de coalición por medio de un valor de "afinidad" obtenido a través de un promedio ponderado. Los valores de afinidad se emplearon para caracterizar afinidades ambientales de grupos de coalición a través de árboles de regresión y mapeo predictivo. También identificamos especies que frecuentemente coexistían con grupos de coalición (especies afiliadas) y aquellas que frecuentemente coexistían con cubiertas altas (afiliados dominantes), considerándolas como alternativas a las especies prevalentes y dominantes. Siguiendo este enfoque, identificamos diez grupos de coalición en Zion que se superponían en composición y espacialmente en diversos grados. Ambientes relativamente húmedos en un gradiente de baja elevación, zona riparia, a elevación media, cañones estrechos, hasta elevación alta, meseta, estuvieron representadas por tres grupos sobrelapados. Dos grupos que ocupaban medios arenosos y con dunas fueron detectados en Navajo Sandstone, así como dos en la cima de la meseta por encima de esa zona. En elevaciones más bajas, se distinguieron tres grupos de coalición de interacción árida. Cuando se agruparon las asociaciones previamente clasificadas de la Clasificación Vegetal Nacional basándose en las afinidades compartidas con los grupos de coalición, la disposición se diferenció de los esquemas de clasificación existentes, pero eran interpretables según el ambiente. A pesar de que estos patrones dependen de las condiciones al momento de la recolección de datos, proporcionan un punto de referencia que se podría utilizar para evaluar y predecir cambios en la comunidad vegetal en el parque. Con la atención adecuada a las cuestiones del muestreo y análisis, nuestro enfoque de caracterización de la comunidad se podría aplicar en otros ambientes como una alternativa o suplemento a la clasificación de vegetación convencional.

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Zion National Park (Zion), Utah, is best known for its striking geological features but also boasts a high diversity of plant taxa and plant communities. Over 800 native vascular plant species (Fertig and Alexander 2009, Fertig et al. 2012) and 95 vegetation associations (Cogan et al. 2004) are distributed across pronounced edaphic and climatic gradients within the park (Harper 1993, Biek et al. 2003, Cogan et al. 2004, O'Meara 2006, Fowler et al. 2007, Fertig and Alexander 2009). The concentrated and contrasting environmental and botanical diversity of Zion contribute to the park's scientific and conservation value. Given the U.S. National Park Service mandate to protect natural resources for the enjoyment of present and future generations, information on the distribution, composition and environmental attributes of plant communities at Zion is important for science-based resource management (NPS 2006).

Numerous workers have contributed to current knowledge of vascular plant communities at Zion. Plant collection efforts from 1894 to the present have documented the flora of the park and provided insights concerning species distributions and habitat relations (reviewed in Fertig and Alexander 2009, Fertig et al. 2012). Woodbury's (1933) monograph of biotic communities was followed by more detailed descriptions of specific plant communities such as hanging gardens (Malanson 1980, Malanson and Kay 1980, Welsh 1989, Fowler et al. 2007) and isolated mesa tops (Madany and West 1983, 1984). Two park-wide, plot-based vegetation surveys have been carried out at Zion, one in 1987–1989 (Harper 1993, Harper et al. 2001) and the other in 1999–2003 (Cogan et al. 2004). Harper (1993) and Harper et al. (2001) identified 10 major vegetation types at Zion using an informal, expert-knowledge approach, while Cogan et al. (2004) characterized vegetation more formally and in greater detail according to the U.S. National Vegetation Classification (NVC) (Grossman et al. 1998, FGDC 2008, Jennings et al. 2009). These studies have jointly yielded an enviable amount of information but they have not exhausted all that can be known about plant communities at Zion. In this paper we demonstrate that even in the absence of new data, alternative approaches for data analysis and synthesis can provide valuable new information and insights.

Harper et al. (2001) and Cogan et al. (2004) followed conventional vegetation classification practices of delineating spatially discrete vegetation types differentiated primarily by dominant species or vegetation structure. While these practices are widely followed and useful for many purposes (Mueller-Dombois and Ellenberg 1974, Grossman et al. 1998), they result in community characterizations that emphasize certain ecological patterns at the possible expense of others. Continuous gradations of community composition due to individualistic species responses (Gleason 1926, 1939) can be obscured by discrete community models, and distributions of subordinate species might not be well represented by those of dominants. These issues are relevant at Zion because species responses to the park's complex overlay of environmental gradients are likely to be individualistic, and because the number of structurally or numerically dominant species is small relative to the number of species in the flora as a whole (Cogan et al. 2004, Fertig and Alexander 2009).

In this paper we present an alternative plant community characterization for Zion that mirrors the earlier vegetation classification of Harper (1993) but is neither spatially discrete nor built around dominant species. Instead of following Harper's (1993) approach using dominant species as classification criteria, then characterizing the floristic composition of communities thus classified, we essentially reversed the process by first identifying species groups defined by presence-absence patterns, then identifying dominant species and otherwise characterizing the communities and environments where these species groups occur. This was accomplished by reanalyzing the Harper (1993) data set using coalition clustering and other algorithms from the RCLUS computer program (Sanderson et al. 2006) in combination with regression tree modeling (Breiman 1993) and predictive mapping (Ferrier and Guisan 2006). Because RCLUS is relatively new and its algorithms are here applied in a novel way, one of our objectives is to outline the conceptual and methodological basis of our approach. We draw conceptual parallels that align our approach with Curtis's (1959) modal and prevalent species concepts, applied here in a spatially nondiscrete way. We demonstrate the ecological insights gained from our approach by comparing our results

directly with those of Harper et al. (2001) and Cogan et al. (2004). We also use our results to build an alternative higher-level classification of the NVC associations described by Cogan et al. (2004) that reflects their position in relation to environmental gradients at Zion.

METHODS

Study Area

Zion National Park (Zion), Utah, USA, covers approximately 590 km^2 at the western edge of the Colorado Plateau physiographic/floristic area, bordering the Great Basin to the northwest and the Mojave Desert to the southwest (Biek et al. 2003, McLaughlin 1986). Climate at Zion is mostly semiarid and temperate but varies greatly across an elevation gradient of 1128–2660 m (Cogan et al. 2004). Precipitation is concentrated in winter/spring frontal storms (bringing snow to higher elevations) and late-summer monsoons (Woodbury 1933, Mortensen 1977). At Zion Canyon (1234 m), weather records from 1904 to 2012 show a mean annual precipitation of 382 mm and mean temperatures of 5 °C in January and 29 °C in July (WRCC 2014).

Horizontally aligned exposures of sedimentary rocks are prominent at Zion. The oldest strata occur at low elevations on the southwestern side of the park and on slightly higher elevations on the northwestern side where the Taylor Creek thrust fault disrupts their stratigraphic continuity (Biek et al. 2003, O'Meara 2006). The lowermost geologic formations (Kaibab, Moenkopi, Chinle, Moenhave, and Kayenta) contain alternating bands of mudstone, siltstone, sandstone, conglomerate, limestone, and gypsum that erode into badlands, slopes, and cliffs (Biek et al. 2003). These strata are dwarfed by the larger cliffs and 'slickrock' exposures of the overlying Navajo Sandstone (the park's primary scenic attraction), which is further overlain by sandstone, limestone, shale, and gypsum deposits of the Temple Cap, Carmel, and Cedar Mountain formations (Biek et al. 2003, O'Meara 2006). The sedimentary sequence is in turn partially covered by alluvial, lacustrine, landslide, talus, residual, eolian, and volcanic (basalt flows and cinder cones) deposits (Biek et al. 2003, O'Meara 2006).

Soils at Zion are generally poorly developed and have been classified as rock outcrops, entisols, aridisols, mollisols, and alfisols (Mortensen 1977). Some soils have distinctive physical and chemical properties, as exemplified by the bentonite shrink-swell clays of the Petrified Forest member of the Chinle Formation (Biek et al. 2003). Cryptobiotic crusts are present on many soil surfaces and contribute to soil stability and fertility (cf. Belnap et al. 2000).

Although most of Zion currently has an undeveloped wilderness character, vegetation has been affected by historic floodplain agriculture, livestock grazing, and fire suppression, resulting in increases in invasive annuals and woody plants at the expense of native grasses and forbs (Woodbury 1933, Madany and West 1983, Cogan et al. 2004). Although livestock numbers have dropped since the early twentieth century, mule deer (*Odocoileus hemionus*) have increased in areas of high human visitation, resulting in declines in cottonwood (*Populus fremontii*) and other riparian species (Ripple and Beschta 2006). The troublesome invasive species cheatgrass (*Bromus tectorum*), red brome (*Bromus rubens*), ripgut brome (*Bromus diandrus*), and tamarisk (*Tamarix* spp.) were already well-established in Zion at the time of the Harper (1993) and Cogan et al. (2004) vegetation surveys.

Vegetation Data

Our primary data source is the vegetation survey carried out in 1987–1989 by Dr. K.T. Harper and associates (Harper 1993, Harper et al. 1992, 2001, 2003), which we refer to as the *Harper Survey.* This was the first park-wide, plot-based vegetation survey conducted for Zion. The Harper survey followed a systematic sampling strategy in which U.S. Geological Survey (USGS) cadastral section corners and corresponding park boundary markers served as sampling targets (Fig. 1A). In addition to 270 plots located at or near these markers, 18 plots were placed using subjective criteria so as to capture spatially restricted plant communities (riparian areas, hanging gardens, and old fields). Data collected within 100-m^2 circular plots (or rectangular, in 6 cases) included vascular plant species composition following Welsh et al. (1987), ocular estimates of species cover classes according to the Braun-Blanquet scale (Braun-Blanquet 1932), and percent cover of bare soil, rock, litter, and cryptogams (Harper 1993, Harper et al. 2001).

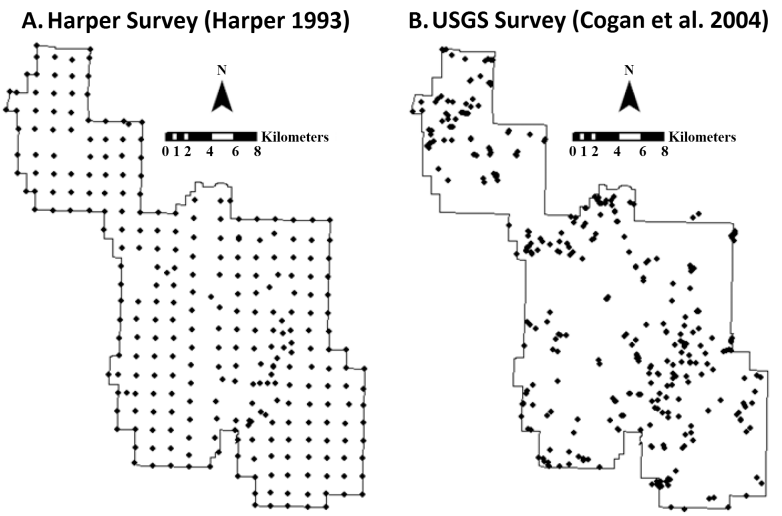

Fig. 1. Plot locations in Zion National Park, Utah, as sampled by 2 vegetation surveys referenced in this paper.

Harper (1993) used the Harper survey data to classify the vegetation of Zion into ten vegetation types that were concisely summarized in Harper et al. (2001). Plots were assigned to vegetation types "commonly used by land managers in the area" based on dominant species and environmental context (Harper et al. 2001). Prevalent and modal species were characterized for each vegetation type following Curtis (1959). Prevalent species are defined as the most frequently encountered species (based on plot occurrences) within a community or vegetation type, where the number of prevalent species is equal to the species density (average number of species per plot) for the community (Curtis 1959, Harper et al. 2001). Modal species are defined as prevalent species that reach their greatest frequency in a given community relative to other communities under study. In Harper et al. (2001), modal species were identified for each vegetation type relative to the others described at Zion.

The Hanging Gardens vegetation type described by Harper (1993) and Harper et al. (2001) incorporated data from published studies of Malanson and Kay (1980) and Welsh (1989); however, these data were excluded from the current analysis, which uses only plot data from the actual Harper survey.

We also draw from plot data originating with the USGS–NPS Vegetation Characterization Program at Zion (Cogan et al. 2004), hereafter *USGS Survey*, which featured 346 circular, square, or rectangular plots (Fig. 1B) ranging from 100 m^2 to 400 m^2 where plant species were identified following Kartesz (1999). A gradsect strategy (Gillison and Brewer 1985) was used to divide Zion into biophysical units (BPUs) that were mapped and targeted for field sampling. Accessible polygons of each BPU were targeted by field survey teams who placed plots on sites deemed representative of major vegetation types and relatively homogeneous in terms of vegetation structure and composition (Cogan et al. 2004). Plot data were collected in 1999–2000.

Cogan et al. (2004) used the USGS survey data to classify and map the vegetation of Zion following the U.S. National Vegetation Classification System (NVC) (FGDC 2008, Jennings et al. 2009). Each plot was assigned to an association nested within higher levels of the NVC as defined at the time of publication (Grossman et al. 1998, Cogan et al. 2004). Multivariate analysis of species cover class data by strata guided the classification process (Cogan et al. 2004).

We merged the Harper data set, the list of prevalent and modal species by vegetation type from Harper et al. (2001), the USGS data sets containing species composition and NVC classification by plot, and our RCLUS results (described below) into a single database. Taxonomic names from these sources

were standardized to Welsh et al. (2003) nomenclature so that they could be matched from one data set to another.

Coalition Clustering

We used coalition clustering, a nonhierarchical agglomerative clustering algorithm included in the program RCLUS (Sanderson et al. 2006), to identify groups of species with similar patterns of presence-absence in the Harper data set. RCLUS was developed as a tool for R-mode (species-based) clustering of community data sets. The name *coalition clustering* underscores the individualistic variability of species within the clusters (coalitions) that the algorithm builds. Coalition clustering generates clusters of positively associated species here referred to as *coalition groups.* The term *core species,* used by Sanderson et al. (2006) to refer to species belonging to a group, is here replaced by the term *coalition species.*

Different coalition clustering solutions can be obtained by varying 3 user-defined parameters of the algorithm: association coefficient, threshold association value, and minimum number of occurrences for inclusion in groups. Clustering solutions may also vary from one run of the algorithm to another because of the random nature of the agglomerative process (Sanderson et al. 2006). The clustering solution presented here was selected from among a small number of variants obtained using the phi coefficient at a threshold value of 0.15, allowing species occurring in 3 or more plots to be included in groups.

Association coefficients measure the degree to which 2 species show the same pattern of presence and absence in a data set, calculated from the cells of a two-way presence-absence contingency table:

		Species 1	
		Present	*Absent*
Species 2	*Present*	*a*	*b*
	Absent	*c*	*d*

The phi coefficient incorporates all 4 cells of the table according to the formula

$$\text{phi coefficient} = \frac{ad - bc}{\sqrt{(a+b)(a+c)(b+d)(c+d)}}.$$

Phi ranges from –1 (negative association) to +1 (positive association) and is independent of the total number of occurrences in the table (Jackson et al. 1989, Tichý and Chytrý 2006).

Coalition clustering agglomerates species whose mean pairwise association is higher than the user-defined threshold. The algorithm initiates the first group with a randomly selected species and then randomly cycles through the remaining species, adding them to existing groups or initiating new groups as appropriate. Species can belong to multiple groups with the exception that species already present in an existing group cannot initiate a new group. The algorithm undergoes several cycles of adding species, removing species and merging clusters allowing the composition of species groups to stabilize. The threshold association value affects group number and size; high thresholds tend to produce many small groups in contrast to few large groups at low thresholds (Sanderson et al. 2006).

Once the Coalition Clustering algorithm is complete, RCLUS saves the mean association—here referred to as *affinity*—of each species to each group (Sanderson et al. 2006). Affinity values provide a quantitative measure of the relationship between individual species and coalition groups (calculated for all species, not just those belonging to groups). RCLUS also averages affinity values for each group across all species in each plot, yielding values that can be correlated with environmental variables at plot locations (Sanderson et al. 2006). Our use of the term *affinity* thus has a specific quantitative meaning that encompasses 3 contexts: species affinities to species groups (mean pairwise association with members of the group), spatial affinities of species groups (plot-averaged species affinities), and environmental affinities of species groups (environmental correlates of spatial affinities).

Affiliation and Dominance Calculations

In addition to generating coalition groups, RCLUS contains a function that calculates *percent co-occurrence* of each species to each coalition group. Percent co-occurrence is calculated by summing joint presences across all pairings of a focal species with the species comprising a coalition group and then standardizing by the maximum possible number of joint presences. Using the notation of presence-absence frequencies, this can be represented as follows:

		Focal species	
		Present	*Absent*
Coalition species	*Present*	*a*	*b*

$$\text{Percent co-occurrence (affiliation)} = \frac{\sum_{sp1}^{spN} a}{\sum_{sp1}^{spN} (a+b)}$$

Thus percent co-occurrence of the focal species to the coalition group is the sum of joint presences between the focal species and each of the coalition species in the group (*sp1* to *spN*), standardized by the total number of occurrences of all the coalition species. We have adopted the term *affiliation* to use interchangeably with percent co-occurrence.

Using percent co-occurrence values from RCLUS, we identified a set of species with high affiliation (*affiliate species*) for each coalition group. Given that Curtis (1959) used species density, the mean number of species per plot in a community, to determine how many species to include in prevalent species lists, we followed an analogous procedure for determining the number of affiliate species for each coalition group. The species density of a coalition group was calculated as the mean number of species occurring in plots where coalition species occurred, weighting plots by how many coalition species they contained.

Extending the affiliate species concept further to include abundance as well as occurrence, we calculated the abundance of each affiliate species as its mean cover across plots containing coalition species, weighted once again by the number of coalition species per plot. Arithmetic midpoints of cover classes were used in these calculations. In this way we were able to identify the dominant species occurring alongside members of each coalition group. Affiliate species with mean cover >2% were considered *dominant-affiliate* for our purposes.

Environmental Modeling and Mapping

Plot-averaged affinity values of coalition species groups, obtained as described above for each plot of the Harper survey, were integrated with environmental variables for correlative modeling. We selected 5 variables—elevation, slope, topographic exposure, topographic position, and geologic substrate—that are proxies for the major physical and chemical gradients affecting plant distributions at Zion. GIS layers for these variables were available or easily created and integrated in ArcGIS (ESRI 2003, 2004) (Appendixes 1, 2). Our use of GIS-based variables permitted predictive mapping of species group affinities beyond plot locations (Ferrier and Guisan 2006).

Plot coordinates from the Harper Survey, originally marked on paper maps, were digitized manually with the help of a high-resolution aerial orthophoto of Zion National Park (Cogan et al. 2004), digital USGS topographic maps, and cadastral survey marker coordinates acquired through the USDI Bureau of Land Management (BLM 2006). Hawth's Tools (Beyer 2004) was used to extract environmental data values for each plot based on its coordinates.

Elevation and other topographic variables were obtained from a 10-m digital elevation model (DEM) acquired from the U.S. National Park Service (NPS, personal communication). Slope and exposure were calculated using the *slope* and *hillshade* functions, respectively, in ArcGIS Spatial Analyst (ESRI 2004) (Appendix 1). *Hillshade* was implemented at 215° azimuth and 45° altitude such that exposure values were highest on steep southwest-facing slopes where solar heat loading is expected to be highest (cf. McCune and Keon 2002). Topographic position was defined using the Topographic Position Index (TPI), calculated as the difference in elevation between a pixel and the mean of surrounding pixels within a defined radius (Weiss 2001). We created 2 TPI layers at radii of 50 m (Appendix 1) and 100 m.

A 1:24,000-scale digital geologic map built from multiple maps of the Utah Geologic Survey (O'Meara 2006) was converted to raster format at the same resolution as the DEM and simplified from about 100 map units to 16 geologic substrate classes (Table 1, Appendix 2). We merged units with similar lithology, spatial continuity, and/or topographic characteristics, guided by exploratory analyses of relationships between putative substrate groupings and coalition group affinities. Our groupings include each of the major geologic formations of the park (Moenkopi [+Kaibab], Chinle, Moenhave, Kayenta, Navajo, Temple Cap, and Carmel [+Cedar Mountain]) and Quaternary deposits grouped according to their dominant depositional material (alluvium, colluvium, eolian, lacustrine, mass movement, residuum, and

TABLE 1. Geologic substrate classes used for environmental modeling of plant coalition group affinities at Zion National Park, Utah. For each substrate class, corresponding map units from a digital geologic map of the Utah Geological Survey (O'Meara 2006) are shown in the rightmost column.

Code	Substrate class	Description[a]	Map units[b]
All	Alluvium	river/stream deposits	Qa*, Qf
Bas	Basalt	volcanics (flows, cinders, ash)	Qb*, Qms(b)
Car	Carmel (+Cedar Mountain) Formation	limestone, shale, sandstone, siltstone, gypsum	Jc*, Kcmc
Chi	Chinle Formation	mudstone, claystone, siltstone, sandstone, conglomerate	TRc*
Col	Colluvium	unconsolidated fine gravity deposits	Qc*
Eol	Eolian	unconsolidated wind deposits	Qe*
Kay	Kayenta Formation	siltstone, sandstone, mudstone	Jk*
Lac	Lacustrine	lake deposits	Ql*
Mca	Mass movement/colluvium/ alluvial pediment-mantle	massive gravity deposits mixed with fine gravity and river/stream deposits	Qmcp*
Mnk	Moenkopi (+Kaibab) Formation	siltstone, mudstone, limestone, sandstone, conglomerate, gypsum, dolomite	TRm*, Pk*
Mnv	Moenave Formation	mudstone, sandstone, siltstone	Jm*
Nav	Navajo Sandstone	sandstone	Jn*
Res	Residuum	deposits from *in situ* weathering	Qr*
Sli	Slide/slump/flow	massive gravity deposits (slides, slumps, and flows)	Qmfy, Qms*
Tal	Talus	coarse gravity deposits	Qmt*, QTng
Tem	Temple Cap Formation	sandstone, siltstone, mudstone	Jt*

[a]Substrate description summarized from Biek et al. (2003) and O'Meara (2006)
[b]Map units as coded in O'Meara (2006)
*Wildcard indicating multiple map units containing the listed prefix

volcanics). Mass movement deposits were further split into 3 classes that occupy different topographic settings in the park: (1) talus, (2) slides/slumps/flows and (3) mass movement/colluvium/alluvial pediment mantle deposits (Table 1, Appendix 2).

Environmental affinities of coalition groups (relationships between plot-averaged species group affinities and environmental variables) were modeled using regression tree analysis (Breiman 1993, Crawley 2007) in SPLUS (Insightful Corp. 2005) via the *tree* function with consistent splitting rules (mincut = 5, minsize = 10, mindev = 0.1) . Multiple runs of random 10-fold cross-validation were applied to each model to determine the best number of terminal nodes minimizing total deviance (Crawley 2007), and models were pruned accordingly.

Relating Groups to Previously-described Vegetation Types

We quantified the degree to which vegetation types described by Harper et al. (2001) and Cogan et al. (2004) were compositionally similar to our coalition groups. This was accomplished by averaging, for each coalition group, species affinity values of matching species attributed to each vegetation type. For the Harper et al. (2001) data set, we calculated mean affinity values across modal species of vegetation types. For the USGS (Cogan et al. 2004) data set we averaged affinity values across all matching species recorded in plots, then further averaged across plots within NVC associations. NVC associations sharing similar averaged affinities across all (10) coalition groups were then identified through cluster analysis, using Pearson's correlation coefficient and average linkage hierarchical clustering in R (Crawley 2007, R Development Core Team 2010).

RESULTS

Coalition Groups and Their Environmental Affinities

Eleven coalition groups were identified through coalition clustering at a threshold value of phi = 0.15. One group containing 6 species (*Artemisia dracunculus, Elymus spicatus, Sisymbrium altissimum, Galium aparine, Physalis hederifolia,* and *Tragopogon dubius*) was excluded from further analysis because of its limited distribution in disturbed low-elevation environments. The remaining 10 groups contained 9–36 species each and collectively captured 169 of the 511 species recorded by

the Harper vegetation survey (Table 2, Appendix 3). These coalition groups can be readily described in terms of their environmental affinities at Zion, and we have given each group a name that describes the environmental setting for which it demonstrates greatest affinity (Table 2, Figs. 2–5). Coalition clustering's allowance for overlapping group membership resulted in 34 cases of species belonging to 2 groups and one case of a species (*Amelanchier utahensis*) belonging to 3 groups. Environmental affinities of coalition groups also overlap to varying degrees, as depicted in predictive maps accompanying regression tree models (Figs. 2–5). In the group descriptions that follow, we highlight these cases of compositional and environmental overlap and interpret their ecological significance.

Three coalition groups were linked to mesic conditions at Zion: Streambank, High Plateau, and Crevice Canyon. The Streambank group (Table 2A) contained several species, including *Baccharis emoryi*, *Salix exigua*, *Tamarix chinensis*, and *Populus fremontii*, with affinities for low-elevation riparian zones at Zion. Regression tree analysis confirmed the riparian setting: affinities were highest on alluvium or lacustrine substrates below 1356 m with low topographic positions (TPI at 50-m radius < –0.51) (Fig. 2A). The Streambank group also had moderately high affinities for low topographic positions on other substrates (likely intermittent streams) and at high elevations (>2321 m), presumably because mesic conditions at Zion's highest elevations are favorable for some riparian species. The High Plateau group, which had highest affinity at elevations above 2243 m (Fig. 2B), shared 3 coalition species (*Bromus carinatus*, *Elymus trachycaulus*, and *Poa pratensis*) with Streambank (Table 2A–B). Coalition species unique to the High Plateau group include *Stellaria jamesiana*, *Lupinus sericeus*, *Prunus virginiana*, *Stipa lettermanii*, *Rosa woodsii*, and *Juniperus scopulorum*. (Table 2B).

The Crevice Canyon group (Table 2C, Fig. 2C) occupied an environmental setting intermediate between Streambank and High Plateau: mid-elevation Navajo Sandstone canyons where topographic shading and intermittent water flow produce cool mesic conditions. Sites with these conditions have extremely low TPI values (i.e., TPI at 50-m radius < –35; Fig. 2C). Outside of these canyons, the Crevice Canyon group had higher affinity for higher elevations (Fig. 2C), exhibiting an affinity pattern very similar to that of the High Plateau group (Fig. 2B). The canopy dominant species *Abies concolor* and the herbs *Thalictrum fendleri* and *Taraxacum officinale* were coalition species of both Crevice Canyon and High Plateau (Table 2B–C). In addition, the Crevice Canyon group shared 4 species (*Acer negundo*, *Elymus canadensis*, *Equisetum hymenale*, and *Agrostis exarata*) with the Streambank group (Table 2A) and 5 (*Heuchera rubescens*, *Zauschneria latifolia*, *Holodiscus dumosus*, *Selaginella underwoodii*, *Brickellia grandiflora*, and *Erigeron sionis*) with the Slickrock group (Table 2D).

As their names suggest, the Slickrock and Upland Sands groups were differentiated by substrate preferences despite their common affinity for Navajo Sandstone (Fig. 3). While having 4 coalition species in common (the tree dominant *Pinus ponderosa* plus *Arenaria fendleri*, *Chrysopsis villosa*, and *Linanthastrum nuttallii*) (Table 2D–E), the Slickrock group was characterized by species typical of exposed sandstone outcrops (e.g., *Petrophytum caespitosum*, *Cercocarpus intricatus*, *Castilleja scabrida*, *Muhlenbergia thurberi*, and *Ivesia sabulosa*) (Table 2D), whereas Upland Sands species included the shrub dominant *Arctostaphylos patula* plus several sand-loving species (e.g., *Cryptantha cinerea*, *Abronia fragrans*, *Artemisia campestris*, *Penstemon laevis*, and *Tradescantia occidentalis*) (Table 2E). The high affinity of Upland Sands for Navajo Sandstone can be attributed to the group's presence on pockets of sand smaller than the mapping scale of the geologic layer (O'Meara 2006). Plot data support this observation: in plots mapped to Navajo Sandstone, Slickrock affinity was positively correlated with percent rock cover (Spearman's rho = 0.50), while Upland Sands affinity was negatively correlated (Spearman's rho = –0.15). The Upland Sands group also had relatively high affinity for eolian sand deposits large enough to have been mapped by O'Meara (2006), as well as the sandstone-dominated Temple Cap formation. Both Upland Sands and Slickrock had higher affinities for higher elevations (>1753–1782 m) within the Navajo Sandstone zone (Fig. 3). Beyond the Navajo Sandstone, the Slickrock group had its highest affinity value in sites with low TPI (TPI at

TABLE 2. Coalition and affiliate species of Zion National Park based on coalition clustering of 1987–1989 vegetation survey data. Occ. = number of plot occurrences out of 288 total. Affin. = affinity of a coalition species to its coalition group, calculated as the mean value of the phi coefficient of association between the species and others in the group. Affil. = affiliation of an affiliate species with coalition species, calculated as percent co-occurrence. Cvr. = mean cover of affiliate species weighted by co-occurrences with coalition species. Species in boldface are both coalition species and affiliate species for a given group. Underlined species are dominant affiliates (weighted mean cover ≥ 2%).

Coalition species	Occ.	Affin.	Affiliate species	Occ.	Affil.	Cvr.
A. STREAMBANK						
Baccharis salicina	3	0.46	***Acer negundo***	18	0.53	2.3
Salix exigua	3	0.46	*Bromus tectorum*	130	0.51	5.1
Tamarix chinensis	5	0.43	***Bromus diandrus***	10	0.47	8.3
Populus fremontii	6	0.39	***Equisetum hyemale***	8	0.44	0.8
Equisetum hyemale	8	0.37	***Poa pratensis***	14	0.42	4.3
Verbascum thapsus	5	0.37	*Artemisia ludoviciana*	51	0.42	0.4
***Sonchus* sp.**	3	0.37	*Phacelia heterophylla*	42	0.41	0.3
Agrostis exarata	3	0.35	*Poa fendleriana*	190	0.41	1.8
Bromus diandrus	10	0.34	***Populus fremontii***	6	0.40	4.6
Juncus arcticus	3	0.31	***Elymus trachycaulus***	10	0.40	0.8
Elymus canadensis	4	0.27	*Chrysopsis villosa*	74	0.39	1.6
Acer negundo	18	0.25	***Tamarix chinensis***	5	0.37	0.4
Bromus carinatus	9	0.25	***Bromus carinatus***	9	0.36	0.6
Poa compressa	3	0.24	***Verbascum thapsus***	5	0.35	0.2
Elymus trachycaulus	10	0.24	*Quercus gambelii*	135	0.34	5.7
Poa pratensis	14	0.20	***Baccharis salicina***	3	0.30	2.3
Datura wrightii	3	0.20	***Salix exigua***	3	0.30	5.0
Fraxinus velutina	6	0.19	***Elymus canadensis***	4	0.29	0.1
			Gutierrezia sp.	94	0.28	0.3
			***Sonchus* sp.**	3	0.25	0.1
			Agrostis exarata	3	0.24	0.1
			Fraxinus velutina	6	0.23	4.2
			Artemisia sp.	2	0.23	0.4
			Melilotus sp.	2	0.23	0.1
			Oenothera longissima	2	0.23	0.1
B. HIGH PLATEAU						
Stellaria jamesiana	18	0.33	*Quercus gambelii*	135	0.81	22.8
Senecio eremophilus	3	0.31	***Symphoricarpos oreophilus***	58	0.65	11.0
Lupinus sericeus	9	0.29	***Vicia americana***	43	0.61	5.1
Prunus virginiana	10	0.29	*Poa fendleriana*	190	0.61	2.3
Mertensia arizonica	7	0.29	***Polygonum douglasii***	39	0.45	0.3
Bromus carinatus	9	0.27	*Amelanchier utahensis*	141	0.44	3.1
Amelanchier alnifolia	11	0.27	*Carex rossii*	67	0.43	0.4
Stipa nelsonii	5	0.26	***Stellaria jamesiana***	18	0.42	2.4
Stipa lettermanii	12	0.25	*Arabis perennans*	124	0.35	0.2
Vicia americana	43	0.25	*Senecio multilobatus*	99	0.32	0.2
Poa pratensis	14	0.25	***Juniperus scopulorum***	21	0.31	0.9
Rosa woodsii	12	0.24	***Abies concolor***	19	0.31	3.4
Achillea millefolium	6	0.20	*Phacelia heterophylla*	42	0.29	0.2
Taraxacum officinale	11	0.20	***Poa pratensis***	14	0.29	4.4
Symphoricarpos oreophilus	58	0.20	*Eriogonum racemosum*	59	0.28	0.1
Thalictrum fendleri	12	0.20	*Solidago velutina*	38	0.27	1.2
Chenopodium fremontii	3	0.20	***Prunus virginiana***	10	0.27	0.7
Abies concolor	19	0.19	***Amelanchier alnifolia***	11	0.27	0.7
Elymus trachycaulus	10	0.18	***Stipa lettermanii***	12	0.27	0.3
Juniperus scopulorum	21	0.18	*Acer grandidentatum*	29	0.26	2.7
Polygonum douglasii	39	0.17	***Rosa woodsii***	12	0.26	0.7
Osmorhiza occidentalis	4	0.16	*Opuntia macrorhiza*	120	0.26	0.4
Bromus anomalus	5	0.16	*Pachystima myrsinites*	54	0.26	1.6
Erigeron speciosus	6	0.15				
C. CREVICE CANYON						
Eupatorium herbaceum	12	0.36	*Quercus gambelii*	135	0.69	7.1
Viola canadensis	5	0.33	*Poa fendleriana*	190	0.67	4.5
Cystopteris fragilis	6	0.32	***Acer grandidentatum***	29	0.60	6.2
Acer negundo	18	0.32	***Acer negundo***	18	0.52	5.5
Polypodium hesperium	6	0.27	***Eupatorium herbaceum***	12	0.48	0.2
Galium triflorum	4	0.26	*Pachystima myrsinites*	54	0.46	3.3

TABLE 2. Continued.

Coalition species	Occ.	Affin.	Affiliate species	Occ.	Affil.	Cvr.
Acer grandidentatum	29	0.26	***Pseudotsuga menziesii***	18	0.45	4.1
Rubus leucodermis	4	0.26	***Holodiscus dumosus***	21	0.44	0.9
Bromus ciliatus	12	0.26	*Solidago velutina*	38	0.44	0.3
Pseudotsuga menziesii	18	0.26	***Abies concolor***	19	0.44	5.5
Heuchera rubescens	12	0.25	*Draba asprella*	33	0.39	0.2
Smilacina racemosa	6	0.25	*Artemisia ludoviciana*	51	0.39	0.4
Mimulus guttatus	3	0.25	***Heuchera rubescens***	12	0.38	0.2
Taraxacum officinale	11	0.24	*Arabis perennans*	124	0.38	0.2
Philadelphus microphyllus	10	0.24	***Bromus ciliatus***	12	0.38	0.2
Disporum trachycarpum	4	0.23	*Stephanomeria tenuifolia*	51	0.37	0.2
Thalictrum fendleri	12	0.23	***Zauschneria latifolia***	15	0.37	0.2
Elymus canadensis	4	0.23	***Selaginella underwoodii***	17	0.36	0.7
Abies concolor	19	0.22	*Eriogonum racemosum*	59	0.36	0.2
Epilobium glandulosum	3	0.22	*Chrysopsis villosa*	74	0.35	0.7
Goodyera oblongifolia	5	0.21	*Penstemon rostriflorus*	30	0.33	0.2
Muhlenbergia racemosa	3	0.21	*Senecio multilobatus*	99	0.33	0.2
Aralia racemosa	3	0.20	***Philadelphus microphyllus***	10	0.33	0.7
Sphaeromeria ruthiae	3	0.20	***Thalictrum fendleri***	12	0.33	0.4
Zauschneria latifolia	15	0.20	*Mahonia repens*	29	0.33	0.5
Holodiscus dumosus	21	0.19	***Taraxacum officinale***	11	0.29	0.1
Chimaphila menziesii	5	0.19	*Phacelia heterophylla*	42	0.29	0.3
Epilobium ciliatum	3	0.19				
Epilobium brachycarpum	3	0.18				
Selaginella underwoodii	17	0.17				
Brickellia grandiflora	10	0.17				
Erigeron sionis	4	0.17				
Aster welshii	6	0.16				
Pteridium aquilinum	3	0.16				
Equisetum hyemale	8	0.16				
Agrostis exarata	3	0.16				
D. SLICKROCK						
Petrophytum caespitosum	12	0.31	*Poa fendleriana*	190	0.86	4.1
Holodiscus dumosus	21	0.31	***Chrysopsis villosa***	74	0.61	1.1
Cercocarpus intricatus	40	0.30	*Quercus gambelii*	135	0.56	5.6
Castilleja scabrida	40	0.29	*Senecio multilobatus*	99	0.56	0.3
Muhlenbergia thurberi	12	0.28	***Pinus ponderosa***	60	0.53	5.3
Selaginella underwoodii	17	0.27	*Opuntia macrorhiza*	120	0.53	0.5
Ivesia sabulosa	7	0.27	***Cercocarpus intricatus***	40	0.51	1.5
Zauschneria latifolia	15	0.25	***Stephanomeria tenuifolia***	51	0.50	0.4
Arenaria fendleri	23	0.24	***Castilleja scabrida***	40	0.49	0.2
Erigeron canaani	16	0.23	*Amelanchier utahensis*	141	0.49	1.7
Eriogonum jamesii	10	0.23	*Arabis perennans*	124	0.48	0.2
Erigeron sionis	4	0.22	*Arctostaphylos patula*	94	0.47	5.5
Leptodactylon pungens	8	0.22	***Arenaria macradenia***	46	0.41	0.5
Stephanomeria tenuifolia	51	0.21	*Carex rossii*	67	0.40	0.3
Draba asprella	33	0.21	***Solidago velutina***	38	0.37	0.3
Trifolium longipes	10	0.20	***Draba asprella***	33	0.36	0.2
Penstemon humilis	27	0.20	***Holodiscus dumosus***	21	0.34	0.6
Pinus ponderosa	60	0.20	*Eriogonum racemosum*	59	0.32	0.2
Brickellia grandiflora	10	0.20	***Penstemon humilis***	27	0.32	0.2
Chrysopsis villosa	74	0.20	***Arenaria fendleri***	23	0.31	0.2
Monardella odoratissima	6	0.20	*Chaenactis douglasii*	44	0.31	0.1
Solidago velutina	38	0.19	*Phlox austromontana*	54	0.30	0.4
Linanthastrum nuttallii	19	0.18	*Pachystima myrsinites*	54	0.28	1.4
Sedum lanceolatum	3	0.18	***Selaginella underwoodii***	17	0.28	0.9
Heuchera rubescens	12	0.17	*Bromus tectorum*	130	0.27	0.6
Wyethia arizonica	5	0.17				
Arenaria macradenia	46	0.15				
E. UPLAND SANDS						
Cryptantha cinerea	17	0.26	*Poa fendleriana*	190	0.83	5.1
Chaenactis douglasii	44	0.25	***Opuntia macrorhiza***	120	0.72	1.1
Abronia fragrans	20	0.25	***Senecio multilobatus***	99	0.64	0.4
Hymenopappus filifolius	11	0.24	***Arctostaphylos patula***	94	0.62	10.1

TABLE 2. Continued.

Coalition species	Occ.	Affin.	Affiliate species	Occ.	Affil.	Cvr.
Artemisia campestris	14	0.23	*Amelanchier utahensis*	141	0.55	2.3
Penstemon laevis	26	0.23	*Quercus gambelii*	135	0.52	6.6
Tradescantia occidentalis	22	0.22	***Chrysopsis villosa***	74	0.50	1.5
Arctostaphylos patula	94	0.21	*Arabis perennans*	124	0.48	0.2
Opuntia macrorhiza	120	0.21	***Erysimum asperum***	64	0.43	0.2
Eriogonum alatum	6	0.20	***Pinus ponderosa***	60	0.41	5.6
Chrysopsis villosa	74	0.19	***Phlox austromontana***	54	0.41	0.6
Senecio multilobatus	99	0.19	*Bromus tectorum*	130	0.39	1.1
Bouteloua gracilis	19	0.19	***Chaenactis douglasii***	44	0.39	0.2
Phlox austromontana	54	0.19	*Juniperus osteosperma*	115	0.36	2.2
Arenaria fendleri	23	0.19	*Gilia inconspicua*	84	0.34	0.2
Linanthastrum nuttallii	19	0.18	*Festuca octoflora*	74	0.33	0.3
Pinus ponderosa	60	0.17	*Eriogonum racemosum*	59	0.31	0.2
Erysimum asperum	64	0.16	*Stephanomeria tenuifolia*	51	0.30	0.2
Polygonum douglasii	39	0.15	*Carex rossii*	67	0.29	0.2
			Polygonum douglasii	39	0.28	0.1
			Sporobolus cryptandrus	50	0.27	0.2
			Arenaria macradenia	46	0.27	0.3
			Yucca angustissima	41	0.26	0.3
			Penstemon laevis	26	0.25	0.2
			Machaeranthera canescens	40	0.25	0.1
			Stipa hymenoides	65	0.25	0.2
F. ROCKY SLOPES						
Fraxinus anomala	45	0.24	***Poa fendleriana***	190	0.85	5.8
Arabis perennans	124	0.24	***Amelanchier utahensis***	141	0.67	3.5
Erigeron utahensis	41	0.22	***Arabis perennans***	124	0.65	0.3
Poa fendleriana	190	0.21	***Opuntia macrorhiza***	120	0.61	1.0
Quercus turbinella	50	0.21	***Juniperus osteosperma***	115	0.58	4.1
Erysimum asperum	64	0.21	***Senecio multilobatus***	99	0.51	0.3
Opuntia macrorhiza	120	0.20	*Bromus tectorum*	130	0.50	1.3
Pinus monophylla	64	0.20	*Quercus gambelii*	135	0.46	7.0
Juniperus osteosperma	115	0.19	***Gilia inconspicua***	84	0.43	0.2
Haplopappus scopulorum	42	0.18	*Arctostaphylos patula*	94	0.42	6.2
Shepherdia rotundifolia	17	0.18	***Erysimum asperum***	64	0.38	0.2
Penstemon eatonii	23	0.18	***Pinus monophylla***	64	0.37	2.9
Amelanchier utahensis	141	0.17	*Gutierrezia* sp.	94	0.37	0.5
Senecio multilobatus	99	0.16	***Quercus turbinella***	50	0.32	3.6
Gilia inconspicua	84	0.15	***Fraxinus anomala***	45	0.30	0.9
Streptanthus cordatus	38	0.15	*Festuca octoflora*	74	0.30	0.2
			Cryptantha sp. (annual)	60	0.29	0.2
			Erigeron utahensis	41	0.28	0.2
			Stipa hymenoides	65	0.28	0.2
			Chrysopsis villosa	74	0.27	0.8
			Haplopappus scopulorum	42	0.27	0.5
			Eriogonum racemosum	59	0.27	0.1
			Phlox austromontana	54	0.26	0.5
			Pinus edulis	53	0.25	1.8
G. ARID LOWLANDS						
Bromus rubens	43	0.37	***Bromus tectorum***	130	0.78	3.4
***Gutierrezia* sp.**	94	0.28	***Gutierrezia* sp.**	94	0.70	1.3
Baileya multiradiata	8	0.27	***Juniperus osteosperma***	115	0.69	4.1
Ephedra nevadensis	18	0.26	***Gilia inconspicua***	84	0.64	0.3
Draba verna	40	0.26	*Poa fendleriana*	190	0.61	3.2
Gilia inconspicua	84	0.26	***Festuca octoflora***	74	0.58	0.4
***Hilaria* sp.**	41	0.25	*Arabis perennans*	124	0.49	0.3
Festuca octoflora	74	0.25	***Cryptantha* sp. (annual)**	60	0.48	0.3
Coleogyne ramosissima	13	0.24	***Bromus rubens***	43	0.48	0.5
Opuntia erinacea	17	0.23	***Pinus monophylla***	64	0.45	2.6
Bouteloua eriopoda	5	0.23	*Opuntia macrorhiza*	120	0.45	0.7
Eriogonum palmerianum	15	0.22	***Draba verna***	40	0.40	0.2
Astragalus nuttallianus	9	0.22	*Amelanchier utahensis*	141	0.39	2.0
Bromus tectorum	130	0.21	***Hilaria* sp.**	41	0.38	1.1
***Cryptantha* sp. (annual)**	60	0.21	*Stipa hymenoides*	65	0.33	0.3

TABLE 2. Continued.

Coalition species	Occ.	Affin.	Affiliate species	Occ.	Affil.	Cvr.
Eriastrum eremicum	7	0.21	*Quercus turbinella*	50	0.31	3.5
Psorothamnus fremontii	11	0.20	*Elymus elymoides*	58	0.30	0.2
Encelia frutescens	4	0.20	*Erigeron utahensis*	41	0.28	0.2
Yucca baccata	17	0.19	*Arctostaphylos patula*	94	0.28	4.0
Stipa speciosa	15	0.19	***Descurainia pinnata***	28	0.25	0.2
Eriastrum sparsiflorum	13	0.18	*Artemisia tridentata*	55	0.24	1.7
Swertia albomarginata	11	0.18	*Stipa comata*	39	0.24	1.1
Descurainia pinnata	28	0.17	*Eriogonum davidsonii*	32	0.24	0.1
Rhus aromatica	23	0.17	*Senecio multilobatus*	99	0.23	0.1
Juniperus osteosperma	115	0.17				
Eriogonum inflatum	3	0.17				
Linanthus dichotomus	14	0.16				
Pinus monophylla	64	0.16				
H. LOWLAND FLATS						
Lycium pallidum	3	0.34	*Bromus tectorum*	130	0.76	18.0
Erodium cicutarium	10	0.29	*Gutierrezia* sp.	94	0.58	2.0
Atriplex canescens	10	0.27	***Chamaesyce albomarginata***	23	0.54	1.2
Tragopogon dubius	8	0.24	*Juniperus osteosperma*	115	0.48	1.6
Lactuca serriola	13	0.22	***Sphaeralcea grossulariifolia***	14	0.39	0.2
Cirsium wheeleri	8	0.22	***Erodium cicutarium***	10	0.38	0.8
Chamaesyce albomarginata	23	0.21	***Lactuca serriola***	13	0.38	0.2
Sphaeralcea grossulariifolia	14	0.21	*Hilaria* sp.	41	0.36	1.3
Elymus smithii	3	0.19	***Atriplex canescens***	10	0.35	0.9
			Poa fendleriana	190	0.32	1.3
			Sporobolus cryptandrus	50	0.30	0.5
			Tragopogon dubius	8	0.28	0.1
			Festuca octoflora	74	0.28	0.2
			Stipa comata	39	0.28	1.4
			Gilia inconspicua	84	0.27	0.1
			Cirsium wheeleri	8	0.26	0.2
			Amelanchier utahensis	141	0.26	1.5
			Elymus elymoides	58	0.24	0.1
			Quercus gambelii	135	0.24	2.6
			Bromus rubens	43	0.23	0.3
			Artemisia tridentata	55	0.22	1.8
			Cryptantha sp. (annual)	60	0.22	0.1
I. UPPER MESA TOP						
Lathyrus lanszwertii	20	0.24	***Quercus gambelii***	135	0.78	15.1
Peraphyllum ramosissimum	10	0.24	***Amelanchier utahensis***	141	0.78	4.3
Balsamorhiza sagittata	8	0.22	*Poa fendleriana*	190	0.78	4.3
Phlox longifolia	11	0.22	*Arabis perennans*	124	0.49	0.2
Penstemon linarioides	13	0.21	*Opuntia macrorhiza*	120	0.45	0.8
Swertia radiata	11	0.20	***Carex rossii***	67	0.45	0.5
Zigadenus paniculatus	12	0.19	*Senecio multilobatus*	99	0.43	0.2
Purshia tridentata	36	0.18	*Juniperus osteosperma*	115	0.43	2.5
Quercus gambelii	135	0.18	***Symphoricarpos oreophilus***	58	0.41	3.3
Symphoricarpos oreophilus	58	0.17	***Pinus edulis***	53	0.39	3.6
Mertensia fusiformis	3	0.17	*Arctostaphylos patula*	94	0.38	5.3
Chrysothamnus depressus	5	0.16	*Pachystima myrsinites*	54	0.33	1.5
Amelanchier utahensis	141	0.16	*Pinus ponderosa*	60	0.28	4.0
Carex rossii	67	0.16	*Erysimum asperum*	64	0.27	0.1
Pinus edulis	53	0.15	*Bromus tectorum*	130	0.27	0.8
			Vicia americana	43	0.26	1.5
			Phlox austromontana	54	0.25	0.7
			Eriogonum racemosum	59	0.24	0.1
			Cercocarpus montanus	33	0.23	2.0
			Lathyrus lanszwertii	20	0.22	0.9
			Solidago velutina	38	0.20	0.4
J. LOWER MESA TOP						
Viola purpurea	10	0.27	***Amelanchier utahensis***	141	0.80	4.2
Cercocarpus montanus	33	0.26	***Quercus gambelii***	135	0.77	13.9
Pinus edulis	53	0.22	*Poa fendleriana*	190	0.75	4.1

TABLE 2. Continued.

Coalition species	Occ.	Affin.	Affiliate species	Occ.	Affil.	Cvr.
Carex rossii	67	0.21	*Arabis perennans*	124	0.50	0.2
Pachystima myrsinites	54	0.21	***Carex rossii***	67	0.48	0.6
Amelanchier utahensis	141	0.20	*Opuntia macrorhiza*	120	0.44	0.8
Swertia radiata	11	0.19	*Senecio multilobatus*	99	0.44	0.2
Pedicularis centranthera	10	0.18	***Pachystima myrsinites***	54	0.43	1.8
Peraphyllum ramosissimum	10	0.18	*Arctostaphylos patula*	94	0.41	5.5
Quercus gambelii	135	0.18	***Pinus edulis***	53	0.41	4.0
Physaria newberryi	7	0.16	*Juniperus osteosperma*	115	0.41	2.6
Mahonia repens	29	0.16	*Symphoricarpos oreophilus*	58	0.33	2.4
			Cercocarpus montanus	33	0.31	2.9
			Pinus ponderosa	60	0.27	3.6
			Bromus tectorum	130	0.25	0.8
			Erysimum asperum	64	0.25	0.1
			Phlox austromontana	54	0.24	0.6
			Vicia americana	43	0.24	1.2
			Mahonia repens	29	0.24	0.3
			Eriogonum racemosum	59	0.22	0.1
			Fraxinus anomala	45	0.22	0.6

100-m radius > –21.24) that corresponded to talus deposits immediately below Navajo Sandstone cliffs (Fig. 3A).

The group with highest affinity for the steep sloping terrain below Navajo Sandstone cliffs was given the name "Rocky Slopes." *Fraxinus anomala, Erigeron utahensis, Poa fendleriana,* and *Quercus turbinella* were prominent members of this group (Table 2F). The first split of the Rocky Slopes regression tree model identified substrate as an important affinity predictor, with lower affinity for Carmel, alluvium, colluvium, eolian, lacustrine and residuum than for other substrates (Fig. 4A). Rocky Slopes affinity values were low in the deep canyon zone (TPI at 100-m radius < –35) (Fig. 4A) in contrast to the Crevice Canyon group (Fig. 2C), but higher in other low TPI areas adjacent to cliffs. The highest Rocky Slopes affinities were associated with the Kayenta formation which is particularly extensive in the Taylor Creek thrust fault area of northwestern Zion (Fig. 4A). The broad zone of relatively high affinity above, below, and around the Kayenta formation can be attributed to the broad distribution of several members of the Rocky Slopes group, including *Poa fendleriana, Amelanchier utahensis,* and *Arabis perennans.* These species occupy a wide range of environments at Zion but form a coalition with more narrowly distributed species such as *Shepherdia rotundifolia* (Table 2F).

The Rocky Slopes group shared 3 coalition species (*Opuntia macrorhiza, Senecio multilobatus,* and *Erysimum asperum*) with the Upland Sands group (Table 2E) and 3 others (*Pinus monophylla, Juniperus osteosperma,* and *Gilia inconspicua*) with the lower-elevation Arid Lowlands group (Table 2G). *Pinus monophylla* and *J. osteosperma* are well-known dominants of Great Basin woodlands (West 1999) and epitomize the Great Basin affinities of many of the Arid Lowlands coalition species. Other coalition species of the Arid Lowlands group, including *Coleogyne ramossima, Baileya multiradiata,* and *Eriastrum eremicum,* have geographic affinities for the Mojave Desert and lower-elevation Colorado Plateau rather than the Great Basin (Welsh et al. 2003). Included in this mixture is the common Mojave Desert invasive species *Bromus rubens* as well as its Great Basin counterpart *Bromus tectorum. Gutierrezia* spp. (*G. sarothrae* and *G. microcephala*), indicators of grazing disturbance history (Ladyman 2004), also had high affinity for the Arid Lowlands group (Table 2G).

The arid character of sites occupied by the Arid Lowlands group was verified by its regression tree model which indicated higher affinity for sites below 1596 m elevation (Fig. 4B). Within this low-elevation zone the Arid Lowlands group had lower affinity for deep canyons (TPI at 100-m radius < –22), substrates associated with riparian areas (alluvium and lacustrine) and substrates concentrated at higher elevations (Kayenta, talus, Navajo and eolian), except where these substrates were highly exposed (exposure > 215). At somewhat higher elevations (1596–1818 m) the Arid

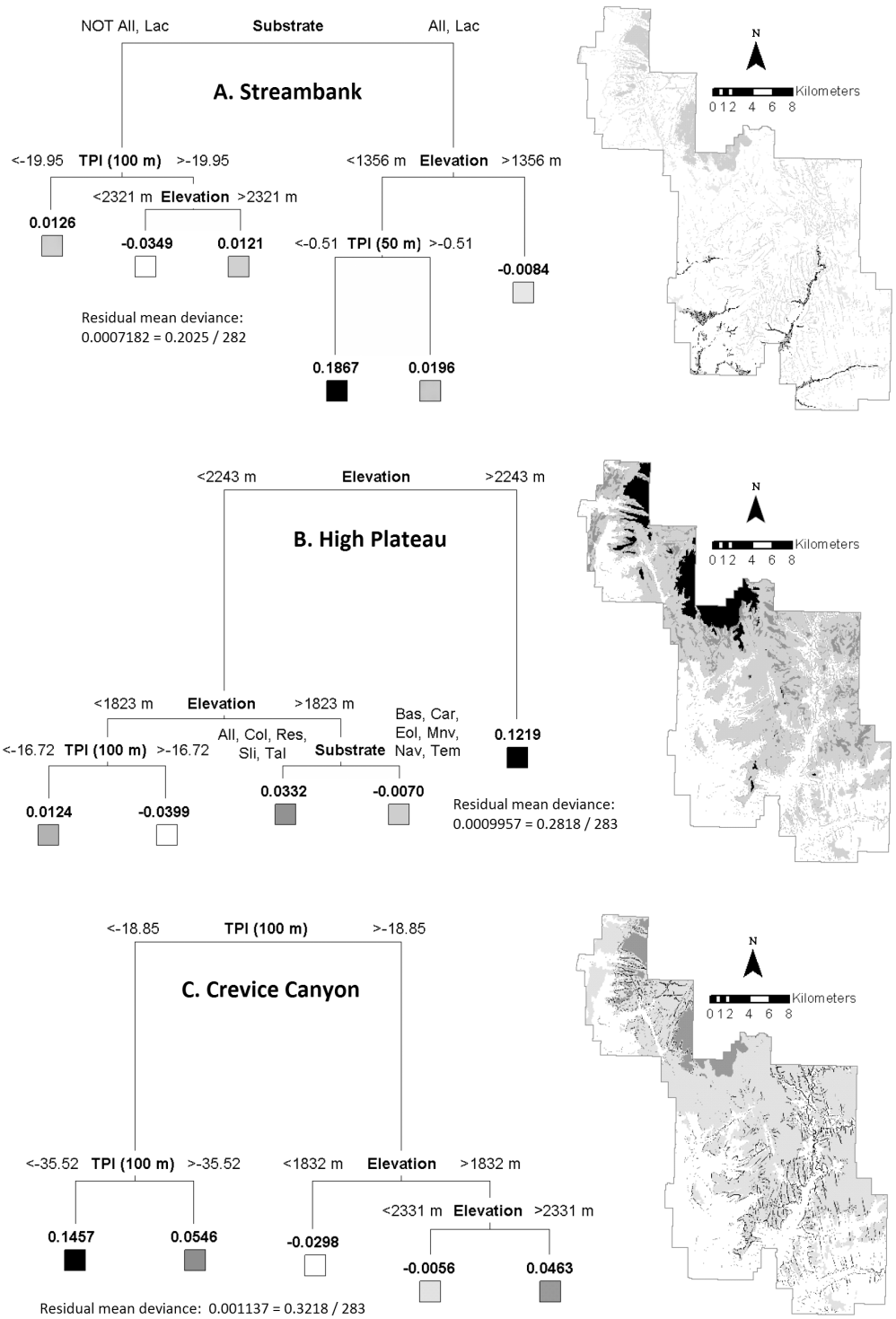

Fig. 2. Regression tree models and maps for Streambank, High Plateau and Crevice Canyon coalition groups at Zion National Park, Utah. Mean affinity values at terminal nodes are in units of the phi coefficient. Predicted distribution of affinity values are mapped using shading shown at tree tips. TPI (50/100 m) = topographic position index (50- or 100-m radius). See Table 1 for key to substrate codes.

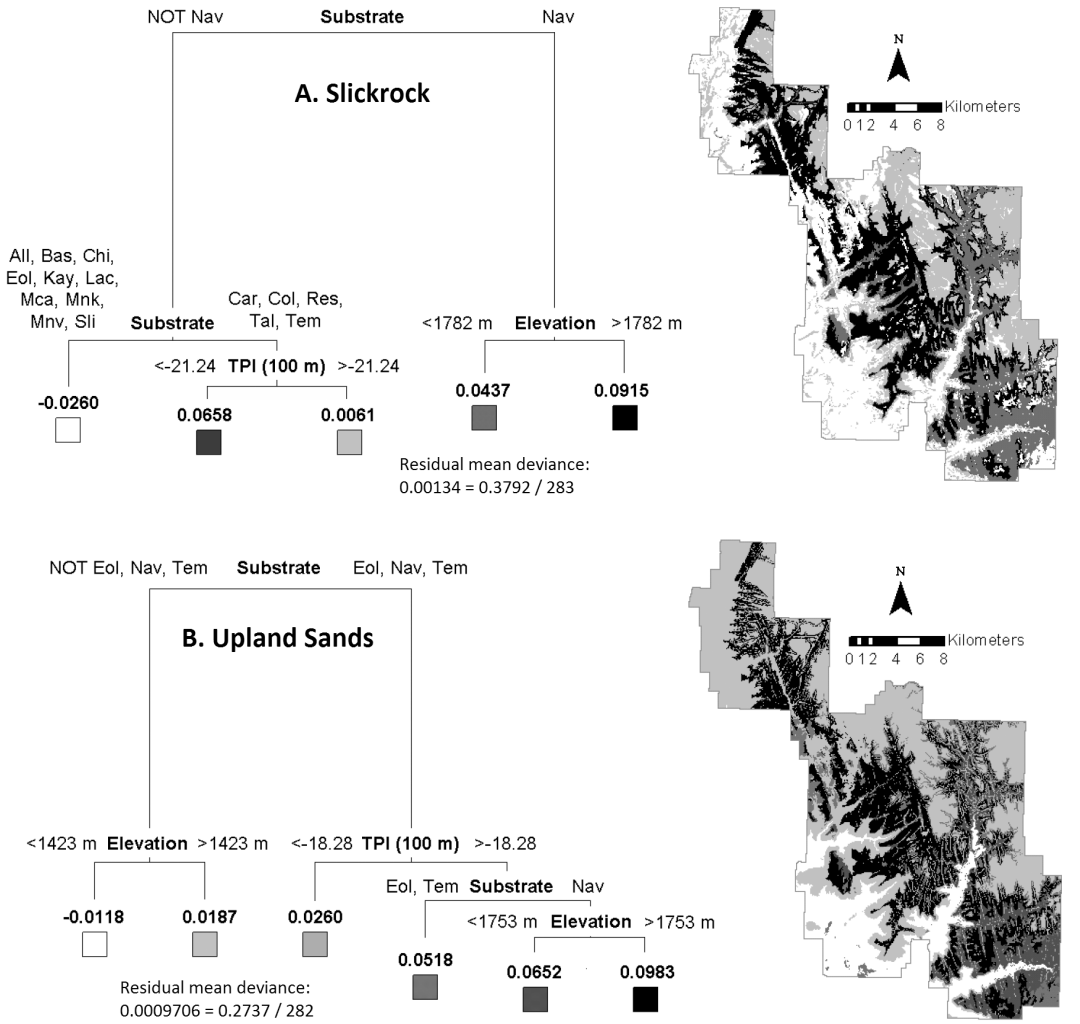

Fig. 3. Regression tree models and maps for Slickrock and Upland Sands coalition groups at Zion National Park, Utah. Mean affinity values at terminal nodes are in units of the phi coefficient. Predicted distribution of affinity values are mapped using shading shown at tree tips. TPI (100-m) = topographic position index at 100-m radius. See Table 1 for key to substrate codes.

Lowlands group likewise had higher affinity for more exposed sites (exposure > 130) (Fig. 4B) where the moisture/temperature regime was presumably similar to lower elevations.

Lowland Flats, another low-elevation species group, had high affinities for sites below 1388 m, especially alluvium and Moenkopi substrates with TPI (50-m radius) > –0.5 (Fig. 4C). In Zion Canyon, these conditions correspond with floodplains and benches above the zone where the Streambank group is concentrated (Fig. 2A). These portions of Zion Canyon have been subject to intensive agriculture in the past and bear the marks of this land-use history. A combination of native species (e.g., *Lycium pallidum*, *Atriplex canescens*, *Sphaeralcea grossulariifolia*, *Elymus smithii*) and exotics associated with disturbance (*Erodium circutarium*, *Tragopogon dubius*, *Lactuca serriola*) typified the Lowland Flats group (Table 2H). Various combinations of these species also occurred throughout Zion at the lower elevations. Above 1388 m elevation, higher Lowland Flat affinities were associated with flatter areas (slope < 6%) on mostly unconsolidated substrates (Fig. 4C).

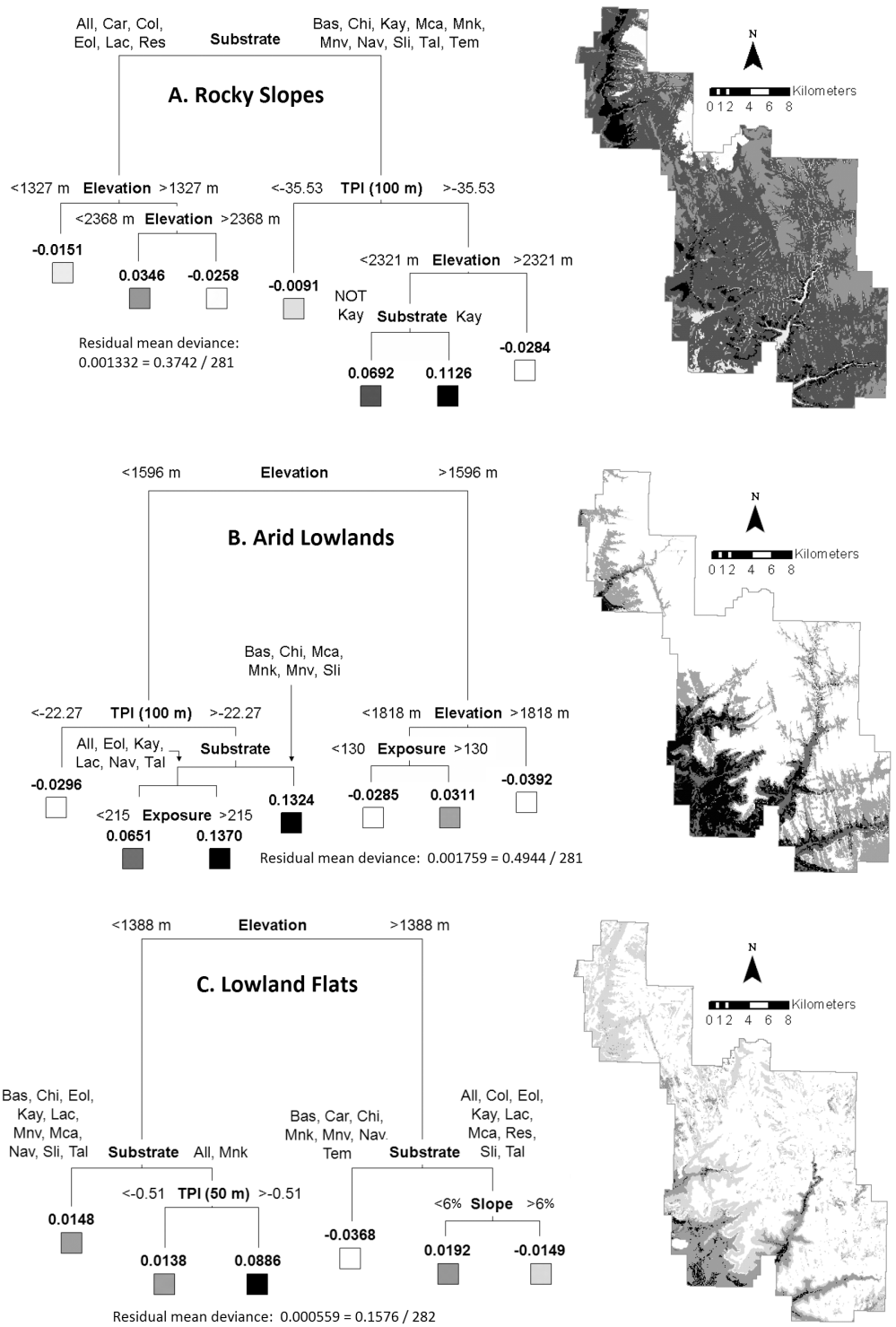

Fig. 4. Regression tree models and maps for Rocky Slopes, Arid Lowlands and Lowland Flats coalition groups at Zion National Park, Utah. Mean affinity values at terminal nodes are in units of the phi coefficient. Predicted distribution of affinity values are mapped using shading shown at tree tips. TPI (50/100 m) = topographic position index (50- or 100-m radius). See Table 1 for key to substrate codes.

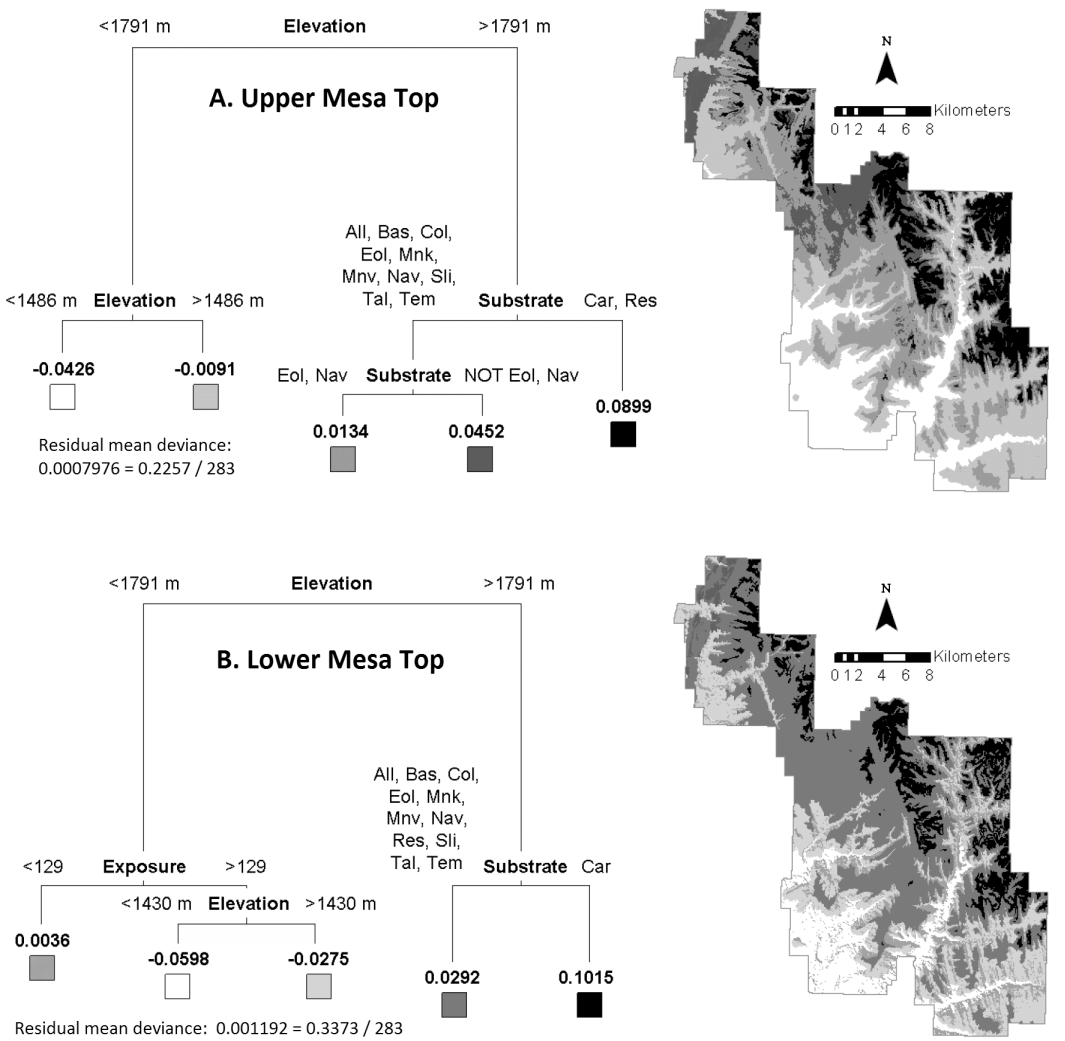

Fig. 5. Regression tree models and maps for Upper and Lower Mesa Top coalition groups at Zion National Park, Utah. Mean affinity values at terminal nodes are in units of the phi coefficient. Predicted distribution of affinity values are mapped using shading shown at tree tips. See Table 1 for key to substrate codes.

Coalition Clustering yielded 2 groups associated with the Carmel formation that caps the Navajo Sandstone on the eastern and northern sides of Zion. We interpreted one group (Upper Mesa Top) as indicating slightly more mesic settings than the other group (Lower Mesa Top). Highest affinity values for both groups were found in a zone defined by the Carmel formation above 1791 m, but outside of this zone the Upper Mesa Top group's affinities are shifted toward higher elevations than Lower Mesa Top's (Fig. 5). The 2 Mesa Top groups share a set of prominent woody species (*Pinus edulis*, *Quercus gambelii*, *Amelanchier utahensis*, and *Peraphyllum ramosissimum*) as well as 2 herbaceous species (*Carex rossii* and *Swertia radiata*), but the affinity order of these species is almost exactly reversed for the 2 groups, i.e., affinity of *P. ramosissimum* > *S. radiata* > *A. utahensis* > *C. rossii* > *P. edulis* for Upper Mesa Top (Table 2I), whereas the opposite sequence is true for Lower Mesa Top (Table 2J). Two members of these groups overlap with other groups: *Symphoricarpos oreophilus* links Upper Mesa Top to the High Plateau group (Table 2B) and

Amelanchier utahensis links both Mesa Top groups to the Rocky Slopes group (Table 2F).

Affiliate Species of Coalition Groups

Many but not all coalition species were also affiliate species of their coalition groups (Table 2, bold), meaning that they co-occurred with high frequency. The percentage of coalition species that were also affiliate species ranged from 36% for Crevice Canyon group (Table 2C) to 83% for Streambank (Table 2A). Each group also had 10–16 affiliate species that were not coalition species (Table 2), meaning that they frequently co-occurred but did not share overall distribution/association patterns with members of the group. The total number of affiliate species, which reflects the mean species density in plots where coalition species were concentrated, ranged from 21 for the Lower Mesa Top group (Table 2J) to 27 for Crevice Canyon (Table 2C).

As a general pattern, the most widely distributed species had the highest affiliation values and were affiliated with the most coalition groups. *Poa fendleriana,* the most frequently encountered species at 190 occurrences, was an affiliate of all 10 described groups (Table 2). Other widely distributed species with multiple affiliations included *Quercus gambelii, Amelanchier utahensis, Bromus tectorum, Arabis perennans, Senecio multilobatus,* and *Opuntia macrorhiza* (Table 2). In each of these cases, the species was affiliated with several additional groups beyond the one(s) where it belonged as a coalition species. Some species, including *Artemisia ludoviciana, Artemisia tridentata, Elymus elymoides, Eriogonum racemosum, Machaeranthera canescens, Phacelia heterophylla, Sporobolus cryptandrus, Stipa comata, Stipa hymenoides,* and *Yucca angustissima,* had the distinction of being affiliate species without belonging to any of the coalition groups.

Weighted mean cover ranged from a fraction of a percent for most affiliate species (Table 2) to 23% for *Quercus gambelii* in the High Plateau group (Table 2B), followed by *Bromus tectorum* in the Lowland Flats group at 18% (Table 2H). A total of 25 affiliate species met our criteria for dominance (weighted mean cover > 2%) in relation to one or more groups (Table 2, underlined entries). Ten of these were dominant in only one group, while 5 species were dominant in 5 or more groups (*Quercus gambelii, Poa fendleriana, Amelanchier utahensis*, *Arctostaphylos patula,* and *Juniperus osteosperma*) (Table 2).

Relations to Previously Described Vegetation Types

To a certain extent, our 10 coalition groups resembled the 10 vegetation types previously described by Harper et al. (2001). Some coalition groups were compositionally very similar to modal species of Harper et al.'s (2001) vegetation types (Fig. 6, Appendix 4). For example, 7 of the 9 coalition species of the Lowland Flats group were modal species of the Abandoned Fields type (Appendix 4). The Arid Lowlands, Slickrock, High Plateau, and Streambank groups corresponded relatively closely with the Blackbrush, Rock Crevice, Douglas Fir–White Fir, and Riparian vegetation types, respectively (Fig. 6). However, the correspondence was not exact, and some groups had high correspondence with multiple vegetation types, namely, Upland Sands (with Ponderosa Pine, Mountain Brush, and Rock Crevice), Crevice Canyon (with Riparian, Douglas/White Fir, and Hanging Gardens), and the Mesa Top groups (with Douglas/White Fir, Ponderosa Pine and Juniper-Pinyon) (Fig. 6).

When clustered according to coalition group affinities, NVC associations were arranged into groups that reflected environmental affinities but did not have uniform physiognomy (Fig. 7, Appendix 5). The 11 clusters highlighted in Fig. 7 were named for their predominant environmental (i.e., coalition group) affinities and the mixture of physiognomic classes they contained. These clusters were nested in 2 major groups (Xeric and Mesic Zion Vegetation) and 4 major subgroups (Fig. 7). Some associations emerged as outliers whose environmental affinities seemed poorly matched with their neighboring clusters (Needle-and-Thread Great Basin Herbaceous, Coyote Willow/Barren Shrubland, and Green Rabbitbrush/Kentucky Bluegrass Semi-natural Shrubland) and these associations were excluded from the 10-cluster classification (Fig. 7, Appendix 5). These outliers may be associations sampled by the USGS survey that were missed or poorly captured by the Harper survey (see discussion below).

	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Streambank
Abandoned Fields	0.17	0.07	-0.03	-0.04	-0.04	-0.07	-0.05	-0.03	-0.03	-0.01
Blackbrush	0.02	0.21	0.04	-0.03	-0.06	-0.09	-0.08	-0.06	-0.05	-0.02
Sagebrush	0.04	0.09	0.01	-0.01	-0.05	-0.07	-0.05	-0.03	-0.04	-0.01
Juniper-Pinyon	-0.05	0.03	0.14	-0.01	-0.02	0.07	0.04	-0.06	-0.04	-0.07
Mountain Brush	-0.04	-0.04	0.10	0.13	0.02	-0.01	0.01	0.03	0.01	0.00
Rock Crevice	-0.05	-0.03	0.07	0.13	0.16	-0.03	-0.04	-0.05	0.01	-0.04
Ponderosa Pine	-0.07	-0.07	0.09	0.15	0.08	0.04	0.06	-0.02	-0.03	-0.05
Douglas Fir-White Fir	-0.04	-0.09	-0.01	-0.01	0.07	0.09	0.06	0.10	0.11	-0.01
Hanging Gardens	-0.02	-0.03	-0.03	-0.01	0.06	-0.01	-0.01	0.01	0.10	0.04
Riparian	-0.01	-0.04	-0.05	-0.03	0.02	-0.04	-0.04	0.04	0.13	0.18

Fig. 6. Correspondence between vegetation units of Harper et al. (2001) (rows) and coalition species groups of the current study (columns) at Zion National Park, Utah. Values shown are mean affinities (in units of the phi coefficient) of modal species of each vegetation unit in relation to each coalition group (see also Appendix 4).

DISCUSSION

Our analysis of plant community variation and community-environment relationships at Zion revealed several patterns that were overlooked or obscured in previous community characterizations. Important patterns revealed by our analysis include (A) floristic similarities between communities of low-elevation riparian zones (Streambank) and high elevations (High Plateau), linked by mid-elevation communities of narrow sandstone canyons (Crevice Canyon), (B) contrasting communities of sandstone bedrock (Slickrock) and sand deposits (Upland Sands) on the Navajo Sandstone Formation, (C) subtle community differentiation related to elevation within the Carmel Formation (Upper and Lower Mesa Top), and (D) continuity of communities containing Mojave Desert and Great Basin species within a xeric low-elevation zone (Arid Lowlands).

Our unique results can be attributed to the way in which we defined and characterized communities as coalition groups rather than conventional vegetation types. Although we used the (nearly) identical dataset that Harper (1993) and Harper et al. (2001) used to characterize vegetation types at Zion, our characterization was based on coalition clustering of species association patterns as opposed to site classification based on dominant species and vegetation structure. Our 10 coalition groups are comparable in scale to the 10 vegetation types described by Harper et al. (2001) but lack discrete spatial boundaries and reflect multispecies distribution patterns independent of species commonness or abundance—although we were also able to identify the most common and abundant species associated with the coalition groups (affiliate and dominant-affiliate species) in secondary analysis steps. Our coalition groups likewise differ from the NVC associations described by Cogan et al. (2004), although the latter represent a finer scale of characterization that we were able to cross-walk to our broader coalition group scheme.

Species Groups and the Individualistic Concept

Coalition groups can be considered *species groups* according to most definitions of the term as used by plant community ecologists. They are (*phyto-*) *sociological species groups* comprised of species with similar association patterns (Doing 1969, Holzner et al. 1978) and also qualify as *statistical species groups* derived through multivariate analysis (Bruelheide and Chytrý 2000, McCune and Grace 2002). Although our coalition groups are not *ecological species groups* as defined by European schools of ecosystem classification (Mueller-Dombois and Ellenberg 1974, Kashian et al. 2003) they are clearly "ecological" in the sense of being correlated with environmental variation, such that species within groups can be interpreted as having similar environmental affinities. Given the strength and interpretive value of

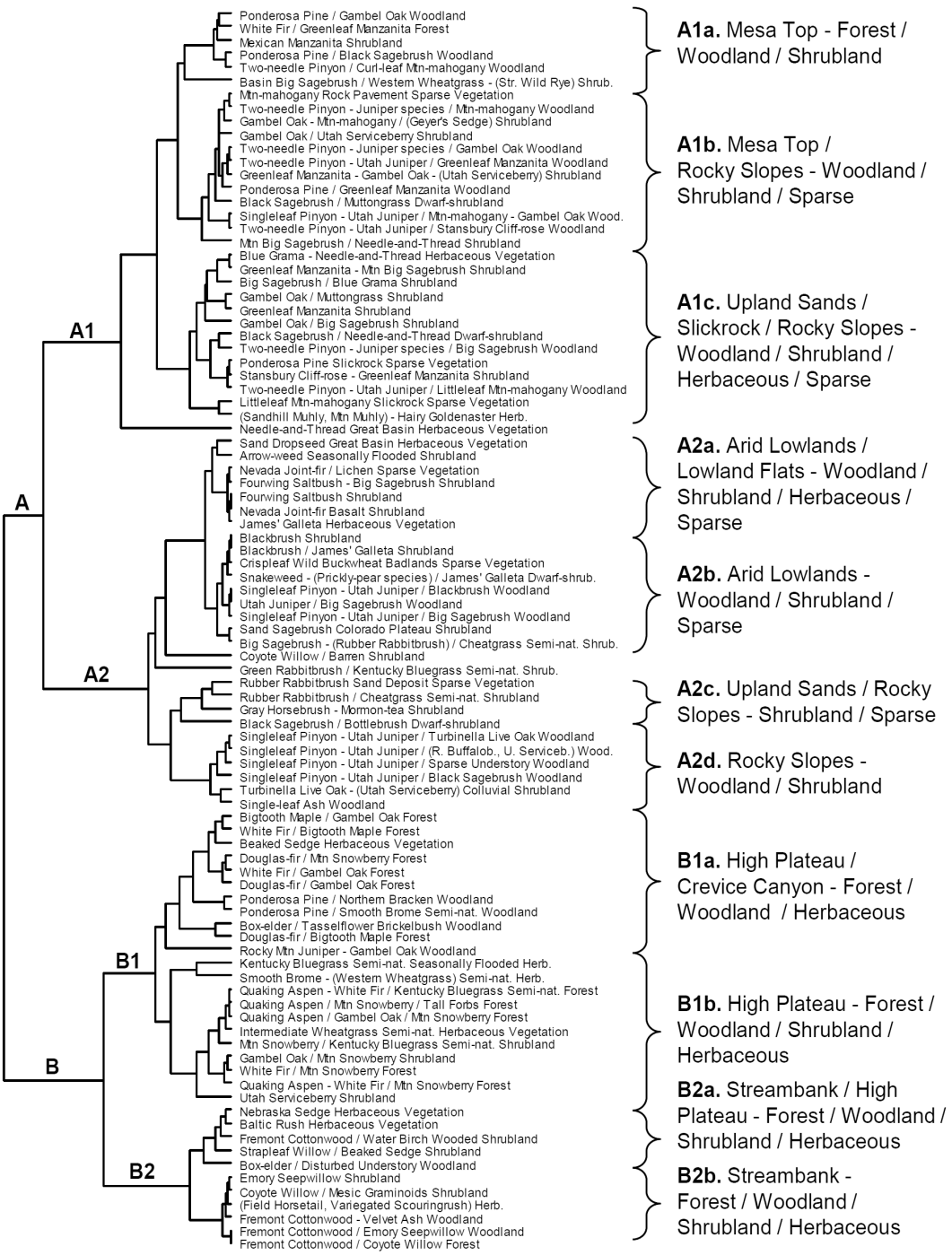

Fig. 7. Cluster dendrogram of National Vegetation Classification (NVC) associations of Zion National Park, Utah (Cogan et al. 2004), based on compositional affinities to 10 coalition groups presented in this paper. Names are assigned to clusters at 3 levels. A = Xeric Zion Vegetation, B = Mesic Zion Vegetation. A1 = Mesa Top/Upland Sands/Slickrock/ Rocky Slopes, A2 = Lowlands/Rocky Slopes/Upland Sands, B1 = High Plateau/Crevice Canyon, B2 = Streambank/ High Plateau.

these environmental correlations (Fig. 2–5), we opted to use environmentally descriptive names instead of following the widespread convention of naming species groups based plant taxa (e.g. Holzner et al. 1978, Kashian et al. 2003).

We propose that the term *individualistic species group* also applies to coalition groups because their nondiscrete spatial patterns, overlapping composition and fuzzy attributes reflect notions of species individualism and community continuity espoused by Gleason (1926, 1939). Gleason is well known for having pointed out difficulties of discrete community classification stemming from individualistic species distributions, having noted that "every species of plant is a law unto itself, the distribution of which in space depends upon its individual peculiarities" (Gleason 1926, p. 26). But he also recognized that some species are sufficiently aligned in their distributions to warrant group recognition:

> The [individualistic] concept is by no means opposed to the recognition of the synusia, or union, defining it as a group of plants whose physiological demands are so similar that they are regularly selected by the same environment and consequently regularly live together (Gleason 1939, p. 108).

Hence an individualistic approach to community characterization permits the dual objective of identifying spatially-associated species possessing similar ecological requirements, while also recognizing and quantifying species differences.

Unlike methods such as TWINSPAN or COCKTAIL which characterize species groups in relation to discrete site groups (Bruelheide and Chytrý 2000), the coalition clustering approach extracts groups lacking discrete boundaries (beyond the overall boundaries of the chosen study area). Any clustering method carried out in R-mode (clustering species but not sites) (McCune and Grace 2002) would likewise yield spatially nondiscrete groups. Coalition groups have an added distinction of being compositionally nondiscrete (i.e., overlapping in their species membership). The only sense in which coalition groups are "discrete" is that any one group is composed of a distinct set of member species, but even this form of discreteness is diluted by our use of affinity values to characterize degrees of membership. We note conceptual and mathematical similarities between our affinity calculations and fuzzy set theory: species affinity is essentially identical to fuzzy membership, group-averaged affinity to relative cardinality, and plot-averaged affinity to fuzzy species richness as described by Olivero et al. (2011).

Although coalition clustering does not require or produce spatially discrete community units, it is influenced by discontinuities in species distribution patterns. Multiple species can have coinciding distributions marked by quasi-discrete distribution boundaries due to abrupt environmental transitions, even if these species would otherwise show unaligned individualistic environmental responses (Austin and Smith 1989). Relatively abrupt transitions in hydrology, substrate and elevation are present at Zion and are reflected in our coalition groups. The Streambank and Crevice Canyon groups, for example, were concentrated in mesic environments immediately adjacent (at the scale of 10 × 10-m pixels) to xeric environments dominated by the Lowland Flats, Arid Lowlands or Slickrock groups (Fig. 2–4). The Navajo Sandstone cliff zone forms a natural break in the Zion landscape that was detectable as a dividing line in regression tree models, e.g., the first split of the Arid Lowlands model at 1596 m elevation lies at approximately the base of the Navajo Sandstone cliffs in the main section of the park (Fig. 4B), while the first split of the Mesa Top groups (1791 m) lies near the top of this same set of cliffs (Fig. 5).

In other instances, our coalition clustering results indicate gradual rather than abrupt changes in community composition and environmental conditions. The 2 Mesa Top groups overlapped extensively in composition (Table 2I–J), spatial distribution and environmental affinities (Fig. 5), leading us to conclude that they represent subtle distinctions along a continuum. The Arid Lowlands group also appears to represent a continuum that was not subdivided at our selected threshold level. We note, however, that at a threshold of phi = 0.2 (instead of 0.15), 2 Arid Lowlands subgroups emerged, one with Great Basin/higher-elevation affinities and the other with Mojave Desert/lower-elevation affinities (Fig. 8). Like the 2 Mesa Top groups, these 2 Arid Lowlands subgroups had many species in common, and species with higher affinity for one group tended to have lower affinity for the other (with the exception of *Bromus rubens*, which was the highest-affinity species for both groups) (Fig. 8).

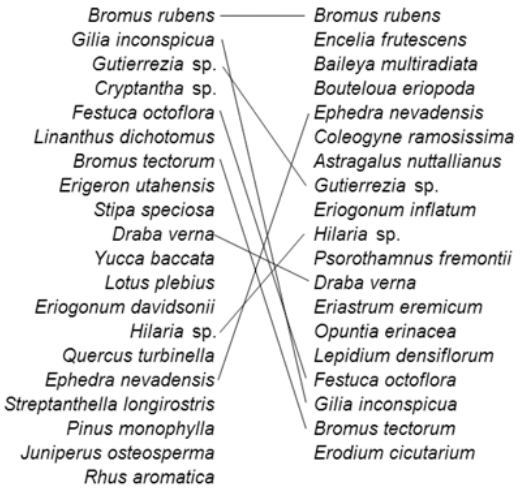

Fig. 8. Two Arid Lowlands coalition groups at Zion National Park, Utah, obtained through coalition clustering in RCLUS at a threshold affinity value of phi = 0.2. Species are in descending order of group affinity and lines connect species shared by both groups. The left group has Great Basin (higher elevation) affinities and the right group has Mojave Desert (lower elevation) affinities.

Coalition Clustering Methodology

We emphasize that our coalition groups portray one of many possible coalition clustering solutions, as illustrated by the alternative Arid Lowlands groupings discussed above. Through experimentation with different association coefficients and threshold levels, we arrived at a solution at the desired scale that agreed with our field experience at Zion. Thus our approach differs from clustering approaches that seek to identify an optimal set of clusters with minimal within-group and maximal between-group variation (Kaufman and Rousseeuw 1990, Aho et al. 2008). Cluster evaluation techniques (Aho et al. 2008) could conceivably be applied to find an optimal threshold level resulting in a set of coalition groups with minimal species overlap. However, given our assertion that overlapping composition contributes to the individualistic character of coalition groups, we argue that flexibility in selecting a threshold level enhances the usefulness of coalition clustering as an exploratory tool.

By applying coalition clustering to our data using the phi coefficient of association we were able to generate clusters containing mixtures of common and rarer species. In many cases, species belonging to the same coalition group did not actually co-occur in any plots, but the negative pairwise associations of these species were overridden by their shared positive associations with other species belonging to the group. Species occurring in multiple plots provided a glue that held species occurring in fewer plots together in the same group. Our use of the phi coefficient contributed to this result because phi incorporates joint absence information and is less sensitive to differences in species frequency than presence-only coefficients such as the Jaccard index (Jackson et al. 1989, Sanderson et al. 2006). Species clustering based on presence-only coefficients tends to group species according to their frequency unless additional standardization steps are followed (Jackson et al. 1989, McCune and Grace 2002). The phi coefficient has the drawback of being undefined when 2 species have perfectly overlapping distributions or when one species' distribution is nested within the other, but we did not encounter either of these situations in our data set. Phi is always negative when 2 species never occur together, but can also be negative when 2 species occur together with few joint absences (e.g., a pair of ubiquitous species). In our analysis, co-occurring ubiquitous species would justifiably have been excluded from coalition groups, but this situation was minimally relevant because the most ubiquitous species (*Poa fendleriana*) occurred in 66% of plots but no other species exceeded 50% occurrence. Our results would therefore likely have been similar had we used a coefficient that increases monotonically with increasing joint presence, such as that of Baroni-Urbani and Buser (1976).

In contrast to Harper et al. (2001), whose community characterization began with dominant species followed by prevalent and modal species *sensu* Curtis (1959), our characterization began with a conceptual equivalent of modal species (coalition species) followed by equivalents of prevalent and dominant species (affiliate and dominant-affiliate species, respectively). Modal species are conceptually similar to what other authors have termed faithful, diagnostic, differential or character species, all of which denote concentration of species occurrences in one or more communities relative to others (Braun-Blanquet 1932, Aho et al. 2008, Jennings et al. 2009). Coalition species likewise express this concept of community fidelity, but in relation to a species group rather than

a set of spatially defined communities. Unlike strict definitions of faithful species, coalition species can be "faithful" to more than one group. Prevalent species as defined by Curtis (1959) are essentially synonymous with what others have termed constant species (Braun-Blanquet 1932, Jennings et al. 2009), with the added criterion of using species density (average number of species per plot) to determine the number of prevalent species for a community (Curtis 1959, Harper et al. 2001). Our procedures for identifying affiliate and dominant-affiliate species followed the logic of the prevalent species concept in a way that, to our knowledge, is novel and could be applied to any set of species groups (coalition groups or otherwise). Although our measures of affiliation (percent co-occurrence) and weighted mean cover are not directly comparable with constancy and mean cover calculated for discrete communities, their values can be readily used for comparisons within and across species groups.

Perspectives on Vegetation Classification

By characterizing dominant species in relation to species groups, we gained a different perspective of dominant species than previous authors who focused on them *a priori* for vegetation classification. Our analysis identified as dominant-affiliates many of the same species that defined vegetation types of Harper et al. (2001), but some of these species were spread among multiple coalition groups. *Pinus ponderosa,* which defined the Ponderosa Pine vegetation type of Harper et al. (2001), emerged as a dominant-affiliate species of 4 coalition groups (Upper and Lower Mesa Top, Upland Sands and Slickrock); likewise *Abies concolor* of the White Fir–Douglas Fir vegetation type was a dominant-affiliate of both High Plateau and Crevice Canyon; and dominants of Juniper-Pinyon (*Pinus edulis, Pinus monophylla, Juniperus osteosperma*) and Mountain Brush (*Quercus gambelii, Amelanchier utahensis*) vegetation types were dominant-affiliates of 2 or more coalition groups each (Table 2). These mismatches highlight the discordance between abundance patterns of single species and presence-absence patterns of broader species sets. Because dominant species and growth forms such as ponderosa pine, white fir, juniper-pinyon and mountain brush are generalists that occupy multiple environmental settings at Zion, their use as classification criteria by Harper et al. (2001) led to environmentally ambiguous vegetation types. Some of these ambiguities were clarified in a subsequent paper (Harper et al. 2003) that split the Juniper-Pinyon vegetation type into 3 subtypes: a higher elevation subtype containing *Pinus edulis* (like the Mesa Top groups), a mid-elevation subtype with *Pinus monophylla* (like Rocky Slopes) and a low-elevation subtype with *Juniperus osteosperma* but no *Pinus* (like Arid Lowlands). Cogan et al. (2004) differentiated pinyon-juniper vegetation in a similar way at the NVC alliance level.

Our hierarchical rearrangement and reclassification of NVC associations on the basis of coalition group affinities (Fig. 7) differs substantially from the way these associations have been treated under the NVC system. According to the NVC classification hierarchy followed by Cogan et al. (2004), associations were nested within 6 major higher levels (alliance, formation, formation subgroup, formation group, formation subclass, formation class), each defined by specific characteristics including dominant species, substrate, hydrologic regime, anthropogenic disturbance, leaf phenology, leaf structure, plant habit, and life form (Grossman et al. 1998). The NVC hierarchy was recently revised through the addition of new levels between alliance and formation (group, macrogroup and division) and changes to classification criteria designed to make groupings more ecologically meaningful (FGDC 2008, Faber-Langendoen et al. 2009, NatureServe 2013, USNVC 2013). Upper levels of the new NVC hierarchy reflect general growth form differences indicative of broad-scale environments or "global macroclimatic factors", while successively lower levels reflect finer physiognomic and floristic distinctions indicative of finer-scale climate, geology, substrate, hydrology, moisture/nutrient factors, and disturbance regimes (Faber-Langendoen et al. 2009). The NVC hierarchy might thus be expected to portray environmental affinities at Zion in a manner similar to our coalition groups; however, our coalition group–based hierarchy was poorly aligned with both the older and newer NVC classification (Appendixes 6, 7). Some NVC groupings were concentrated within certain clusters of our hierarchy—e.g., Singleleaf Pinyon – (Utah Juniper) Woodland Alliance in the Rocky Slopes Woodland/Shrub cluster—but others were spread across multiple clusters, as

illustrated by the mixture of associations with multiple physiognomies (forest, woodland, shrubland, etc.) within groupings of our 3-tiered classification (Fig. 7). These differences can be attributed to the emphasis placed on physiognomy and dominant species at all levels of the NVC hierarchy, in contrast to our strictly floristic, presence/absence–based approach to classification.

Comparisons can also be made between our coalition group–based hierarchy of NVC associations (Fig. 7) and the Terrestrial Ecological Systems Classification (TESC) that has been applied at Zion (Comer et al. 2003, Comer and Schulz 2007, NatureServe 2013). The TESC was developed to complement the NVC by grouping associations or alliances that "tend to naturally co-occur with similar environmental settings, ecological dynamics, and/or environmental gradients" (Comer and Schulz 2007, p. 326), forming "ecological systems" that can more easily be mapped and related to environmental variation at landscape to regional scales (Comer et al. 2003, Comer and Schulz 2007). An ecological system can include multiple physiognomic types that occur in a similar environment, such as successional stages ranging from herbaceous vegetation to shrubland to woodland within a riparian floodplain (Comer and Schulz 2007). Given these criteria, the TESC approach could potentially yield ecological groupings similar to those we identified at Zion. Upon cross-walking our coalition-group based hierarchy with ecological systems (Appendix 8), we did indeed find general similarities, such as alignment of the North American Warm Desert Lower Montane Riparian Woodland and Shrubland system with the Streambank group. However, the concordance between the 2 classifications is far from exact, and we note that the ecological systems contain less physiognomic variability than clusters in our hierarchy (Fig. 7, Appendix 8). Like the NVC hierarchy, the TESC as currently applied to vegetation types at Zion appears to emphasize physiognomic/structural uniformity at the expense of environmental similarity. These observations are not intended as criticisms of the NVC and TESC approaches but rather highlight their strengths and weaknesses in relation to our approach. No single community characterization approach is likely to serve all purposes; hence our characterization is finely tuned to represent conditions at Zion, but unlike the NVC and TESC it cannot be straightforwardly transferred to other landscapes with different combinations of species and environments.

Sampling Strategy and Modeling Issues

Our ability to extrapolate coalition group affinities beyond park boundaries or interpolate them beyond plot locations within the park was limited by sampling and modeling constraints (cf. Elith and Leathwick 2009). Environmental conditions such as higher or lower elevations in the surrounding region beyond the park were not sampled, and important community-environment variation within the park may have also been missed. Furthermore, the environmental variables we used posed limitations on predictive modeling; for example, the lacustrine substrate class noticeably overpredicted Streambank (Fig. 2A) and underpredicted Rocky Slopes (Fig. 4A) affinities in the Coalpits Wash area (southwestern side of park), where—unlike in Zion Canyon—lacustrine deposits are not associated with riparian areas.

Ideally, a different set of more natural landscape boundaries could have been used to delimit our study area; but given that national park boundaries were used, the mostly systematic sampling strategy followed by the Harper survey was advantageous for capturing community and environmental variation in a relatively unbiased way. Dismissing the unlikely possibility that the approximately 1.6-km distance between Harper survey plots coincides with periodic environmental variation at Zion, the more-or-less evenly spaced plot arrangement (Fig. 1A) can be viewed as an area-proportional sample of Zion's environments.

Environmental conditions that were more frequent in the landscape were captured with greater frequency by the Harper survey, in contrast to the USGS survey, which sought to capture the range of environmental variation without regard for frequency through a gradsect sampling strategy (Cogan et al. 2004). The effects of these different sampling strategies can be illustrated by histograms of plot-environment combinations compared proportionally with background environmental variation at Zion (Figs. 9, 10) (Calenge 2006). The Harper data set had an overrepresentation of low elevations, low slopes, moderate exposures (Fig. 9A), and alluvial substrates (Fig. 10A) that can

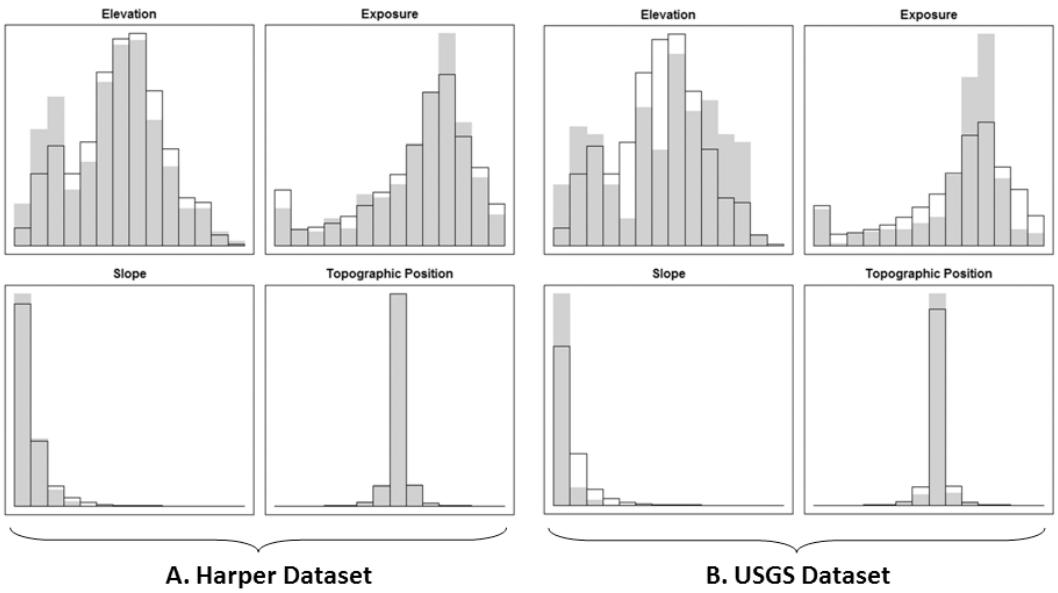

Fig. 9. Histograms showing background frequencies of topographic variables at Zion National Park, Utah (solid border bars), compared proportionally with plot representation of the same variables (shaded bars) by 2 different vegetation surveys (left and right). Based on 50-m-resolution generalizations of 10-m-resolution grids covering the park. Derived using function "histniche" of the adehabitat package (Calenge 2006) in R 2.8.0 (R Development Core Team 2008).

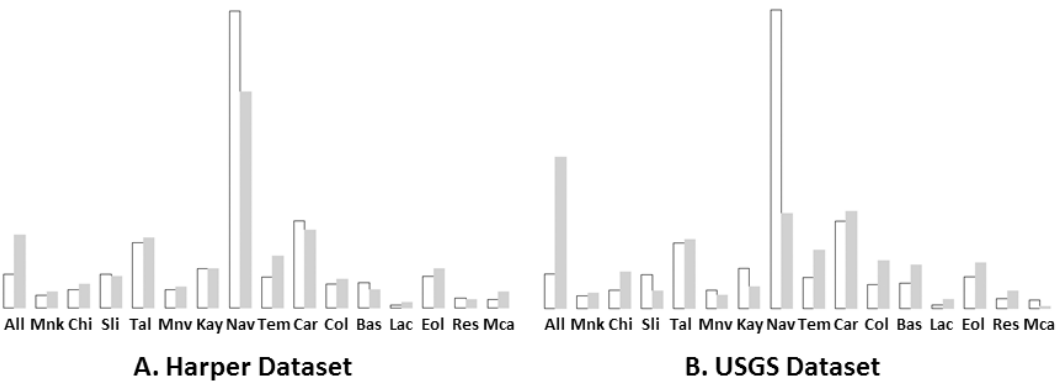

Fig. 10. Histograms showing background frequencies of geologic substrate variables at Zion National Park, Utah (solid border bars), compared proportionally with plot representation of the same variables (shaded bars) by 2 different vegetation surveys (left and right). See Table 1 for key to substrate codes. Based on 50-m-resolution generalizations of 10-m-resolution grids covering the park. Derived using function "histniche" of the adehabitat package (Calenge 2006) in R 2.8.0 (R Development Core Team 2008).

be attributed at least in part to the nonsystematic riparian and old field plots included in the survey. On the other hand, excessively steep or bare plot locations were avoided or adjusted by Harper survey workers, leading to an underrepresentation of high slopes and Navajo Sandstone substrates (Fig. 9A, 10A). However, these same patterns of environmental over- and underrepresentation were present to an even greater degree in the USGS data set (Fig. 9B, 10B). Consequently the Harper data set has a larger, comparatively more representative sample of common environments (such as the Navajo Sandstone), while the USGS data set has better representation of rarer, more unique environments and communities. The Harper

survey captured "transitional" areas with heterogeneous vegetation that would have been avoided by the USGS survey, while USGS likely captured spatially restricted vegetation types that were missed by Harper. These differences between survey data sets, as well as differences due to year of sampling, plot size, and data collection techniques, must be kept in mind when comparing our results with results derived from the USGS survey (i.e., Fig. 7, Appendixes 5–8).

Temporal Scale, Fire, and Weather

Our community characterization is best viewed as a snapshot that captures community patterns in relation to environment conditions at a specific area within a specific timeframe. Conditions at Zion in the late 1980s when the Harper survey was conducted included the effects of previous decades of agricultural disturbance, livestock grazing, and fire suppression (Woodbury 1933, Madany and West 1983) but not the effects of more recent wildfires within the park, such as the 4256-ha Kolob Fire of 2006 (Brisbin et al. 2013). Most Harper Survey plots were classified by field workers as late-seral or climax with respect to time since fire, although 2 plots on the Horse Pasture Plateau burned in 1988 and were sampled later the same year. These recently-burned plots, despite their reduced cover relative to surrounding woodlands, readily blended into the Mesa Top coalition groups in our analysis, suggesting that the fire had a minimal effect on species composition as measured by presence-absence, at least initially. This supports the view that species presence-absence patterns are less sensitive to short-term environmental fluctuations and disturbances than abundance patterns, making presence-absence a more stable measure indicative of longer-term ecological processes than abundance (Allen and Starr 1982, Wilson 2012). However, the stability of presence-absence patterns can be expected to vary due to variation in plant longevity and sensitivity to disturbance. Other studies in plant communities similar to those at Zion have reported shifts in species presence-absence due to fire, often characterized by the loss of fire-intolerant shrubs and trees combined with an influx of annual species (Koniak 1985, Paysen et al. 2000, Ott et al. 2001, Huisinga et al. 2005, Engel and Abella 2011). Some species that might persist initially after fire could later die out, if for example invasive *Bromus* species become dominant and cause recurring fires (Bagchi et al. 2013). The recent fires at Zion could have therefore altered some of the community patterns we have presented here, though this does not diminish the value of our characterization as a baseline reference.

Long-term fire history has been implicated as a factor determining current distributions of pinyon-juniper woodland versus mountain brush in areas that could support either vegetation type, with mountain brush occupying sites where the fire-return interval has been shorter (Floyd et al. 2000). Although our coalition clustering analysis did not reveal discrete differences between these 2 vegetation types, the 2 Mesa Top coalition groups were partially aligned with them. The fire-sensitive species *Pinus edulis* and *Cercocarpus montanus* had higher affinity for the Lower Mesa Top group than fire-tolerant mountain brush species *Quercus gambelii*, *Amelanchier utahensis*, *Balsamorhiza sagittata*, and *Symphoricarpos oreophilus* (Floyd et al. 2000, USDA–FS 2013), but in the Upper Mesa Top group the fire-tolerant species had higher affinity (Table 2I–J). These 2 Mesa Top groups might thus reflect differences in long-term fire history that have left a subtle imprint on species presence-absence patterns.

The patterns we detected at Zion also reflect weather conditions and fluctuations during the years leading up to the time of data collection in 1987–1989. Weather data from the park show periods of above-average precipitation during the years 1978–1983, near-average from 1984–1988, and below-average in 1989 (Witwicki 2013). Annual species sensitive to yearly precipitation fluctuations may have been sparser in 1989; however, most sampling of low elevations where most of these annual species occur took place in 1987–1988.

Since the late 1980s, Zion has experienced large fluctuations in annual precipitation and a gradual warming trend (Witwicki 2013) that is projected to continue (Polley et al. 2013). In light of evidence from elsewhere in southwestern North America (Kelly and Goulden 2008, Fellows and Goulden 2012, Brusca et al. 2013), upward elevational shifts in plant species distributions could have occurred at Zion during this period. Relative to other areas with less abrupt elevation gradients, plant species

at Zion might be expected to easily disperse to higher elevations, although species with affinities for certain horizontally-layered geologic substrates might find their preferred substrate unavailable higher up. The degree to which coalition groups will remain associated through continued climate change is unknown, but from a probabilistic perspective, we suggest 2 general rules: (1) species will likely become increasingly disassociated with the passage of time as their individualistic responses to climate change emerge, yet (2) species currently more strongly associated will likely remain associated for longer than more weakly associated species. We suggest that species association patterns such as those we have quantified for Zion have predictive value in both space and time.

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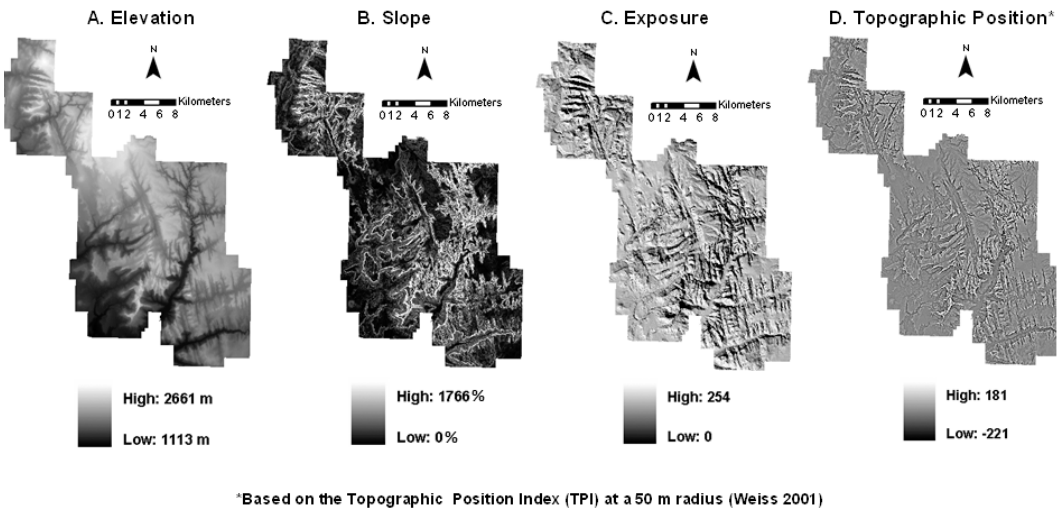
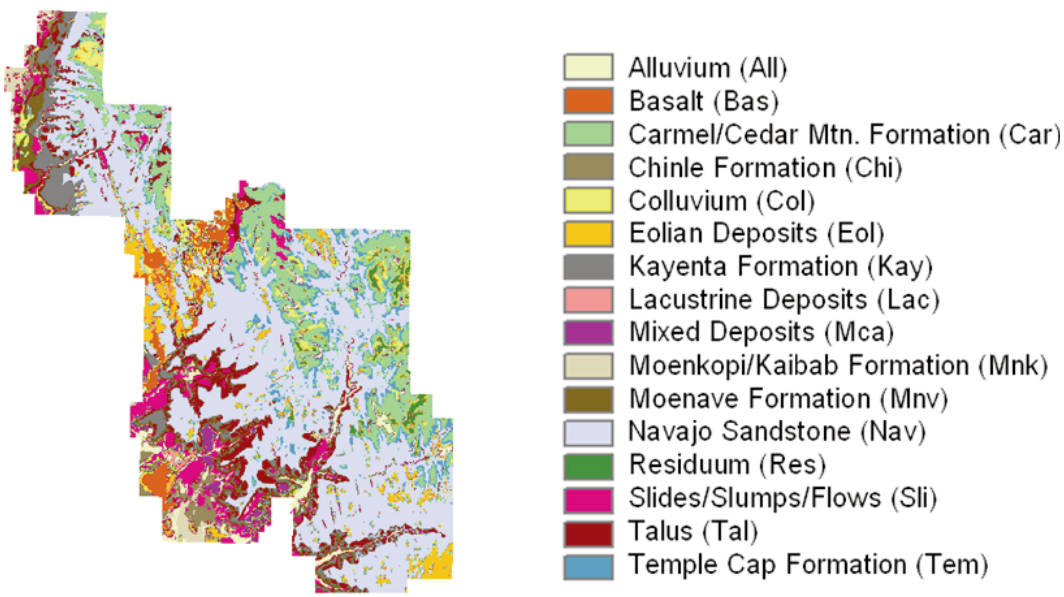


APPENDIX 1. Abiotic environmental variable layers derived from a 10-m-resolution digital model of Zion National Park, Utah.



APPENDIX 2. Geologic substrate classes derived from a 1:24,000-scale digital geologic map of Zion National Park, Utah, and vicinity (O'Meara 2006).

APPENDIX 3. Vascular plant species recorded by the Harper vegetation survey (1987–1989) at Zion National Park, Utah, and their affinities to coalition species groups. # Occ. = number of plot occurrences out of 288 plots total. Affinities are mean pairwise association values (in units of the phi coefficient) between a species and members of a coalition group. For species that have at least 3 occurrences, values ≥0.15 indicate membership in a group. Green shading by cell value is scaled separately for each column. Nomenclature follows Welsh et al. (2003).

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Abies concolor	Pinaceae	19	-0.0226	-0.0893	-0.0770	-0.0559	0.0865	0.0603	0.0229	0.1859	0.2236	0.0410
Abronia fragrans	Nyctaginaceae	20	-0.0448	-0.0051	0.0253	0.2521	0.0395	-0.0448	-0.0382	-0.0325	-0.0349	-0.0360
Acer glabrum	Aceraceae	6	-0.0269	-0.0484	-0.0117	-0.0307	0.1020	0.0035	-0.0116	0.0185	0.1461	0.0090
Acer grandidentatum	Aceraceae	29	-0.0556	-0.0988	-0.0451	-0.0489	0.0587	0.0312	0.0003	0.1139	0.2614	0.0429
Acer negundo	Aceraceae	18	-0.0226	-0.0711	-0.0929	-0.0678	0.0736	-0.0447	-0.0579	0.0499	0.3163	0.2513
Achillea millefolium	Compositae	6	-0.0003	-0.0443	-0.0386	0.0190	0.0046	-0.0178	0.0136	0.2048	0.0272	0.0380
Actaea rubra	Ranunculaceae	2	-0.0154	-0.0290	-0.0467	-0.0189	0.0224	0.0006	-0.0186	0.0479	0.2531	0.0817
Adiantum capillus-veneris	Polypodiaceae	2	-0.0154	-0.0290	-0.0466	-0.0340	-0.0028	-0.0352	-0.0308	0.0132	0.1540	-0.0025
Adiantum pedatum	Polypodiaceae	1	-0.0109	-0.0204	-0.0291	-0.0027	0.0370	0.0140	-0.0138	0.0581	0.2611	0.1104
Agastache urticifolia	Labiatae	1	-0.0109	-0.0133	-0.0368	-0.0149	-0.0163	-0.0150	-0.0040	0.2240	-0.0098	0.0533
Agoseris aurantiaca	Compositae	1	-0.0109	-0.0071	-0.0067	-0.0149	-0.0163	-0.0051	-0.0059	0.0257	-0.0012	0.0067
Agoseris glauca	Compositae	1	0.0196	0.0051	0.0044	-0.0094	-0.0056	-0.0150	-0.0138	-0.0032	-0.0098	0.0094
Agoseris retrorsa	Compositae	1	0.0537	-0.0144	-0.0290	-0.0073	0.0010	-0.0033	0.0053	0.0870	-0.0098	0.0390
*Agropyron cristatum**	Gramineae	1	0.0689	-0.0204	-0.0142	-0.0112	-0.0099	-0.0150	0.0458	0.0565	-0.0012	-0.0085
Agrostis exarata	Gramineae	3	-0.0189	-0.0164	-0.0469	-0.0211	0.0083	-0.0207	-0.0332	0.0416	0.1570	0.3453
Agrostis scabra	Gramineae	1	-0.0109	-0.0204	-0.0291	-0.0027	0.0370	0.0140	-0.0138	0.0581	0.2611	0.1104
*Agrostis stolonifera**	Gramineae	2	-0.0109	-0.0183	-0.0329	-0.0240	-0.0163	-0.0248	-0.0217	0.0068	0.0093	0.2268
Allium acuminatum	Liliaceae	9	-0.0113	-0.0403	-0.0317	0.0492	-0.0213	-0.0161	0.0051	0.0793	-0.0269	0.0119
Allium macropetalum	Liliaceae	1	-0.0109	-0.0156	-0.0064	0.0599	0.1228	-0.0033	-0.0045	-0.0055	-0.0098	-0.0085
Allium nevadense	Liliaceae	1	-0.0109	-0.0204	-0.0216	0.0856	-0.0029	-0.0024	-0.0019	-0.0127	-0.0098	-0.0085
Allium sp.	Liliaceae	2	0.0062	-0.0075	-0.0014	0.0303	0.1292	-0.0282	-0.0252	-0.0061	0.0107	0.0006
Amelanchier alnifolia	Rosaceae	11	-0.0245	-0.0668	-0.0809	-0.0447	0.0231	0.0570	0.0507	0.2711	0.1498	0.0627
Amelanchier utahensis	Rosaceae	141	-0.0900	-0.0968	0.1661	0.0340	-0.0081	0.1990	0.1598	-0.0446	-0.0817	-0.1249
Andropogon gerardii	Gramineae	3	0.0543	-0.0164	-0.0358	-0.0027	0.0669	-0.0177	-0.0232	-0.0220	0.0281	0.1007
Androstephium breviflorum	Liliaceae	18	0.1286	0.0230	0.0268	0.0390	-0.0266	-0.0414	0.0075	-0.0162	-0.0299	-0.0159
Angelica pinnata	Umbelliferae	1	-0.0109	-0.0204	-0.0291	-0.0027	0.0370	0.0140	-0.0138	0.0581	0.2611	0.1104

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Antennaria microphylla	Compositae	1	-0.0109	-0.0159	-0.0063	0.0034	-0.0035	-0.0150	-0.0138	-0.0127	-0.0098	-0.0085
Antennaria parvifolia	Compositae	2	-0.0154	0.0083	0.0049	0.0489	0.0019	-0.0122	-0.0054	-0.0136	-0.0139	-0.0121
Antennaria rosulata	Compositae	3	-0.0189	-0.0276	-0.0021	-0.0057	0.0238	0.0195	0.0148	0.0635	0.1447	0.0540
Apocynum androsaemifolium	Apocynaceae	2	-0.0154	-0.0290	-0.0414	-0.0189	0.0270	0.0152	-0.0030	0.0476	0.2110	0.0817
Aquilegia chrysantha	Ranunculaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	0.0179	-0.0085
Aquilegia formosa	Ranunculaceae	3	-0.0189	-0.0355	-0.0509	-0.0269	0.0919	-0.0250	-0.0232	-0.0163	0.0585	-0.0070
Aquilegia sp.	Ranunculaceae	2	-0.0154	-0.0290	-0.0466	-0.0286	0.0010	-0.0147	-0.0238	0.0385	0.1668	-0.0025
Arabis hirsuta	Cruciferae	1	-0.0109	-0.0204	0.0010	-0.0035	-0.0109	0.0065	0.0428	0.0474	-0.0098	-0.0085
Arabis perennans	Cruciferae	124	-0.0953	0.0295	0.2379	0.0173	0.0178	0.0472	0.0240	-0.0499	-0.0301	-0.0931
Aralia racemosa	Araliaceae	3	-0.0189	-0.0331	-0.0507	-0.0417	-0.0017	-0.0187	-0.0151	0.0313	0.2012	0.0469
Arceuthobium abietinum	Viscaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0054	-0.0132	-0.0124	0.0096	0.0963	0.0050
Arceuthobium divaricatum	Viscaceae	5	-0.0245	-0.0183	0.1003	0.0123	-0.0047	0.0106	0.0083	-0.0202	-0.0220	-0.0192
Arceuthobium vaginatum	Viscaceae	1	-0.0109	-0.0204	-0.0368	-0.0097	-0.0109	0.0411	0.0110	0.0214	-0.0016	-0.0085
Arctostaphylos patula	Ericaceae	94	-0.1013	-0.0593	0.1132	0.2147	0.0767	0.0893	0.0301	-0.0959	-0.0837	-0.0949
Arenaria fendleri	Caryophyllaceae	23	-0.0544	-0.0513	-0.0408	0.1880	0.2407	-0.0605	-0.0522	-0.0512	-0.0203	-0.0427
Arenaria macradenia	Caryophyllaceae	46	-0.0804	-0.0607	0.1271	0.0990	0.1502	-0.0052	-0.0069	-0.0401	-0.0037	-0.0588
Arenaria pusilla	Caryophyllaceae	1	-0.0109	0.0189	-0.0059	0.0579	0.0148	-0.0132	-0.0124	-0.0127	-0.0098	-0.0085
Argemone munita	Papaveraceae	1	0.0512	-0.0001	-0.0138	-0.0240	-0.0163	-0.0150	-0.0138	-0.0058	-0.0098	-0.0085
Aristida purpurea	Gramineae	26	0.0216	0.1291	0.0011	-0.0051	-0.0026	-0.0986	-0.0888	-0.0646	-0.0393	0.0031
Arnica cordifolia	Compositae	1	-0.0109	-0.0204	-0.0142	-0.0097	-0.0041	0.0778	0.0034	-0.0004	-0.0098	-0.0085
Artemisia arbuscula	Compositae	4	0.0383	-0.0411	-0.0399	-0.0278	-0.0146	0.0007	0.0998	0.1245	0.0005	-0.0095
Artemisia campestris	Compositae	14	-0.0334	-0.0471	-0.0323	0.2341	-0.0044	-0.0462	-0.0361	-0.0341	-0.0315	-0.0327
Artemisia dracunculus	Compositae	12	0.0695	-0.0227	-0.0022	-0.0069	-0.0291	-0.0208	-0.0178	-0.0225	-0.0260	-0.0138
Artemisia filifolia	Compositae	3	-0.0189	0.0497	-0.0347	-0.0349	-0.0250	-0.0431	-0.0308	-0.0220	-0.0170	-0.0016
Artemisia frigida	Compositae	1	-0.0109	-0.0204	-0.0216	-0.0115	0.0069	0.0247	0.0354	0.0580	-0.0016	-0.0085
Artemisia ludoviciana	Compositae	51	-0.0089	0.0007	0.1161	0.0261	0.0346	-0.0376	-0.0201	0.0195	0.0962	0.1026
Artemisia sp.	Compositae	2	-0.0154	-0.0198	-0.0370	-0.0290	-0.0196	-0.0352	-0.0308	0.0197	0.0312	0.4632
Artemisia tridentata	Compositae	55	0.0211	0.0237	0.0140	0.0087	-0.0941	-0.0650	-0.0307	-0.0021	-0.0710	-0.0200

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Asclepias subverticillata	Asclepiadaceae	9	0.0355	0.0465	-0.0005	-0.0368	-0.0372	0.0539	-0.0149	-0.0385	-0.0264	-0.0193
Aster glaucodes	Compositae	6	-0.0269	-0.0144	0.0115	-0.0389	-0.0091	-0.0054	-0.0173	0.0135	0.1160	0.1156
Aster sp.	Compositae	1	0.0207	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	-0.0016	0.0906
Aster spathulatus	Compositae	1	0.0290	-0.0204	-0.0220	-0.0177	-0.0099	0.0355	0.0251	0.0679	0.0050	-0.0085
Aster welshii	Compositae	6	-0.0269	-0.0449	-0.0609	-0.0507	-0.0144	-0.0372	-0.0375	0.0224	0.1633	0.1134
Astragalus flavus	Leguminosae	1	-0.0109	0.0218	-0.0287	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Astragalus lancearius	Leguminosae	1	-0.0109	-0.0084	0.0175	0.0125	0.0009	-0.0051	-0.0059	0.0109	-0.0043	-0.0085
Astragalus mollissimus	Leguminosae	1	-0.0109	0.0220	-0.0290	-0.0240	-0.0163	-0.0248	-0.0098	-0.0127	-0.0098	0.0144
Astragalus nuttallianus	Leguminosae	9	0.0317	0.2167	-0.0609	-0.0709	-0.0475	-0.0755	-0.0594	-0.0385	-0.0297	-0.0260
Astragalus piutensis	Leguminosae	6	0.0388	-0.0222	-0.0177	-0.0238	-0.0305	0.0101	0.0300	0.0813	-0.0118	0.0003
Astragalus sp.	Leguminosae	27	-0.0026	0.0839	0.0152	0.0117	-0.0543	-0.0184	0.0463	-0.0225	-0.0394	0.0038
Astragalus subcinereus	Leguminosae	1	-0.0109	-0.0161	0.0011	-0.0175	-0.0163	0.0356	0.0140	-0.0065	-0.0098	-0.0085
Astragalus zionis	Leguminosae	22	-0.0192	-0.0059	0.0676	0.0727	0.0065	0.0252	0.0815	0.0117	-0.0376	-0.0311
Atriplex canescens	Chenopodiaceae	10	0.2722	0.0716	-0.0649	-0.0708	-0.0447	-0.0797	-0.0634	-0.0407	-0.0314	-0.0275
Atriplex confertifolia	Chenopodiaceae	2	0.0099	0.0251	-0.0303	-0.0295	-0.0231	-0.0352	-0.0308	-0.0179	-0.0139	-0.0121
Baccharis salicina	Compositae	3	-0.0189	-0.0139	-0.0469	-0.0335	-0.0226	-0.0431	-0.0377	0.0088	0.0332	0.4594
Baileya multiradiata	Compositae	8	0.0310	0.2654	-0.0188	-0.0432	-0.0368	-0.0711	-0.0622	-0.0363	-0.0280	-0.0245
Balsamorhiza sagittata	Compositae	8	-0.0169	-0.0466	0.0013	-0.0108	-0.0278	0.1063	0.2200	0.0523	-0.0256	-0.0245
Berula erecta	Umbelliferae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Betula occidentalis	Betulaceae	2	-0.0154	-0.0224	-0.0114	-0.0192	0.0012	-0.0007	-0.0086	0.0070	0.0529	0.0360
Bouteloua curtipendula	Gramineae	2	-0.0154	-0.0189	-0.0342	-0.0030	0.0629	-0.0352	-0.0308	-0.0179	-0.0089	-0.0121
Bouteloua eriopoda	Gramineae	5	0.0220	0.2274	-0.0295	-0.0540	-0.0316	-0.0514	-0.0453	-0.0285	-0.0220	-0.0192
Bouteloua gracilis	Gramineae	19	-0.0244	-0.0350	-0.0107	0.1887	-0.0281	-0.0236	0.0192	-0.0029	-0.0361	-0.0306
Brickellia californica	Compositae	4	-0.0066	0.0351	0.0451	-0.0051	0.0036	-0.0400	-0.0357	-0.0125	-0.0159	-0.0082
Brickellia grandiflora	Compositae	10	-0.0350	-0.0516	-0.0105	0.0153	0.1977	0.0232	-0.0173	0.0078	0.1723	0.0031
Brickellia microphylla	Compositae	5	-0.0245	0.0370	0.0673	-0.0131	0.0217	-0.0240	-0.0234	-0.0285	-0.0092	-0.0192
Brickellia oblongifolia	Compositae	2	-0.0154	-0.0055	-0.0153	-0.0251	0.0119	-0.0192	-0.0252	0.0050	0.0747	-0.0025
Bromus anomalus	Gramineae	5	0.0436	-0.0421	-0.0621	-0.0175	-0.0099	-0.0147	0.0014	0.1586	0.1089	0.0533

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Bromus carinatus	Gramineae	9	-0.0196	-0.0434	-0.0574	-0.0456	-0.0372	-0.0416	-0.0107	0.2714	0.0118	0.2511
Bromus ciliatus	Gramineae	12	0.0293	-0.0670	-0.0665	-0.0486	0.0757	-0.0176	-0.0460	0.0473	0.2602	0.0995
*Bromus diandrus**	Gramineae	10	0.0312	-0.0336	-0.0857	-0.0613	-0.0407	-0.0734	-0.0647	-0.0126	0.0071	0.3353
*Bromus rubens**	Gramineae	43	0.0339	0.3680	0.0731	-0.0990	-0.0855	-0.1439	-0.1239	-0.0865	-0.0642	-0.0544
*Bromus tectorum**	Gramineae	130	0.1156	0.2135	0.0710	-0.0590	-0.1214	-0.1832	-0.1512	-0.1083	-0.0873	0.0262
Bromus vulgaris	Gramineae	1	0.0606	-0.0162	-0.0368	-0.0149	-0.0099	-0.0033	0.0053	0.0953	-0.0016	-0.0085
Calamagrostis scopulorum	Gramineae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	0.0179	-0.0085
Calochortus flexuosus	Liliaceae	7	0.0171	0.1303	-0.0365	-0.0562	-0.0395	-0.0626	-0.0550	-0.0302	-0.0261	-0.0160
Calochortus nuttallii	Liliaceae	23	0.0711	0.0121	0.0399	0.0553	-0.0340	-0.0119	-0.0077	0.0074	-0.0329	-0.0153
Camissonia multijuga	Onagraceae	1	-0.0109	0.0127	0.0000	-0.0240	-0.0100	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Camissonia parvula	Onagraceae	2	-0.0154	0.0040	0.0322	0.0436	-0.0006	0.0107	0.0060	-0.0112	-0.0100	-0.0121
Camissonia sp.	Onagraceae	1	-0.0109	-0.0117	-0.0232	-0.0169	-0.0113	-0.0248	-0.0217	0.0263	0.0371	0.3576
Cardamine cordifolia	Cruciferae	1	0.0606	-0.0204	-0.0368	-0.0169	0.0454	-0.0248	-0.0217	-0.0127	0.0547	0.0050
Carex aurea	Cyperaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0099	0.0014	-0.0138	0.0403	0.0491	0.0067
Carex hystericina	Cyperaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	0.0179	-0.0085
Carex occidentalis	Cyperaceae	1	-0.0109	-0.0204	-0.0213	0.0098	0.0029	-0.0248	-0.0217	0.0176	0.0465	0.0870
Carex rossii	Cyperaceae	67	-0.0335	-0.1431	-0.0482	0.0505	0.1222	0.2114	0.1553	0.1027	0.0042	-0.0554
Carex sp.	Cyperaceae	7	-0.0291	-0.0347	-0.0301	0.0315	0.0308	-0.0238	-0.0291	-0.0045	0.0800	0.0708
Castilleja chromosa	Scrophulariaceae	2	-0.0154	-0.0260	-0.0198	0.0174	-0.0022	-0.0212	-0.0196	0.0086	0.0260	0.0556
Castilleja linariifolia	Scrophulariaceae	7	0.0512	-0.0182	-0.0071	-0.0227	-0.0003	0.0218	0.1229	0.0230	0.0120	-0.0101
Castilleja scabrida	Scrophulariaceae	40	-0.0392	-0.0544	-0.0185	0.0831	0.2903	-0.0401	-0.0609	-0.0449	0.0430	-0.0458
Caulanthus cooperi	Cruciferae	1	0.1112	-0.0117	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Caulanthus crassicaulis	Cruciferae	1	-0.0109	-0.0154	-0.0030	-0.0240	-0.0163	0.0103	0.0039	0.0036	-0.0098	-0.0085
Ceanothus martinii	Rhamnaceae	4	0.0182	-0.0389	0.0003	-0.0180	-0.0174	0.1121	0.0788	0.0641	-0.0055	-0.0172
Celtis reticulata	Ulmaceae	2	0.0233	-0.0197	-0.0411	-0.0143	-0.0196	-0.0282	-0.0252	-0.0179	-0.0139	0.0235
Cenchrus longispinus	Gramineae	2	0.0017	-0.0198	-0.0425	-0.0290	-0.0196	-0.0352	-0.0308	0.0097	0.0264	0.2903
Centaurium exaltatum	Gentianaceae	1	0.0196	0.0051	0.0044	-0.0094	-0.0056	-0.0150	-0.0138	-0.0032	-0.0098	0.0094

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Centrostegia thurberi	Polygonaceae	3	-0.0189	0.1220	-0.0116	-0.0303	-0.0221	-0.0431	-0.0263	-0.0220	-0.0170	-0.0149
Cercocarpus intricatus	Rosaceae	40	-0.0741	-0.0732	-0.0008	0.0948	0.3022	-0.0254	-0.0425	-0.0540	0.0241	-0.0535
Cercocarpus montanus	Rosaceae	33	-0.0411	-0.0845	0.0125	-0.0766	-0.0614	0.2588	0.1440	-0.0299	-0.0468	-0.0521
Chaenactis douglasii	Compositae	44	-0.0625	-0.0719	0.1114	0.2527	0.1140	-0.0008	0.0032	-0.0622	-0.0409	-0.0586
Chaenactis stevioides	Compositae	1	-0.0109	0.0466	-0.0212	-0.0177	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Chaetopappa ericoides	Compositae	1	-0.0109	-0.0115	0.0011	-0.0177	-0.0163	0.1087	0.0330	-0.0065	-0.0098	-0.0085
Chamaesyce albomarginata	Euphorbiaceae	23	0.2085	0.0081	-0.0514	-0.0601	-0.0683	0.0486	0.0045	-0.0518	-0.0427	-0.0065
Chamaesyce fendleri	Euphorbiaceae	3	-0.0189	0.0881	0.0804	0.0042	-0.0212	-0.0075	-0.0240	-0.0220	-0.0170	-0.0149
Chenopodium fremontii	Chenopodiaceae	3	-0.0189	-0.0138	-0.0414	-0.0259	-0.0284	-0.0203	0.0029	0.1983	-0.0100	0.0605
Chimaphila menziesii	Pyrolaceae	5	-0.0245	-0.0460	-0.0491	-0.0310	0.0634	0.0085	-0.0139	0.0322	0.1943	0.0404
Chimaphila umbellata	Pyrolaceae	1	-0.0109	-0.0204	-0.0291	-0.0027	0.0370	0.0140	-0.0138	0.0581	0.2611	0.1104
*Chorispora tenella**	Cruciferae	1	0.1195	0.0037	-0.0215	-0.0240	-0.0163	-0.0150	-0.0138	-0.0127	0.0002	0.0114
Chrysopsis jonesii	Compositae	1	-0.0109	-0.0204	-0.0290	-0.0054	0.0507	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Chrysopsis villosa	Compositae	74	-0.0433	-0.0529	0.0206	0.1933	0.1966	-0.0952	-0.0770	-0.0592	0.0364	0.0487
Chrysothamnus depressus	Compositae	5	0.0294	-0.0360	-0.0271	-0.0197	-0.0127	0.0345	0.1618	0.0621	-0.0145	-0.0192
Chrysothamnus greenei	Compositae	1	-0.0109	0.0045	0.0285	-0.0112	-0.0104	-0.0023	-0.0037	-0.0127	-0.0098	-0.0085
Chrysothamnus nauseosus	Compositae	39	-0.0081	0.0136	0.0303	0.1202	-0.0282	-0.0941	-0.0726	-0.0711	-0.0435	0.0411
Chrysothamnus parryi	Compositae	1	-0.0109	-0.0204	-0.0142	0.0130	-0.0109	0.0987	0.0279	-0.0032	-0.0098	-0.0085
Chrysothamnus viscidiflorus	Compositae	6	0.0518	0.0138	0.0050	0.0321	-0.0334	0.0095	0.0182	0.0337	-0.0206	-0.0211
Cirsium arizonicum	Compositae	16	0.0236	-0.0538	0.0075	0.0434	0.1052	0.0028	-0.0078	0.0262	0.0954	0.0911
Cirsium wheeleri	Compositae	8	0.2224	-0.0308	-0.0508	-0.0337	-0.0135	0.0147	0.0741	0.0514	0.0035	-0.0196
Clematis columbiana	Ranunculaceae	3	-0.0006	-0.0355	-0.0552	-0.0252	0.0046	0.0343	-0.0085	0.0509	0.0859	0.0117
Coleogyne ramosissima	Rosaceae	13	0.0145	0.2448	-0.0393	-0.0830	-0.0601	-0.0914	-0.0800	-0.0466	-0.0360	-0.0315
Collinsia parviflora	Scrophulariaceae	2	-0.0154	-0.0255	-0.0199	0.0254	0.0755	-0.0060	-0.0005	0.0123	-0.0139	-0.0121
Collomia grandiflora	Polemoniaceae	4	-0.0219	-0.0178	0.0063	0.0087	0.0116	0.0250	0.0349	0.0067	0.0337	-0.0095
Collomia linearis	Polemoniaceae	2	0.0286	0.0019	-0.0082	-0.0276	-0.0231	-0.0142	-0.0006	0.0544	-0.0139	0.0120
Comandra umbellata	Santalaceae	35	-0.0686	-0.0696	0.0777	0.1314	0.0282	0.0257	0.0821	-0.0146	-0.0470	-0.0505
*Convolvulus arvensis**	Convolvulaceae	1	-0.0109	0.0235	-0.0212	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Cordylanthus kingii	Scrophulariaceae	19	-0.0072	0.0745	0.0772	-0.0369	-0.0655	0.0145	0.0030	-0.0393	-0.0440	-0.0342
Cordylanthus sp.	Scrophulariaceae	1	-0.0109	0.0330	0.0669	-0.0240	-0.0163	-0.0150	-0.0138	-0.0127	-0.0098	-0.0085
Cornus sericea	Cornaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0054	-0.0132	-0.0124	0.0096	0.0963	0.0050
Crepis acuminata	Compositae	3	-0.0189	-0.0118	0.0150	0.0580	0.0018	-0.0193	-0.0003	-0.0178	-0.0170	-0.0149
Crepis occidentalis	Compositae	1	-0.0109	0.0151	0.0314	-0.0097	-0.0104	0.0103	-0.0059	-0.0127	-0.0098	-0.0085
Crepis runcinata	Compositae	2	-0.0154	-0.0156	-0.0085	0.0443	-0.0092	-0.0212	-0.0112	-0.0129	-0.0139	-0.0121
Crepis sp.	Compositae	2	0.0411	-0.0224	-0.0006	-0.0101	-0.0065	-0.0166	0.0171	0.0406	0.0260	0.0264
Cryptantha cinerea	Boraginaceae	17	-0.0462	-0.0177	0.0358	0.2622	-0.0157	-0.0466	-0.0341	-0.0226	-0.0398	-0.0325
Cryptantha circumscissa	Boraginaceae	3	0.0018	0.0247	-0.0137	0.0253	-0.0223	-0.0301	-0.0204	-0.0178	-0.0170	-0.0149
Cryptantha confertiflora	Boraginaceae	31	-0.0351	0.0704	0.1252	0.0887	0.0972	-0.0691	-0.0637	-0.0683	-0.0403	-0.0469
Cryptantha fendleri	Boraginaceae	2	0.0286	-0.0031	-0.0284	-0.0251	-0.0231	-0.0282	-0.0252	-0.0131	-0.0139	-0.0121
Cryptantha humilis	Boraginaceae	1	-0.0109	-0.0111	-0.0095	-0.0240	-0.0163	-0.0248	-0.0028	-0.0127	-0.0098	-0.0085
Cryptantha sp. (annual)	Boraginaceae	60	-0.0026	0.2085	0.1317	0.0211	-0.0596	-0.1192	-0.0796	-0.0746	-0.0776	-0.0639
Cucurbita foetidissima	Cucurbitaceae	1	0.1155	-0.0117	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Cymopterus newberryi	Umbelliferae	1	-0.0109	-0.0106	0.0414	0.1042	-0.0083	-0.0248	-0.0119	0.0007	-0.0098	-0.0085
Cymopterus purpureus	Umbelliferae	15	-0.0240	0.0333	0.0497	-0.0356	-0.0408	0.1293	0.0713	-0.0351	-0.0388	-0.0339
Cymopterus sp.	Umbelliferae	1	0.0133	0.0499	-0.0212	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Cystopteris fragilis	Polypodiaceae	6	0.0155	-0.0505	-0.0547	-0.0311	0.0833	-0.0160	-0.0366	0.0764	0.3184	0.0691
*Dactylis glomerata**	Gramineae	2	-0.0154	-0.0239	-0.0466	-0.0211	-0.0231	-0.0129	0.0009	0.3368	-0.0020	0.0686
Dalea searlsiae	Leguminosae	13	0.0076	0.1213	0.0237	-0.0688	-0.0565	-0.0649	-0.0570	-0.0412	-0.0360	-0.0315
Datura wrightii	Solanaceae	3	-0.0049	-0.0306	-0.0595	-0.0417	-0.0284	-0.0374	-0.0332	-0.0138	-0.0073	0.2023
Delphinium andersonii	Ranunculaceae	1	-0.0109	-0.0106	0.0414	0.1042	-0.0083	-0.0248	-0.0119	0.0007	-0.0098	-0.0085
Delphinium nuttallianum	Ranunculaceae	7	-0.0061	-0.0339	-0.0169	-0.0119	-0.0293	0.0741	0.0510	0.0040	-0.0172	-0.0141
Descurainia californica	Cruciferae	1	0.0779	-0.0084	-0.0142	-0.0007	-0.0045	0.0076	0.0500	0.0264	-0.0098	-0.0085
Descurainia pinnata	Cruciferae	28	-0.0037	0.1716	0.0713	-0.0494	-0.0819	-0.0556	-0.0588	0.0116	-0.0520	-0.0214
*Descurainia sophia**	Cruciferae	1	-0.0109	-0.0204	-0.0279	-0.0165	-0.0163	-0.0150	0.0115	0.0787	-0.0016	0.0103
Disporum trachycarpum	Liliaceae	4	-0.0219	-0.0411	-0.0482	-0.0337	0.0665	0.0404	-0.0081	0.0632	0.2342	0.0494
Distichlis spicata	Gramineae	1	-0.0109	0.0039	-0.0287	-0.0169	-0.0113	-0.0248	-0.0217	-0.0127	0.0131	0.1908

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Dodecatheon pulchellum	Primulaceae	2	-0.0154	-0.0290	-0.0469	-0.0340	-0.0108	-0.0123	-0.0086	-0.0025	0.0387	-0.0025
Draba asprella	Cruciferae	33	-0.0516	-0.0823	0.0124	0.0971	0.2068	0.0802	0.0067	-0.0115	0.1409	-0.0142
Draba cuneifolia	Cruciferae	1	0.0196	0.0051	0.0044	-0.0094	-0.0056	-0.0150	-0.0138	-0.0032	-0.0098	0.0094
*Draba verna**	Cruciferae	40	0.0217	0.2595	0.0867	-0.0141	-0.0704	-0.0816	-0.0745	-0.0737	-0.0615	-0.0189
Dracocephalum parviflorum	Labiatae	1	0.0207	-0.0110	-0.0216	0.0050	-0.0113	0.0014	-0.0040	0.0148	-0.0098	-0.0085
Dryopteris filix-mas	Polypodiaceae	2	-0.0154	-0.0290	-0.0467	-0.0189	0.0224	0.0006	-0.0186	0.0479	0.2531	0.0817
Echinocereus engelmannii	Cactaceae	7	0.0099	0.0998	0.0162	-0.0347	-0.0267	-0.0588	-0.0520	-0.0302	-0.0261	-0.0229
Echinocereus triglochidiatus	Cactaceae	22	-0.0407	0.1003	0.1300	0.0608	0.0065	-0.0478	-0.0232	-0.0488	-0.0394	-0.0377
Eleocharis palustris	Cyperaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Eleocharis parishii	Cyperaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Elymus canadensis	Gramineae	4	-0.0219	-0.0346	-0.0516	-0.0170	0.0062	-0.0254	-0.0357	0.0581	0.2267	0.2742
Elymus elymoides	Gramineae	58	0.0162	0.0923	0.0099	0.0133	0.0141	-0.0536	-0.0274	-0.0206	-0.0247	-0.0314
*Elymus hispidus**	Gramineae	1	-0.0109	-0.0116	0.0146	-0.0026	-0.0053	-0.0051	-0.0059	-0.0127	-0.0043	-0.0085
Elymus smithii	Gramineae	3	0.1929	-0.0112	-0.0420	-0.0185	-0.0115	-0.0119	0.0309	0.0583	-0.0170	0.0127
Elymus sp.	Gramineae	2	-0.0109	-0.0139	-0.0177	-0.0046	-0.0111	-0.0100	-0.0099	-0.0091	-0.0098	-0.0085
Elymus spicatus	Gramineae	6	0.0722	-0.0048	-0.0195	-0.0271	-0.0193	0.0027	0.0116	0.0236	-0.0167	-0.0055
Elymus trachycaulus	Gramineae	10	-0.0042	-0.0334	-0.0334	-0.0351	-0.0399	-0.0503	-0.0244	0.1829	0.0698	0.2409
Encelia frutescens	Compositae	4	0.0475	0.1980	-0.0583	-0.0451	-0.0328	-0.0499	-0.0436	-0.0255	-0.0197	-0.0172
Ephedra nevadensis	Ephedraceae	18	0.0478	0.2637	0.0091	-0.0872	-0.0630	-0.0888	-0.0854	-0.0554	-0.0394	-0.0374
Ephedra viridis	Ephedraceae	16	-0.0215	0.0204	0.0730	0.0153	-0.0456	-0.0459	-0.0326	-0.0466	-0.0366	-0.0303
Epilobium brachycarpum	Onagraceae	3	-0.0189	-0.0331	-0.0461	0.0110	-0.0058	-0.0317	-0.0286	0.0187	0.1830	0.0390
Epilobium ciliatum	Onagraceae	3	0.0225	-0.0355	-0.0595	-0.0253	0.0420	-0.0055	-0.0286	0.0497	0.1889	0.0707
Epilobium glandulosum	Onagraceae	3	-0.0006	-0.0355	-0.0417	-0.0060	0.0404	0.0018	-0.0286	0.0690	0.2225	0.1360
Epilobium sp.	Onagraceae	1	-0.0109	-0.0204	-0.0279	-0.0165	-0.0163	-0.0150	0.0115	0.0787	-0.0016	0.0103
Epipactis gigantea	Orchidaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	0.0179	-0.0085
Equisetum arvense	Equisetaceae	1	-0.0109	-0.0117	-0.0232	-0.0169	-0.0113	-0.0248	-0.0217	0.0263	0.0371	0.3576
Equisetum hyemale	Equisetaceae	8	0.0242	-0.0422	-0.0812	-0.0464	-0.0190	-0.0501	-0.0537	0.0372	0.1603	0.3744
Equisetum laevigatum	Equisetaceae	2	-0.0154	-0.0260	-0.0466	-0.0340	-0.0231	-0.0352	-0.0308	0.0097	0.0132	0.3213

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Eriastrum eremicum	Polemoniaceae	7	-0.0062	0.2058	0.0095	-0.0395	-0.0417	-0.0626	-0.0550	-0.0339	-0.0261	-0.0229
Eriastrum sparsiflorum	Polemoniaceae	13	0.0561	0.1752	-0.0212	-0.0568	-0.0495	-0.0914	-0.0710	-0.0466	-0.0360	-0.0250
Erigeron canaani	Compositae	16	-0.0448	-0.0719	-0.0209	0.1198	0.2338	0.0168	-0.0131	-0.0192	0.0259	-0.0316
Erigeron divergens	Compositae	17	-0.0097	-0.0041	0.0203	-0.0308	-0.0587	-0.0115	0.0173	0.0552	-0.0393	-0.0170
Erigeron flagellaris	Compositae	2	-0.0154	-0.0198	-0.0127	-0.0103	0.0322	-0.0077	-0.0252	0.0184	0.0885	0.2472
Erigeron pumilus	Compositae	1	-0.0109	-0.0116	0.0146	-0.0026	-0.0053	-0.0051	-0.0059	-0.0127	-0.0043	-0.0085
Erigeron religious	Compositae	1	-0.0109	-0.0001	-0.0138	0.0062	0.0029	0.0233	0.0284	0.0007	-0.0098	-0.0085
Erigeron sionis	Compositae	4	-0.0219	-0.0387	-0.0358	0.0211	0.2217	0.0074	-0.0145	0.0187	0.1662	0.0426
Erigeron sp.	Compositae	14	0.0183	-0.0196	0.0122	0.0569	-0.0271	0.0253	0.0560	-0.0216	-0.0246	0.0674
Erigeron speciosus	Compositae	6	0.0224	-0.0409	-0.0374	-0.0328	-0.0154	0.0479	0.0804	0.1538	0.0046	0.0143
Erigeron utahensis	Compositae	41	-0.0341	0.1342	0.2246	0.0464	-0.0274	-0.0700	-0.0681	-0.0713	-0.0588	-0.0560
Eriogonum alatum	Polygonaceae	6	-0.0269	-0.0291	-0.0297	0.2047	0.0216	-0.0118	-0.0125	-0.0224	-0.0147	-0.0211
Eriogonum corymbosum	Polygonaceae	4	0.0057	0.0237	-0.0251	-0.0224	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Eriogonum davidsonii	Polygonaceae	32	-0.0379	0.1334	0.1227	0.0399	-0.0310	-0.0761	-0.0554	-0.0592	-0.0503	-0.0478
Eriogonum fasciculatum	Polygonaceae	3	-0.0189	0.0211	0.0748	-0.0180	-0.0206	0.0043	-0.0128	-0.0220	-0.0170	-0.0149
Eriogonum heracleoides	Polygonaceae	1	-0.0109	-0.0204	-0.0216	0.0856	-0.0029	-0.0024	-0.0019	-0.0127	-0.0098	-0.0085
Eriogonum inflatum	Polygonaceae	3	0.0610	0.1657	-0.0459	-0.0381	-0.0284	-0.0431	-0.0377	-0.0220	-0.0170	-0.0149
Eriogonum jamesii	Polygonaceae	10	-0.0350	-0.0338	-0.0469	0.0466	0.2322	-0.0553	-0.0502	-0.0361	-0.0065	-0.0275
Eriogonum microthecum	Polygonaceae	15	0.0519	0.0652	0.0645	-0.0408	-0.0378	-0.0589	-0.0519	-0.0245	-0.0305	-0.0290
Eriogonum palmerianum	Polygonaceae	15	0.0092	0.2175	0.0316	-0.0719	-0.0476	-0.0797	-0.0779	-0.0503	-0.0369	-0.0339
Eriogonum racemosum	Polygonaceae	59	-0.0291	-0.0898	0.0990	0.1001	0.0704	-0.0038	0.0302	0.0394	0.0517	-0.0253
Eriogonum sp.	Polygonaceae	7	-0.0291	0.0333	0.0162	-0.0002	-0.0297	-0.0475	-0.0430	-0.0339	-0.0261	-0.0229
Eriogonum umbellatum	Polygonaceae	21	-0.0382	-0.0305	0.0243	0.1447	0.0862	-0.0200	0.0085	-0.0145	0.0074	-0.0264
Erioneuron pilosum	Gramineae	2	0.0099	0.1098	-0.0356	-0.0208	0.0332	-0.0352	-0.0308	-0.0179	-0.0139	-0.0121
*Erodium cicutarium**	Geraniaceae	10	0.2865	0.1277	-0.0910	-0.0748	-0.0488	-0.0766	-0.0609	-0.0407	-0.0282	-0.0211
Erysimum asperum	Cruciferae	64	-0.0775	-0.0340	0.2064	0.1601	-0.0076	0.0100	0.0369	-0.0315	-0.0287	-0.0527
Eupatorium herbaceum	Compositae	12	-0.0081	-0.0709	-0.0670	-0.0391	0.1492	0.0054	-0.0365	0.0630	0.3612	0.0462
Euphorbia brachycera	Euphorbiaceae	5	0.0414	-0.0382	-0.0518	0.0127	-0.0217	0.0515	0.0060	-0.0243	-0.0220	-0.0192

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Euphorbia spathulata	Euphorbiaceae	1	0.3561	0.0035	-0.0293	-0.0240	-0.0163	-0.0248	-0.0020	-0.0127	-0.0098	-0.0085
Fendlerella utahensis	Saxifragaceae	1	-0.0109	-0.0204	0.0064	-0.0240	0.0168	0.0473	0.0135	-0.0127	-0.0030	-0.0085
Festuca octoflora	Gramineae	74	0.0169	0.2480	0.0657	0.0993	-0.0069	-0.1467	-0.1123	-0.0946	-0.0819	-0.0469
Fraxinus anomala	Oleaceae	45	-0.0588	0.0431	0.2408	-0.0204	0.0183	0.0824	0.0020	-0.0571	-0.0092	-0.0520
Fraxinus velutina	Oleaceae	6	-0.0169	-0.0349	-0.0638	-0.0478	-0.0313	-0.0546	-0.0496	-0.0130	0.0263	0.1862
Fritillaria atropurpurea	Liliaceae	9	-0.0225	-0.0276	0.0404	0.1442	-0.0179	-0.0199	0.0025	-0.0235	-0.0153	-0.0260
Gaillardia pinnatifida	Compositae	2	0.0770	0.0830	-0.0413	-0.0340	-0.0231	-0.0282	-0.0252	-0.0179	-0.0068	0.0020
Galium aparine	Rubiaceae	6	-0.0144	-0.0180	-0.0198	-0.0275	-0.0202	-0.0195	-0.0191	0.0417	0.0227	0.0290
Galium bifolium	Rubiaceae	2	0.0411	-0.0290	-0.0306	-0.0185	-0.0185	-0.0130	0.0362	0.2181	0.0041	0.0247
Galium multiflorum	Rubiaceae	28	-0.0557	-0.0715	0.1091	0.0320	0.0953	0.0121	-0.0059	-0.0183	0.0520	-0.0249
Galium sp.	Rubiaceae	1	0.0196	0.0007	0.0788	-0.0020	-0.0163	0.0014	-0.0040	-0.0065	-0.0098	-0.0085
Galium trifidum	Rubiaceae	2	-0.0154	-0.0194	0.0132	-0.0006	0.0406	0.0039	-0.0252	0.0003	0.0890	0.0264
Galium triflorum	Rubiaceae	4	-0.0219	-0.0174	-0.0340	-0.0375	0.0169	-0.0196	-0.0310	0.0434	0.2616	0.0562
Garrya flavescens	Garryaceae	9	-0.0331	-0.0363	0.0376	-0.0030	-0.0256	0.0300	-0.0135	-0.0232	-0.0226	-0.0260
Gaura coccinea	Onagraceae	1	0.0249	0.1296	-0.0287	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Gayophytum sp.	Onagraceae	14	0.0125	-0.0316	-0.0370	-0.0369	-0.0406	0.0238	0.0777	0.1380	-0.0272	0.0207
Geranium richardsonii	Geraniaceae	1	-0.0109	-0.0204	-0.0291	-0.0027	0.0370	0.0140	-0.0138	0.0581	0.2611	0.1104
Gilia inconspicua	Polemoniaceae	84	-0.0137	0.2558	0.1513	0.0515	-0.1029	-0.1116	-0.0963	-0.1140	-0.0969	-0.0584
Gilia scopulorum	Polemoniaceae	1	-0.0109	0.0004	0.0031	0.0269	-0.0163	0.0112	-0.0059	0.0014	-0.0098	-0.0085
Glycyrrhiza lepidota	Leguminosae	1	0.1195	0.0037	-0.0215	-0.0240	-0.0163	-0.0150	-0.0138	-0.0127	0.0002	0.0114
Gnaphalium wrightii	Compositae	9	-0.0331	-0.0003	0.0182	0.0485	0.0870	-0.0346	-0.0305	0.0031	0.1052	0.0465
Goodyera oblongifolia	Orchidaceae	5	-0.0245	-0.0460	-0.0690	-0.0374	0.0260	0.0369	-0.0076	0.0882	0.2131	0.0404
Grindelia squarrosa	Compositae	1	0.0449	-0.0117	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Gutierrezia spp.	Compositae	94	0.0989	0.2817	0.0670	-0.0696	-0.0984	-0.1590	-0.1114	-0.1043	-0.0962	-0.0086
Hackelia patens	Boraginaceae	5	0.0219	-0.0146	0.0180	0.0033	-0.0109	-0.0110	-0.0057	0.0411	-0.0125	-0.0192
Haplopappus armerioides	Compositae	1	-0.0109	-0.0204	-0.0294	-0.0174	-0.0163	0.1376	0.0257	-0.0127	-0.0098	-0.0085
Haplopappus gracilis	Compositae	4	0.1243	-0.0202	-0.0699	-0.0411	-0.0278	-0.0449	-0.0397	-0.0255	-0.0081	0.1083
Haplopappus laricifolius	Compositae	1	0.0207	0.0772	0.0151	-0.0240	-0.0106	-0.0150	-0.0138	-0.0127	-0.0098	-0.0085

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Haplopappus scopulorum	Compositae	42	-0.0620	-0.0438	0.1804	0.0711	0.0046	0.0255	0.0324	-0.0509	-0.0055	-0.0515
Helianthella quinquenervis	Compositae	1	-0.0109	-0.0161	-0.0052	-0.0165	-0.0099	0.0461	0.1300	-0.0058	-0.0098	-0.0085
Helianthus annuus	Compositae	2	0.0241	-0.0166	-0.0522	-0.0340	-0.0231	-0.0352	-0.0308	-0.0179	-0.0139	0.0057
Helianthus anomalus	Compositae	2	0.3310	-0.0058	-0.0468	-0.0340	-0.0231	-0.0352	-0.0168	-0.0179	-0.0139	-0.0121
Helianthus nuttallii	Compositae	2	-0.0154	-0.0290	-0.0069	-0.0193	-0.0185	0.0860	0.1539	-0.0021	-0.0139	-0.0121
Heuchera rubescens	Saxifragaceae	12	-0.0292	-0.0709	-0.0461	-0.0292	0.1744	0.0382	-0.0019	0.0476	0.2533	-0.0007
Hieracium fendleri	Compositae	1	-0.0109	-0.0156	-0.0138	0.0744	0.0327	0.0093	-0.0045	-0.0055	0.0131	-0.0085
Hilaria sp.	Gramineae	41	0.1280	0.2507	0.0402	-0.1195	-0.0871	-0.1262	-0.1138	-0.0683	-0.0675	-0.0510
Holodiscus dumosus	Rosaceae	21	-0.0356	-0.0921	-0.0438	0.0077	0.3078	-0.0046	-0.0308	-0.0027	0.1947	-0.0222
*Hordeum murinum**	Gramineae	1	0.3561	0.0035	-0.0293	-0.0240	-0.0163	-0.0248	-0.0020	-0.0127	-0.0098	-0.0085
Hordeum sp.	Gramineae	1	-0.0109	0.0044	-0.0049	0.0480	0.0072	-0.0248	-0.0119	-0.0065	-0.0098	-0.0085
Hydrophyllum occidentale	Hydrophyllaceae	2	-0.0154	-0.0290	-0.0359	-0.0251	0.0522	0.0165	-0.0130	0.0432	0.1573	-0.0025
Hymenopappus filifolius	Compositae	11	-0.0368	-0.0381	-0.0048	0.2352	-0.0077	-0.0134	-0.0248	-0.0122	-0.0309	-0.0242
Hymenoxys cooperi	Compositae	5	0.1070	0.0776	0.0185	-0.0390	-0.0263	-0.0291	-0.0196	0.0033	-0.0183	-0.0192
Ipomopsis aggregata	Polemoniaceae	5	-0.0027	0.0176	0.0435	0.0043	-0.0292	0.0541	0.1344	-0.0049	-0.0220	-0.0112
Ipomopsis congesta	Polemoniaceae	14	-0.0417	-0.0395	0.0396	0.1277	0.0315	-0.0169	-0.0247	-0.0114	-0.0070	-0.0024
Iva axillaris	Compositae	1	-0.0109	-0.0117	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	0.0166
Ivesia sabulosa	Rosaceae	7	-0.0291	-0.0435	-0.0373	0.0594	0.2693	-0.0287	-0.0318	-0.0284	0.0105	-0.0229
Jamesia americana	Saxifragaceae	2	0.0352	-0.0260	-0.0466	-0.0290	0.0206	-0.0282	-0.0252	0.0007	0.1444	0.0538
Juncus arcticus	Juncaceae	3	-0.0189	-0.0305	-0.0471	-0.0180	-0.0143	-0.0431	-0.0377	0.0325	0.0552	0.3103
Juncus ensifolius	Juncaceae	2	-0.0154	-0.0228	-0.0425	-0.0290	-0.0150	-0.0166	-0.0252	0.0472	0.0611	0.2580
Juncus tenuis	Juncaceae	1	-0.0109	-0.0117	-0.0232	-0.0169	-0.0113	-0.0248	-0.0217	0.0263	0.0371	0.3576
Juniperus osteosperma	Cupressaceae	115	0.0251	0.1706	0.1868	-0.0462	-0.1486	0.0226	0.0318	-0.1258	-0.1273	-0.1076
Juniperus scopulorum	Cupressaceae	21	-0.0178	-0.0775	-0.0461	-0.0170	-0.0283	0.0539	0.0409	0.1754	0.0134	0.0109
Koeleria macrantha	Gramineae	1	0.0689	-0.0159	-0.0217	0.0052	-0.0109	0.0235	0.0359	0.0344	-0.0098	-0.0085
*Lactuca serriola**	Compositae	13	0.2237	-0.0045	-0.0836	-0.0662	-0.0233	-0.0521	-0.0387	0.0166	0.0243	0.0185
Lactuca tatarica	Compositae	2	0.0069	-0.0223	-0.0359	0.0017	0.0182	0.0109	-0.0126	0.0516	0.1780	0.0721
Lappula occidentalis	Boraginaceae	2	0.0352	-0.0143	-0.0326	-0.0223	-0.0116	-0.0129	0.0009	0.0628	-0.0028	-0.0121

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Lathyrus brachycalyx	Leguminosae	9	-0.0331	-0.0063	0.0917	-0.0259	-0.0346	0.0058	-0.0064	-0.0323	-0.0297	-0.0260
Lathyrus lanszwertii	Leguminosae	20	-0.0150	-0.0783	-0.0283	-0.0158	-0.0433	0.1446	0.2432	0.0463	-0.0253	-0.0321
Layia glandulosa	Compositae	2	-0.0154	0.0319	0.0088	0.0161	-0.0090	-0.0122	-0.0124	-0.0112	-0.0100	-0.0121
*Lepidium campestre**	Cruciferae	1	-0.0109	-0.0204	-0.0294	-0.0240	-0.0163	-0.0033	0.0053	0.1108	0.0136	0.0067
Lepidium densiflorum	Cruciferae	8	0.1484	0.1408	-0.0475	-0.0499	-0.0344	-0.0559	-0.0466	-0.0341	-0.0254	-0.0245
Lepidium fremontii	Cruciferae	1	0.0196	0.0550	-0.0107	-0.0177	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Lepidium lasiocarpum	Cruciferae	1	0.1195	0.0037	-0.0215	-0.0240	-0.0163	-0.0150	-0.0138	-0.0127	0.0002	0.0114
Lepidium montanum	Cruciferae	1	0.0537	-0.0144	-0.0290	-0.0073	0.0010	-0.0033	0.0053	0.0870	-0.0098	0.0390
Leptodactylon pungens	Polemoniaceae	8	-0.0312	-0.0489	-0.0113	0.0261	0.2160	0.0105	0.0036	-0.0213	0.0551	-0.0196
Leptodactylon watsonii	Polemoniaceae	10	-0.0350	0.0074	0.0209	0.0080	0.0732	-0.0228	-0.0311	-0.0149	0.0196	-0.0275
Leucocrinum montanum	Liliaceae	1	-0.0109	0.0073	0.0119	0.0210	-0.0045	0.0076	0.0042	-0.0127	-0.0098	-0.0085
Linanthastrum nuttallii	Polemoniaceae	19	-0.0433	-0.0681	0.0315	0.1760	0.1762	-0.0110	-0.0309	-0.0092	0.0617	-0.0090
Linanthus dichotomus	Polemoniaceae	14	0.0000	0.1643	0.0400	-0.0073	-0.0175	-0.0784	-0.0666	-0.0485	-0.0335	-0.0265
*Linum perenne**	Linaceae	6	-0.0070	-0.0198	0.0699	0.0251	0.0469	0.0372	0.0333	-0.0255	0.0071	-0.0134
Lithophragma tenellum	Saxifragaceae	1	-0.0109	-0.0071	-0.0067	-0.0149	-0.0163	-0.0051	-0.0059	0.0257	-0.0012	0.0067
Lithospermum incisum	Boraginaceae	2	0.0017	0.0099	0.0067	-0.0246	-0.0231	0.0576	0.0026	-0.0131	-0.0139	-0.0121
Lithospermum ruderale	Boraginaceae	2	0.0524	-0.0114	-0.0033	0.0115	-0.0150	-0.0027	0.0386	0.0680	-0.0080	0.0006
Lomatium dissectum	Umbelliferae	4	-0.0219	-0.0389	-0.0354	-0.0296	-0.0269	-0.0035	0.0358	0.1080	-0.0067	0.0000
Lomatium graveolens	Umbelliferae	1	-0.0109	-0.0204	-0.0290	-0.0240	0.0469	0.0256	-0.0045	0.0413	0.1068	-0.0085
Lomatium sp.	Umbelliferae	1	-0.0109	-0.0159	-0.0063	0.0034	-0.0035	-0.0150	-0.0138	-0.0127	-0.0098	-0.0085
Lotus denticulatus	Leguminosae	6	0.1489	0.0262	-0.0177	-0.0513	-0.0379	-0.0439	-0.0235	-0.0285	-0.0242	-0.0211
Lotus plebeius	Leguminosae	17	-0.0171	0.1402	0.1080	0.0393	-0.0188	-0.0600	-0.0524	-0.0514	-0.0374	-0.0363
Lotus utahensis	Leguminosae	12	0.0040	-0.0308	-0.0165	-0.0260	-0.0268	0.0389	0.1321	0.0350	-0.0305	-0.0162
Lupinus argenteus	Leguminosae	1	-0.0109	0.0903	0.0057	-0.0106	-0.0056	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Lupinus brevicaulis	Leguminosae	4	-0.0219	0.0659	-0.0162	-0.0376	-0.0303	-0.0449	-0.0298	-0.0255	-0.0197	-0.0172
Lupinus concinnus	Leguminosae	1	-0.0109	0.0722	0.0141	0.0133	-0.0056	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Lupinus kingii	Leguminosae	2	-0.0154	0.0136	-0.0176	-0.0142	-0.0231	-0.0002	0.0474	-0.0036	-0.0139	-0.0121
Lupinus sericeus	Leguminosae	9	0.0692	-0.0536	-0.0838	-0.0294	-0.0299	0.0016	0.0436	0.2937	-0.0064	0.0352

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Lychnis drummondii	Caryophyllaceae	1	-0.0109	-0.0114	-0.0124	0.0988	0.0029	-0.0248	-0.0217	0.0355	-0.0098	0.0067
Lycium pallidum	Solanaceae	3	0.3355	0.0067	-0.0506	-0.0376	-0.0255	-0.0431	-0.0263	-0.0220	-0.0170	-0.0149
Lygodesmia grandiflora	Compositae	2	-0.0154	0.0277	0.0124	0.0441	-0.0193	-0.0122	-0.0040	-0.0129	-0.0139	-0.0121
Machaeranthera canescens	Compositae	40	-0.0036	0.0284	0.0883	0.1432	-0.0142	-0.0414	-0.0210	-0.0066	-0.0534	-0.0318
Mahonia repens	Berberidaceae	29	-0.0231	-0.0947	-0.0511	-0.0508	-0.0046	0.1614	0.0969	0.0752	0.1310	0.0000
*Medicago lupulina**	Leguminosae	1	-0.0109	-0.0162	-0.0290	-0.0240	-0.0163	-0.0248	-0.0217	0.0015	0.0070	0.2964
*Melilotus alba**	Leguminosae	2	0.0993	-0.0119	-0.0413	-0.0340	-0.0231	-0.0282	-0.0252	-0.0003	-0.0010	0.0723
*Melilotus officinalis**	Leguminosae	1	-0.0109	0.0039	-0.0287	-0.0169	-0.0113	-0.0248	-0.0217	-0.0127	0.0131	0.1908
Melilotus sp.*	Leguminosae	2	-0.0154	-0.0198	-0.0370	-0.0290	-0.0196	-0.0352	-0.0308	0.0197	0.0312	0.4632
Mentzelia integra	Loasaceae	1	0.0554	0.0417	-0.0293	-0.0177	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Mertensia arizonica	Boraginaceae	7	-0.0044	-0.0469	-0.0832	-0.0364	-0.0166	-0.0108	0.0021	0.2907	0.0961	0.1045
Mertensia fusiformis	Boraginaceae	3	-0.0189	-0.0260	-0.0181	-0.0255	-0.0106	0.1384	0.1672	-0.0149	-0.0170	-0.0149
Microseris lindleyi	Compositae	8	0.0141	0.0280	0.0754	0.0552	-0.0134	-0.0329	-0.0171	-0.0204	-0.0223	-0.0211
Microsteris gracilis	Polemoniaceae	28	-0.0384	-0.0110	0.0462	0.0624	0.0171	-0.0096	0.0168	0.0556	-0.0135	-0.0144
Mimulus cardinalis	Scrophulariaceae	2	-0.0154	-0.0260	-0.0466	-0.0340	-0.0231	-0.0282	-0.0252	0.0007	0.1183	0.0442
Mimulus floribundus	Scrophulariaceae	1	-0.0109	0.0337	0.0295	0.0488	0.0036	-0.0150	-0.0138	-0.0127	-0.0098	-0.0085
Mimulus guttatus	Scrophulariaceae	3	-0.0189	-0.0331	-0.0550	-0.0294	0.0063	0.0002	-0.0240	0.0649	0.2451	0.1089
Mimulus parryi	Scrophulariaceae	1	-0.0109	0.0073	0.0119	0.0210	-0.0045	0.0076	0.0042	-0.0127	-0.0098	-0.0085
Mirabilis multiflora	Nyctaginaceae	7	0.1470	0.1333	-0.0178	-0.0565	-0.0365	-0.0588	-0.0442	-0.0339	-0.0223	-0.0152
Mirabilis pumila	Nyctaginaceae	1	0.0491	0.0152	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Monardella odoratissima	Labiatae	6	0.0025	-0.0488	-0.0627	-0.0131	0.1961	-0.0348	-0.0324	-0.0244	0.0404	-0.0155
Montia perfoliata	Portulacaceae	3	-0.0189	-0.0110	0.0469	0.0374	0.0018	-0.0149	-0.0227	-0.0033	0.0138	0.0167
Muhlenbergia asperifolia	Gramineae	2	0.0770	-0.0089	-0.0358	-0.0340	-0.0231	-0.0282	-0.0252	-0.0079	0.0051	0.2180
Muhlenbergia montana	Gramineae	2	-0.0154	-0.0224	-0.0306	0.0769	0.0860	-0.0117	-0.0120	-0.0129	-0.0045	-0.0121
Muhlenbergia pungens	Gramineae	5	-0.0245	-0.0001	-0.0069	0.1187	-0.0227	-0.0316	-0.0295	-0.0253	-0.0220	-0.0192
Muhlenbergia racemosa	Gramineae	3	-0.0006	-0.0355	-0.0507	-0.0256	0.0293	0.0018	-0.0286	0.0515	0.2055	0.0806
Muhlenbergia sp.	Gramineae	1	-0.0109	-0.0115	0.0011	-0.0177	-0.0163	0.1087	0.0330	-0.0065	-0.0098	-0.0085
Muhlenbergia thurberi	Gramineae	12	-0.0174	-0.0610	-0.0526	0.0809	0.2838	-0.0207	-0.0274	-0.0274	0.0811	-0.0182

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Myosurus cupulatus	Ranunculaceae	1	-0.0109	-0.0068	0.0019	-0.0177	-0.0163	0.0014	-0.0138	-0.0127	-0.0098	-0.0085
Nasturtium officinale	Cruciferae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Navarretia breweri	Polemoniaceae	5	0.0225	-0.0303	-0.0351	-0.0051	-0.0103	0.0073	0.0645	0.0414	-0.0220	0.0022
Nicotiana attenuata	Solanaceae	1	0.0512	-0.0001	-0.0138	-0.0240	-0.0163	-0.0150	-0.0138	-0.0058	-0.0098	-0.0085
Oenothera caespitosa	Onagraceae	9	-0.0033	-0.0030	0.0777	0.0068	-0.0066	0.0235	0.0220	-0.0001	-0.0194	-0.0139
Oenothera longissima	Onagraceae	2	-0.0154	-0.0198	-0.0370	-0.0290	-0.0196	-0.0352	-0.0308	0.0197	0.0312	0.4632
Oenothera pallida	Onagraceae	12	-0.0224	0.0081	0.0494	0.1056	-0.0116	-0.0433	-0.0436	-0.0284	-0.0092	0.1363
Oenothera sp.	Onagraceae	2	0.1635	-0.0057	-0.0413	-0.0340	-0.0231	-0.0282	-0.0252	-0.0179	-0.0068	0.0020
Opuntia erinacea	Cactaceae	17	-0.0068	0.2280	0.0095	-0.0750	-0.0492	-0.0720	-0.0542	-0.0497	-0.0380	-0.0261
Opuntia macrorhiza	Cactaceae	120	-0.0871	0.0051	0.1969	0.2100	0.0551	0.0113	0.0278	-0.0893	-0.0880	-0.1079
Opuntia phaeacantha	Cactaceae	9	0.1030	0.0449	0.0187	0.0060	-0.0339	-0.0589	-0.0420	-0.0291	-0.0297	-0.0200
Opuntia polyacantha	Cactaceae	3	-0.0189	0.0721	-0.0325	-0.0381	-0.0284	-0.0431	-0.0377	-0.0220	-0.0170	-0.0149
Opuntia whipplei	Cactaceae	3	0.0158	0.0719	-0.0459	-0.0339	-0.0255	-0.0431	-0.0377	-0.0220	-0.0170	-0.0149
Orobanche fasciculata	Orobanchaceae	2	-0.0154	-0.0220	0.0088	0.1714	0.0019	-0.0282	-0.0098	-0.0085	-0.0139	-0.0121
Orobanche uniflora	Orobanchaceae	1	-0.0109	-0.0026	0.0039	0.0039	-0.0163	0.0246	0.0886	0.0076	-0.0098	-0.0085
Oryzopsis micrantha	Gramineae	2	-0.0154	-0.0254	0.0236	-0.0089	-0.0003	0.0515	-0.0018	0.0008	-0.0089	0.0012
Osmorhiza occidentalis	Umbelliferae	4	-0.0060	-0.0258	-0.0429	-0.0358	0.0221	0.0098	-0.0047	0.1617	0.1010	0.0541
Pachystima myrsinites	Celastraceae	54	-0.0573	-0.1407	-0.0118	0.0118	0.0706	0.2096	0.1310	0.0248	0.1121	-0.0386
Panicum sp.	Gramineae	2	-0.0154	-0.0052	-0.0199	0.0220	-0.0029	-0.0352	-0.0238	0.0140	0.0194	0.2472
Pectocarya setosa	Boraginaceae	3	0.0226	0.0666	-0.0321	-0.0339	-0.0255	-0.0431	-0.0263	-0.0220	-0.0170	-0.0149
Pedicularis centranthera	Scrophulariaceae	10	-0.0194	-0.0305	0.0315	-0.0249	-0.0408	0.1849	0.1029	-0.0235	-0.0314	-0.0275
Pediomelum mephiticum	Leguminosae	2	0.0069	0.0005	0.0142	-0.0157	-0.0231	0.0063	0.0156	-0.0179	-0.0139	-0.0121
Pellaea truncata	Polypodiaceae	1	-0.0109	-0.0008	0.0154	-0.0174	-0.0163	-0.0033	-0.0045	-0.0058	-0.0098	-0.0085
Penstemon angustifolius	Scrophulariaceae	38	-0.0262	-0.0539	0.0177	0.0474	0.0685	0.0513	0.0048	0.0071	0.0290	-0.0272
Penstemon barbatus	Scrophulariaceae	6	-0.0269	-0.0216	0.0152	0.0110	0.0565	0.0150	0.0015	0.0004	0.1087	0.0279
Penstemon comarrhenus	Scrophulariaceae	2	0.0017	0.0004	0.0249	0.0411	-0.0196	0.0076	0.0306	0.0016	-0.0139	0.0006
Penstemon confusus	Scrophulariaceae	3	-0.0189	-0.0032	0.0457	-0.0067	-0.0143	-0.0244	-0.0117	-0.0220	-0.0170	-0.0149
Penstemon eatonii	Scrophulariaceae	23	-0.0439	0.0296	0.1760	0.0390	-0.0203	-0.0281	-0.0238	-0.0371	-0.0302	0.0407

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Penstemon higginsii	Scrophulariaceae	5	-0.0245	-0.0318	-0.0169	-0.0317	-0.0180	0.0574	0.0720	0.0924	-0.0099	-0.0124
Penstemon humilis	Scrophulariaceae	27	-0.0593	-0.0565	0.0790	0.1052	0.2021	-0.0007	-0.0125	-0.0374	0.0411	-0.0438
Penstemon laevis	Scrophulariaceae	26	-0.0532	-0.0162	0.0773	0.2316	0.0846	-0.0416	-0.0335	-0.0542	-0.0342	-0.0456
Penstemon linarioides	Scrophulariaceae	13	0.0007	-0.0437	-0.0164	-0.0284	-0.0471	0.0904	0.2105	0.0331	-0.0360	-0.0167
Penstemon pachyphyllus	Scrophulariaceae	1	-0.0109	0.0759	0.0043	-0.0034	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Penstemon palmeri	Scrophulariaceae	19	-0.0032	0.1018	0.0837	-0.0440	-0.0310	-0.0624	-0.0480	-0.0468	-0.0295	0.0380
Penstemon rostriflorus	Scrophulariaceae	30	-0.0179	-0.0415	0.0496	-0.0137	0.1297	0.0101	-0.0091	0.0460	0.1111	-0.0184
Peraphyllum ramosissimum	Rosaceae	10	-0.0016	-0.0473	-0.0258	-0.0263	-0.0351	0.1847	0.2389	0.0165	-0.0293	-0.0275
Perityle tenella	Compositae	1	-0.0109	-0.0204	-0.0368	-0.0240	0.0041	-0.0248	-0.0217	-0.0127	0.0277	0.0050
Peteria thompsoniae	Leguminosae	5	0.0215	0.1095	-0.0140	-0.0511	-0.0311	-0.0559	-0.0489	-0.0254	-0.0220	-0.0192
Petradoria pumila	Compositae	2	0.0128	-0.0290	-0.0066	0.0259	0.0074	-0.0060	0.0762	0.0069	-0.0139	-0.0121
Petrophytum caespitosum	Rosaceae	12	-0.0385	-0.0612	-0.0582	0.0268	0.3143	0.0020	-0.0243	-0.0130	0.1274	0.0088
Phacelia fremontii	Hydrophyllaceae	6	-0.0144	0.1215	0.0457	-0.0356	-0.0354	-0.0399	-0.0365	-0.0313	-0.0242	-0.0211
Phacelia heterophylla	Hydrophyllaceae	42	-0.0498	-0.0651	0.0028	0.0973	0.0148	-0.0231	-0.0256	0.1026	0.0676	0.1188
Phacelia ivesiana	Hydrophyllaceae	1	0.0196	0.0051	0.0044	-0.0094	-0.0056	-0.0150	-0.0138	-0.0032	-0.0098	0.0094
Phacelia palmeri	Hydrophyllaceae	1	0.0554	0.0417	-0.0293	-0.0177	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Philadelphus microphyllus	Saxifragaceae	10	-0.0248	-0.0600	-0.0154	-0.0246	0.1294	0.0352	-0.0116	0.0565	0.2350	0.0047
Phlox austromontana	Polemoniaceae	54	-0.0767	-0.0520	0.1251	0.1886	0.0721	0.0491	0.0433	-0.0512	-0.0503	-0.0675
Phlox longifolia	Polemoniaceae	11	0.0053	-0.0238	0.0293	-0.0061	-0.0282	0.1193	0.2187	-0.0028	-0.0293	-0.0234
Phoradendron juniperinum	Viscaceae	14	-0.0331	-0.0010	0.1106	0.0545	-0.0285	0.0484	0.0399	-0.0264	-0.0335	-0.0327
Phragmites australis	Gramineae	2	-0.0154	-0.0087	-0.0409	-0.0290	-0.0196	-0.0352	-0.0308	-0.0079	0.0143	0.3451
Physalis hederifolia	Solanaceae	8	0.0857	-0.0088	-0.0355	-0.0285	-0.0332	0.0003	-0.0346	-0.0226	-0.0044	0.0376
Physalis longifolia	Solanaceae	1	0.1195	0.0037	-0.0215	-0.0240	-0.0163	-0.0150	-0.0138	-0.0127	0.0002	0.0114
Physaria chambersii	Cruciferae	3	-0.0049	-0.0200	0.0859	-0.0097	-0.0166	0.0871	0.0155	-0.0220	-0.0170	-0.0149
Physaria ludoviciana	Cruciferae	3	-0.0189	0.0209	0.0691	0.1120	-0.0154	-0.0187	-0.0113	-0.0137	-0.0170	-0.0149
Physaria newberryi	Cruciferae	7	-0.0106	-0.0018	0.0068	-0.0185	-0.0416	0.1630	0.0418	-0.0279	-0.0261	-0.0229
Physaria rectipes	Cruciferae	3	-0.0189	-0.0058	0.0326	0.1040	-0.0168	-0.0187	-0.0125	-0.0143	-0.0170	-0.0149
Physaria wardii	Cruciferae	1	-0.0109	-0.0161	-0.0141	-0.0163	0.0010	0.0474	0.2013	-0.0065	-0.0098	-0.0085

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Physocarpus alternans	Rosaceae	1	-0.0109	-0.0204	0.0064	-0.0240	0.0168	0.0473	0.0135	-0.0127	-0.0030	-0.0085
Pinus edulis	Pinaceae	53	-0.0363	-0.0799	0.0969	0.0150	-0.0519	0.2160	0.1513	-0.0540	-0.0481	-0.0640
Pinus monophylla	Pinaceae	64	-0.0639	0.1617	0.1964	-0.0616	-0.1071	-0.1054	-0.0930	-0.0808	-0.0790	-0.0597
Pinus ponderosa	Pinaceae	60	-0.0574	-0.1236	-0.0675	0.1735	0.1993	0.0611	0.0717	-0.0050	0.0285	-0.0322
Plantago patagonica	Plantaginaceae	13	0.1238	0.1362	-0.0524	0.0399	-0.0229	-0.0564	-0.0376	-0.0292	-0.0360	-0.0315
Poa bigelovii	Gramineae	8	0.0487	0.1065	-0.0240	-0.0542	-0.0388	-0.0675	-0.0593	-0.0329	-0.0280	-0.0181
*Poa bulbosa**	Gramineae	1	0.0848	-0.0162	-0.0368	-0.0169	-0.0113	-0.0248	-0.0217	-0.0127	-0.0016	0.0094
*Poa compressa**	Gramineae	3	0.0185	-0.0296	-0.0550	-0.0320	-0.0183	-0.0307	-0.0221	0.0583	0.0051	0.2434
Poa fendleriana	Gramineae	190	-0.1391	-0.0620	0.2132	0.1283	0.1186	0.0577	0.0891	-0.0417	-0.0072	-0.0837
*Poa pratensis**	Gramineae	14	-0.0045	-0.0598	-0.0991	-0.0276	-0.0409	-0.0455	-0.0258	0.2466	0.0391	0.2027
Poa secunda	Gramineae	4	-0.0219	-0.0150	0.0621	0.0318	0.0205	-0.0237	-0.0227	-0.0207	-0.0162	-0.0172
Poa sp.	Gramineae	1	0.0196	0.0257	0.0239	-0.0177	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Polygonum douglasii	Polygonaceae	39	-0.0015	-0.0693	-0.0321	0.1548	0.0311	0.0050	0.0855	0.1711	-0.0403	-0.0010
Polypodium hesperium	Polypodiaceae	6	-0.0269	-0.0470	-0.0363	-0.0402	0.0592	-0.0031	-0.0263	0.0408	0.2726	0.0228
Populus fremontii	Salicaceae	6	-0.0139	-0.0177	-0.0756	-0.0534	-0.0362	-0.0613	-0.0487	0.0008	0.0149	0.3936
Populus tremuloides	Salicaceae	2	-0.0154	-0.0290	-0.0359	-0.0100	-0.0095	-0.0199	-0.0116	0.0909	0.0426	0.0664
Prunus virginiana	Rosaceae	10	0.0293	-0.0582	-0.0766	-0.0404	-0.0332	0.0307	0.0676	0.2923	0.0006	0.0201
Pseudotsuga menziesii	Pinaceae	18	-0.0476	-0.0849	-0.0415	-0.0183	0.1328	0.0553	0.0042	0.0309	0.2559	0.0212
Psoralidium lanceolatum	Leguminosae	4	0.0437	0.0173	-0.0447	-0.0232	-0.0303	-0.0449	-0.0337	-0.0255	-0.0146	0.0044
Psorothamnus fremontii	Leguminosae	11	0.0240	0.2031	-0.0107	-0.0679	-0.0532	-0.0747	-0.0660	-0.0428	-0.0330	-0.0289
Pteridium aquilinum	Polypodiaceae	3	-0.0189	-0.0327	-0.0371	0.0472	0.0421	-0.0009	-0.0232	0.0407	0.1626	0.1094
Pterospora andromedea	Monotropaceae	2	-0.0154	-0.0204	-0.0137	-0.0027	-0.0071	-0.0007	-0.0126	0.0241	0.0224	-0.0121
Purshia mexicana	Rosaceae	15	-0.0140	0.0794	0.0437	-0.0691	-0.0602	-0.0049	-0.0317	-0.0468	-0.0388	-0.0339
Purshia tridentata	Rosaceae	36	-0.0398	-0.0642	0.0241	0.0959	-0.0355	0.1318	0.1832	-0.0297	-0.0563	-0.0475
Quercus gambelii	Fagaceae	135	-0.0835	-0.2123	-0.0259	0.0354	0.0422	0.1792	0.1804	0.1418	0.0666	-0.0480
Quercus turbinella	Fagaceae	50	-0.0617	0.1136	0.2131	0.0456	-0.0280	-0.0980	-0.0825	-0.0805	-0.0597	-0.0524
Ranunculus andersonii	Ranunculaceae	1	-0.0109	0.0337	0.0295	0.0488	0.0036	-0.0150	-0.0138	-0.0127	-0.0098	-0.0085
Ranunculus sp.	Ranunculaceae	1	-0.0109	-0.0117	-0.0232	-0.0169	-0.0113	-0.0248	-0.0217	0.0263	0.0371	0.3576

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
*Ranunculus testiculatus**	Ranunculaceae	2	0.0241	-0.0166	-0.0522	-0.0340	-0.0231	-0.0352	-0.0308	-0.0179	-0.0139	0.0057
Rhus aromatica	Anacardiaceae	23	-0.0011	0.1709	0.1113	-0.0483	-0.0489	-0.0629	-0.0392	-0.0439	-0.0425	-0.0388
Ribes velutinum	Saxifragaceae	1	-0.0109	-0.0161	0.0011	-0.0175	-0.0079	-0.0051	-0.0059	-0.0058	-0.0035	-0.0085
Robinia neomexicana	Leguminosae	1	-0.0109	0.0029	0.0022	-0.0149	-0.0163	-0.0051	0.0130	0.0826	-0.0098	0.0255
Rosa woodsii	Rosaceae	12	0.0277	-0.0648	-0.0878	-0.0490	-0.0177	0.0722	0.0501	0.2403	0.0501	0.0438
*Rubia tinctoria**	Rubiaceae	1	0.1195	0.0037	-0.0215	-0.0240	-0.0163	-0.0150	-0.0138	-0.0127	0.0002	0.0114
Rubus leucodermis	Rosaceae	4	-0.0219	-0.0390	-0.0585	-0.0420	0.0088	-0.0278	-0.0310	0.0373	0.2611	0.0432
Rumex hymenosepalus	Polygonaceae	2	0.0912	0.0270	-0.0411	-0.0340	-0.0231	-0.0352	-0.0308	-0.0179	-0.0139	-0.0121
Salix exigua	Salicaceae	3	-0.0189	-0.0139	-0.0469	-0.0335	-0.0226	-0.0431	-0.0377	0.0088	0.0332	0.4594
Salix scouleriana	Salicaceae	2	-0.0154	-0.0290	-0.0466	-0.0340	-0.0185	-0.0166	-0.0182	0.0239	0.0423	0.0246
Salvia dorrii	Labiatae	3	-0.0189	0.0757	0.0290	-0.0148	-0.0249	-0.0301	-0.0273	-0.0220	-0.0170	-0.0149
Samolus floribundus	Primulaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Saxifraga rhomboidea	Saxifragaceae	1	-0.0109	-0.0159	-0.0006	0.0311	0.0898	0.0053	-0.0092	-0.0029	0.0390	-0.0085
Scirpus microcarpus	Cyperaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Scirpus pungens	Cyperaceae	1	-0.0109	0.0039	-0.0287	-0.0169	-0.0113	-0.0248	-0.0217	-0.0127	0.0131	0.1908
*Secale cereale**	Gramineae	2	-0.0154	-0.0197	-0.0464	-0.0340	-0.0231	-0.0282	-0.0252	-0.0179	-0.0139	-0.0121
Sedum debile	Crassulaceae	2	-0.0154	-0.0290	-0.0064	-0.0009	0.1569	-0.0060	-0.0005	0.0304	0.0922	-0.0025
Sedum lanceolatum	Crassulaceae	3	-0.0189	-0.0245	-0.0156	0.1417	0.1751	-0.0182	-0.0178	-0.0095	0.0031	-0.0149
Selaginella underwoodii	Selaginellaceae	17	-0.0462	-0.0703	-0.0063	0.0248	0.2741	0.0094	-0.0260	0.0099	0.1728	-0.0180
Selaginella utahensis	Selaginellaceae	2	-0.0154	-0.0255	-0.0142	0.0623	0.1932	-0.0269	-0.0242	-0.0129	0.0264	-0.0121
Selaginella watsonii	Selaginellaceae	1	-0.0109	-0.0015	0.0336	0.0405	0.0036	0.0076	0.0042	-0.0032	-0.0043	-0.0085
Senecio eremophilus	Compositae	3	-0.0189	-0.0314	-0.0552	-0.0312	-0.0284	-0.0125	0.0038	0.3109	0.0063	0.0600
Senecio hydrophilus	Compositae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Senecio multilobatus	Compositae	99	-0.0802	-0.1087	0.1615	0.1919	0.1136	0.0662	0.0478	-0.0288	-0.0054	-0.0606
Senecio spartioides	Compositae	26	-0.0242	-0.0684	-0.0308	0.0456	0.0257	-0.0538	-0.0629	0.0085	0.1054	0.0200
Shepherdia rotundifolia	Elaeagnaceae	17	-0.0160	0.1196	0.1785	-0.0524	-0.0565	-0.0523	-0.0547	-0.0453	-0.0397	-0.0271
Silene antirrhina	Caryophyllaceae	3	-0.0189	0.0432	0.0061	0.0642	0.0129	-0.0307	-0.0278	-0.0178	-0.0131	0.0034
Silene verecunda	Caryophyllaceae	5	-0.0245	-0.0317	0.0558	0.0450	0.0094	0.0048	-0.0040	-0.0124	-0.0171	-0.0192

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
*Sisymbrium altissimum**	Cruciferae	4	0.0640	0.0076	-0.0258	-0.0328	-0.0249	-0.0350	-0.0222	0.0272	-0.0197	0.0090
*Sisymbrium irio**	Cruciferae	2	0.0271	0.0024	-0.0425	-0.0290	-0.0196	-0.0352	-0.0308	0.0097	0.0194	0.2472
Smilacina racemosa	Liliaceae	6	-0.0139	-0.0488	-0.0248	-0.0427	0.0917	0.0248	-0.0148	0.0463	0.2531	0.0089
Smilacina stellata	Liliaceae	3	-0.0189	-0.0355	-0.0640	-0.0334	-0.0215	0.0102	-0.0142	0.0284	0.0379	-0.0060
*Solanum sarrachoides**	Solanaceae	1	-0.0109	-0.0162	-0.0368	-0.0123	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Solanum sp.	Solanaceae	1	-0.0109	-0.0162	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Solidago velutina	Compositae	38	0.0085	-0.1190	-0.0889	0.0046	0.1890	0.0614	0.1036	0.0889	0.1476	-0.0134
Sonchus sp.*	Compositae	3	-0.0006	-0.0280	-0.0428	-0.0338	0.0013	-0.0207	-0.0332	0.0413	0.0915	0.3652
Sphaeralcea ambigua	Malvaceae	2	-0.0154	-0.0100	-0.0176	-0.0142	-0.0231	0.0068	0.0530	-0.0036	-0.0139	-0.0121
Sphaeralcea grossulariifolia	Malvaceae	14	0.2053	0.0710	-0.0075	-0.0691	-0.0565	-0.0771	-0.0643	-0.0423	-0.0347	-0.0224
Sphaeralcea parvifolia	Malvaceae	1	-0.0109	-0.0043	-0.0264	-0.0115	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Sphaeromeria ruthiae	Compositae	3	-0.0189	-0.0331	-0.0550	-0.0417	0.0001	-0.0374	-0.0332	0.0187	0.1957	0.0469
Sporobolus contractus	Gramineae	2	0.0188	-0.0230	-0.0522	-0.0340	-0.0231	-0.0282	-0.0252	-0.0179	-0.0068	0.0665
Sporobolus cryptandrus	Gramineae	50	0.0570	0.0424	0.0237	0.1236	-0.0302	-0.1019	-0.0813	-0.0708	-0.0588	-0.0061
Stanleya pinnata	Cruciferae	2	0.0823	0.0677	-0.0303	-0.0340	-0.0142	-0.0352	-0.0308	-0.0179	-0.0139	-0.0121
Stellaria jamesiana	Caryophyllaceae	18	0.0048	-0.0822	-0.1064	-0.0712	-0.0308	0.0271	0.0497	0.3314	0.0534	0.0380
Stephanomeria exigua	Compositae	1	-0.0109	-0.0043	-0.0264	-0.0115	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Stephanomeria runcinata	Compositae	2	0.0315	0.0213	-0.0105	-0.0144	-0.0153	-0.0212	-0.0196	-0.0179	-0.0100	-0.0121
Stephanomeria tenuifolia	Compositae	51	-0.0564	-0.0310	0.0846	0.1172	0.2097	-0.0459	-0.0537	-0.0463	0.0698	-0.0371
Stipa comata	Gramineae	39	0.0881	0.1120	0.0299	0.0637	-0.0626	-0.0597	-0.0169	-0.0122	-0.0602	-0.0490
Stipa hymenoides	Gramineae	65	-0.0221	0.0813	0.0886	0.0327	-0.0549	-0.0027	-0.0408	-0.0788	-0.0721	-0.0355
Stipa lettermanii	Gramineae	12	-0.0077	-0.0631	-0.0723	-0.0170	-0.0363	0.0173	0.0911	0.2524	-0.0184	0.0318
Stipa nelsonii	Gramineae	5	0.0436	-0.0389	-0.0550	-0.0215	-0.0285	-0.0135	0.0612	0.2604	-0.0069	0.0320
Stipa neomexicana	Gramineae	1	0.0249	0.0040	-0.0135	-0.0240	-0.0100	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Stipa pinetorum	Gramineae	2	0.0411	-0.0227	-0.0200	0.0077	-0.0155	0.0865	0.0987	0.0254	-0.0139	-0.0121
Stipa speciosa	Gramineae	15	-0.0254	0.1855	0.0749	-0.0627	-0.0373	-0.0881	-0.0779	-0.0467	-0.0332	-0.0292
Streptanthella longirostris	Cruciferae	11	-0.0200	0.1109	0.1070	0.0203	0.0009	-0.0483	-0.0412	-0.0386	-0.0243	-0.0234
Streptanthus cordatus	Cruciferae	38	-0.0361	0.0388	0.1502	-0.0189	-0.0797	0.0734	0.0374	-0.0617	-0.0623	-0.0533

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Streptopus amplexifolius	Liliaceae	1	-0.0109	0.0045	0.0285	-0.0112	-0.0104	-0.0023	-0.0037	-0.0127	-0.0098	-0.0085
Swertia albomarginata	Gentianaceae	11	-0.0219	0.1751	0.0796	-0.0462	-0.0533	-0.0511	-0.0527	-0.0428	-0.0330	-0.0289
Swertia radiata	Gentianaceae	11	-0.0245	-0.0538	-0.0337	-0.0212	-0.0251	0.1911	0.1982	0.0332	-0.0213	-0.0289
Swertia utahensis	Gentianaceae	2	-0.0154	0.0028	-0.0200	-0.0045	-0.0140	-0.0212	-0.0196	-0.0179	-0.0139	-0.0121
Symphoricarpos oreophilus	Caprifoliaceae	58	-0.0154	-0.1199	-0.0154	-0.0492	-0.0478	0.1381	0.1700	0.2005	-0.0018	-0.0198
Talinum parviflorum	Portulacaceae	1	-0.0109	-0.0111	-0.0142	0.1325	0.0441	-0.0033	-0.0045	-0.0055	-0.0098	-0.0085
*Tamarix chinensis**	Tamaricaceae	5	-0.0245	-0.0253	-0.0696	-0.0476	-0.0322	-0.0559	-0.0489	0.0066	0.0266	0.4269
*Taraxacum officinale**	Compositae	11	0.0097	-0.0636	-0.0846	-0.0492	0.0331	-0.0170	-0.0108	0.2013	0.2364	0.1004
Tetradymia canescens	Compositae	9	-0.0062	-0.0212	0.0466	0.0890	-0.0134	-0.0331	0.0013	-0.0027	-0.0185	-0.0260
Thalictrum fendleri	Ranunculaceae	12	-0.0057	-0.0697	-0.0848	-0.0473	0.0290	0.0072	-0.0048	0.1990	0.2305	0.0461
Thelypodium laxiflorum	Cruciferae	7	-0.0291	-0.0363	0.0363	-0.0046	0.0139	-0.0327	-0.0249	0.0083	0.1166	0.0474
Thermopsis montana	Leguminosae	4	-0.0219	-0.0411	-0.0546	-0.0139	-0.0028	0.0401	0.0435	0.0581	0.0169	0.0308
Thysanocarpus curvipes	Cruciferae	10	-0.0252	0.0346	0.0630	0.0645	0.0103	-0.0466	-0.0401	-0.0296	-0.0253	-0.0116
Townsendia incana	Compositae	1	-0.0109	0.0220	-0.0290	-0.0240	-0.0163	-0.0248	-0.0098	-0.0127	-0.0098	0.0144
Townsendia montana	Compositae	1	-0.0109	-0.0106	0.0414	0.1042	-0.0083	-0.0248	-0.0119	0.0007	-0.0098	-0.0085
Toxicodendron rydbergii	Anacardiaceae	2	-0.0154	-0.0260	-0.0414	-0.0340	-0.0108	-0.0053	-0.0030	0.0161	0.1317	0.0538
Tradescantia occidentalis	Commelinaceae	22	-0.0477	0.0149	0.0578	0.2178	-0.0173	-0.0627	-0.0540	-0.0375	-0.0429	-0.0383
*Tragopogon dubius**	Compositae	8	0.2444	-0.0352	-0.0837	-0.0421	-0.0323	-0.0355	0.0085	0.0961	-0.0101	0.0077
*Tribulus terrestris**	Zygophyllaceae	2	0.1011	-0.0230	-0.0522	-0.0290	-0.0196	-0.0352	-0.0308	-0.0179	-0.0068	0.0310
Trifolium longipes	Leguminosae	10	-0.0014	-0.0608	-0.0552	0.0103	0.2031	-0.0044	0.0434	0.0456	0.0265	0.0045
Trifolium sp.	Leguminosae	2	-0.0154	-0.0161	-0.0072	-0.0228	-0.0196	-0.0282	-0.0167	0.0097	0.0194	0.2472
Typha latifolia	Typhaceae	1	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	0.0122	0.0117	0.1572
Valeriana occidentalis	Valerianaceae	1	-0.0109	-0.0204	-0.0217	-0.0092	0.1027	0.0191	0.0034	-0.0127	0.0353	-0.0085
*Verbascum thapsus**	Scrophulariaceae	5	-0.0103	-0.0370	-0.0698	-0.0372	-0.0105	-0.0340	-0.0374	0.1451	0.1323	0.3743
Vicia americana	Leguminosae	43	-0.0117	-0.0951	-0.0621	-0.0652	-0.0499	0.0806	0.1074	0.2497	0.0347	0.0130
Vicia ludoviciana	Leguminosae	1	0.0196	0.0550	-0.0107	-0.0177	-0.0163	-0.0248	-0.0217	-0.0127	-0.0098	-0.0085
Viguiera multiflora	Compositae	12	0.0440	-0.0363	-0.0190	-0.0051	-0.0318	0.0174	0.0916	0.0675	-0.0243	-0.0212

APPENDIX 3. Continued.

Scientific Name	Family	# Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Viola canadensis	Violaceae	5	-0.0245	-0.0441	-0.0655	-0.0388	0.0225	-0.0120	-0.0347	0.0734	0.3300	0.0892
Viola nuttallii	Violaceae	1	-0.0109	-0.0133	-0.0368	-0.0149	-0.0163	-0.0150	-0.0040	0.0934	0.0023	0.0255
Viola purpurea	Violaceae	10	0.0039	-0.0474	-0.0220	-0.0334	-0.0446	0.2702	0.1282	-0.0322	-0.0314	-0.0275
Vitis arizonica	Vitaceae	1	-0.0109	-0.0162	-0.0290	-0.0240	-0.0163	-0.0150	-0.0138	0.0136	0.1491	0.0709
Woodsia oregana	Polypodiaceae	1	-0.0109	-0.0162	0.0052	0.0023	0.0567	0.0140	-0.0138	-0.0004	0.0878	-0.0085
Wyethia arizonica	Compositae	5	-0.0245	-0.0350	-0.0428	0.0301	0.1696	-0.0313	-0.0292	-0.0253	-0.0192	-0.0192
Xanthium strumarium	Compositae	1	-0.0109	-0.0117	-0.0232	-0.0169	-0.0113	-0.0248	-0.0217	0.0263	0.0371	0.3576
Yucca angustissima	Agavaceae	41	-0.0660	-0.0505	0.1162	0.1379	0.0550	-0.0337	-0.0226	-0.0629	-0.0344	-0.0521
Yucca baccata	Agavaceae	17	-0.0066	0.1913	0.0981	-0.0227	-0.0344	-0.0682	-0.0588	-0.0489	-0.0392	-0.0318
Zauschneria latifolia	Onagraceae	15	-0.0160	-0.0558	-0.0283	0.0005	0.2515	-0.0038	-0.0293	0.0217	0.1956	-0.0039
Zigadenus paniculatus	Liliaceae	12	0.1141	-0.0079	-0.0120	-0.0498	-0.0432	0.0843	0.1945	-0.0016	-0.0320	-0.0302

*Exotic species (Welsh et al. 2003, Fertig and Alexander 2009)

APPENDIX 4. Modal species of vegetation types described by Harper et al. (2001) for Zion National Park, Utah (rows), and their affinities to coalition groups (columns; see also Appendix 3). Modal species are prevalent species assigned to the vegetation type where their percent occurrence is highest (Curtis 1959). Affinities are mean pairwise association values (in units of the phi coefficient) between a species and members of a coalition group. Species are listed in descending order of percent occurrence within vegetation types. Green shading by cell value is scaled separately for each column. Nomenclature follows Welsh et al. (2003).

Vegetation Type	Modal Species	% Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Abandoned Fields	*Bromus tectorum*	100	0.1156	0.2135	0.0710	-0.0590	-0.1214	-0.1832	-0.1512	-0.1083	-0.0873	0.0262
Abandoned Fields	*Chamaesyce albomarginata*	67	0.2085	0.0081	-0.0514	-0.0601	-0.0683	0.0486	0.0045	-0.0518	-0.0427	-0.0065
Abandoned Fields	*Sporobolus cryptandrus*	67	0.0570	0.0424	0.0237	0.1236	-0.0302	-0.1019	-0.0813	-0.0708	-0.0588	-0.0061
Abandoned Fields	*Tragopogon dubius*	67	0.2444	-0.0352	-0.0837	-0.0421	-0.0323	-0.0355	0.0085	0.0961	-0.0101	0.0077
Abandoned Fields	*Erodium cicutarium*	50	0.2865	0.1277	-0.0910	-0.0748	-0.0488	-0.0766	-0.0609	-0.0407	-0.0282	-0.0211
Abandoned Fields	*Lactuca serriola*	50	0.2237	-0.0045	-0.0836	-0.0662	-0.0233	-0.0521	-0.0387	0.0166	0.0243	0.0185
Abandoned Fields	*Astragalus nuttallianus*	40	0.0317	0.2167	-0.0609	-0.0709	-0.0475	-0.0755	-0.0594	-0.0385	-0.0297	-0.0260
Abandoned Fields	*Aristida purpurea*	33	0.0216	0.1291	0.0011	-0.0051	-0.0026	-0.0986	-0.0888	-0.0646	-0.0393	0.0031
Abandoned Fields	*Artemisia dracunculus*	33	0.0695	-0.0227	-0.0022	-0.0069	-0.0291	-0.0208	-0.0178	-0.0225	-0.0260	-0.0138
Abandoned Fields	*Atriplex canescens*	33	0.2722	0.0716	-0.0649	-0.0708	-0.0447	-0.0797	-0.0634	-0.0407	-0.0314	-0.0275
Abandoned Fields	*Lycium pallidum*	33	0.3355	0.0067	-0.0506	-0.0376	-0.0255	-0.0431	-0.0263	-0.0220	-0.0170	-0.0149
Abandoned Fields	*Sphaeralcea grossulariifolia*	33	0.2053	0.0710	-0.0075	-0.0691	-0.0565	-0.0771	-0.0643	-0.0423	-0.0347	-0.0224
Blackbrush	*Coleogyne ramosissima*	100	0.0145	0.2448	-0.0393	-0.0830	-0.0601	-0.0914	-0.0800	-0.0466	-0.0360	-0.0315
Blackbrush	*Gilia inconspicua*	90	-0.0137	0.2558	0.1513	0.0515	-0.1029	-0.1116	-0.0963	-0.1140	-0.0969	-0.0584
Blackbrush	*Bromus rubens*	80	0.0339	0.3680	0.0731	-0.0990	-0.0855	-0.1439	-0.1239	-0.0865	-0.0642	-0.0544
Blackbrush	*Gutierrezia microcephala**	80	0.0989	0.2817	0.0670	-0.0696	-0.0984	-0.1590	-0.1114	-0.1043	-0.0962	-0.0086
Blackbrush	*Festuca octoflora*	70	0.0169	0.2480	0.0657	0.0993	-0.0069	-0.1467	-0.1123	-0.0946	-0.0819	-0.0469
Blackbrush	*Hilaria* sp.	60	0.1280	0.2507	0.0402	-0.1195	-0.0871	-0.1262	-0.1138	-0.0683	-0.0675	-0.0510
Blackbrush	*Cryptantha* sp. (annual)	50	-0.0026	0.2085	0.1317	0.0211	-0.0596	-0.1192	-0.0796	-0.0746	-0.0776	-0.0639
Blackbrush	*Draba verna*	50	0.0217	0.2595	0.0867	-0.0141	-0.0704	-0.0816	-0.0745	-0.0737	-0.0615	-0.0189
Blackbrush	*Eriogonum palmerianum*	50	0.0092	0.2175	0.0316	-0.0719	-0.0476	-0.0797	-0.0779	-0.0503	-0.0369	-0.0339
Blackbrush	*Calochortus flexuosus*	40	0.0171	0.1303	-0.0365	-0.0562	-0.0395	-0.0626	-0.0550	-0.0302	-0.0261	-0.0160
Blackbrush	*Descurainia pinnata*	40	-0.0037	0.1716	0.0713	-0.0494	-0.0819	-0.0556	-0.0588	0.0116	-0.0520	-0.0214
Blackbrush	*Ephedra nevadensis*	40	0.0478	0.2637	0.0091	-0.0872	-0.0630	-0.0888	-0.0854	-0.0554	-0.0394	-0.0374
Blackbrush	*Stipa hymenoides*	40	-0.0221	0.0813	0.0886	0.0327	-0.0549	-0.0027	-0.0408	-0.0788	-0.0721	-0.0355
Blackbrush	*Oenothera pallida*	33	-0.0224	0.0081	0.0494	0.1056	-0.0116	-0.0433	-0.0436	-0.0284	-0.0092	0.1363

APPENDIX 4. Continued.

Vegetation Type	Modal Species	% Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Blackbrush	*Eriastrum eremicum*	30	-0.0062	0.2058	0.0095	-0.0395	-0.0417	-0.0626	-0.0550	-0.0339	-0.0261	-0.0229
Blackbrush	*Poa bigelovii*	30	0.0487	0.1065	-0.0240	-0.0542	-0.0388	-0.0675	-0.0593	-0.0329	-0.0280	-0.0181
Blackbrush	*Psorothamnus fremontii*	30	0.0240	0.2031	-0.0107	-0.0679	-0.0532	-0.0747	-0.0660	-0.0428	-0.0330	-0.0289
Sagebrush	*Artemisia tridentata*	100	0.0211	0.0237	0.0140	0.0087	-0.0941	-0.0650	-0.0307	-0.0021	-0.0710	-0.0200
Sagebrush	*Gutierrezia sarothrae*[1]	71	0.0989	0.2817	0.0670	-0.0696	-0.0984	-0.1590	-0.1114	-0.1043	-0.0962	-0.0086
Sagebrush	*Elymus elymoides*	57	0.0162	0.0923	0.0099	0.0133	0.0141	-0.0536	-0.0274	-0.0206	-0.0247	-0.0314
Sagebrush	*Chrysothamnus nauseosus*	43	-0.0081	0.0136	0.0303	0.1202	-0.0282	-0.0941	-0.0726	-0.0711	-0.0435	0.0411
Sagebrush	*Eriastrum sparsiflorum*	29	0.0561	0.1752	-0.0212	-0.0568	-0.0495	-0.0914	-0.0710	-0.0466	-0.0360	-0.0250
Sagebrush	*Erigeron divergens*	29	-0.0097	-0.0041	0.0203	-0.0308	-0.0587	-0.0115	0.0173	0.0552	-0.0393	-0.0170
Sagebrush	*Opuntia phaeacantha*	29	0.1030	0.0449	0.0187	0.0060	-0.0339	-0.0589	-0.0420	-0.0291	-0.0297	-0.0200
Sagebrush	*Pectocarya setosa*	29	0.0226	0.0666	-0.0321	-0.0339	-0.0255	-0.0431	-0.0263	-0.0220	-0.0170	-0.0149
Juniper-Pinyon	*Juniperus osteosperma*	82	0.0251	0.1706	0.1868	-0.0462	-0.1486	0.0226	0.0318	-0.1258	-0.1273	-0.1076
Juniper-Pinyon	*Amelanchier utahensis*	65	-0.0900	-0.0968	0.1661	0.0340	-0.0081	0.1990	0.1598	-0.0446	-0.0817	-0.1249
Juniper-Pinyon	*Arabis holboellii*	57	-0.0953	0.0295	0.2379	0.0173	0.0178	0.0472	0.0240	-0.0499	-0.0301	-0.0931
Juniper-Pinyon	*Pinus monophylla*	53	-0.0639	0.1617	0.1964	-0.0616	-0.1071	-0.1054	-0.0930	-0.0808	-0.0790	-0.0597
Juniper-Pinyon	*Pinus edulis*	34	-0.0363	-0.0799	0.0969	0.0150	-0.0519	0.2160	0.1513	-0.0540	-0.0481	-0.0640
Juniper-Pinyon	*Streptanthus cordatus*	31	-0.0361	0.0388	0.1502	-0.0189	-0.0797	0.0734	0.0374	-0.0617	-0.0623	-0.0533
Juniper-Pinyon	*Erigeron sionis*	29	-0.0219	-0.0387	-0.0358	0.0211	0.2217	0.0074	-0.0145	0.0187	0.1662	0.0426
Mountain Brush	*Eriogonum racemosum*	33	-0.0291	-0.0898	0.0990	0.1001	0.0704	-0.0038	0.0302	0.0394	0.0517	-0.0253
Mountain Brush	*Erysimum asperum*	32	-0.0775	-0.0340	0.2064	0.1601	-0.0076	0.0100	0.0369	-0.0315	-0.0287	-0.0527
Mountain Brush	*Machaeranthera canescens*	32	-0.0036	0.0284	0.0883	0.1432	-0.0142	-0.0414	-0.0210	-0.0066	-0.0534	-0.0318
Mountain Brush	*Phacelia heterophylla*	32	-0.0498	-0.0651	0.0028	0.0973	0.0148	-0.0231	-0.0256	0.1026	0.0676	0.1188
Rock Crevice	*Cercocarpus intricatus*	84	-0.0741	-0.0732	-0.0008	0.0948	0.3022	-0.0254	-0.0425	-0.0540	0.0241	-0.0535
Rock Crevice	*Arenaria fendleri*	64	-0.0544	-0.0513	-0.0408	0.1880	0.2407	-0.0605	-0.0522	-0.0512	-0.0203	-0.0427
Rock Crevice	*Chrysopsis villosa*	64	-0.0433	-0.0529	0.0206	0.1933	0.1966	-0.0952	-0.0770	-0.0592	0.0364	0.0487
Rock Crevice	*Castilleja scabrida*	60	-0.0392	-0.0544	-0.0185	0.0831	0.2903	-0.0401	-0.0609	-0.0449	0.0430	-0.0458
Rock Crevice	*Opuntia macrorhiza*	56	-0.0871	0.0051	0.1969	0.2100	0.0551	0.0113	0.0278	-0.0893	-0.0880	-0.1079
Rock Crevice	*Stephanomeria tenuifolia*	48	-0.0564	-0.0310	0.0846	0.1172	0.2097	-0.0459	-0.0537	-0.0463	0.0698	-0.0371

APPENDIX 4. Continued.

Vegetation Type	Modal Species	% Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Rock Crevice	*Penstemon laevis*	40	-0.0532	-0.0162	0.0773	0.2316	0.0846	-0.0416	-0.0335	-0.0542	-0.0342	-0.0456
Rock Crevice	*Chaenactis douglasii*	36	-0.0625	-0.0719	0.1114	0.2527	0.1140	-0.0008	0.0032	-0.0622	-0.0409	-0.0586
Rock Crevice	*Cryptantha confertiflora*	36	-0.0351	0.0704	0.1252	0.0887	0.0972	-0.0691	-0.0637	-0.0683	-0.0403	-0.0469
Rock Crevice	*Penstemon humilis*	36	-0.0593	-0.0565	0.0790	0.1052	0.2021	-0.0007	-0.0125	-0.0374	0.0411	-0.0438
Rock Crevice	*Quercus turbinella*	32	-0.0617	0.1136	0.2131	0.0456	-0.0280	-0.0980	-0.0825	-0.0805	-0.0597	-0.0524
Rock Crevice	*Erigeron canaani*	28	-0.0448	-0.0719	-0.0209	0.1198	0.2338	0.0168	-0.0131	-0.0192	0.0259	-0.0316
Rock Crevice	*Penstemon rostriflorus*	28	-0.0179	-0.0415	0.0496	-0.0137	0.1297	0.0101	-0.0091	0.0460	0.1111	-0.0184
Ponderosa Pine	*Pinus ponderosa*	97	-0.0574	-0.1236	-0.0675	0.1735	0.1993	0.0611	0.0717	-0.0050	0.0285	-0.0322
Ponderosa Pine	*Poa fendleriana*	85	-0.1391	-0.0620	0.2132	0.1283	0.1186	0.0577	0.0891	-0.0417	-0.0072	-0.0837
Ponderosa Pine	*Arctostaphylos patula*	61	-0.1013	-0.0593	0.1132	0.2147	0.0767	0.0893	0.0301	-0.0959	-0.0837	-0.0949
Ponderosa Pine	*Senecio multilobatus*	52	-0.0802	-0.1087	0.1615	0.1919	0.1136	0.0662	0.0478	-0.0288	-0.0054	-0.0606
Ponderosa Pine	*Phlox austromontana*	39	-0.0767	-0.0520	0.1251	0.1886	0.0721	0.0491	0.0433	-0.0512	-0.0503	-0.0675
Ponderosa Pine	*Polygonum douglasii*	33	-0.0015	-0.0693	-0.0321	0.1548	0.0311	0.0050	0.0855	0.1711	-0.0403	-0.0010
Ponderosa Pine	*Purshia tridentata*	30	-0.0398	-0.0642	0.0241	0.0959	-0.0355	0.1318	0.1832	-0.0297	-0.0563	-0.0475
Ponderosa Pine	*Arenaria macradenia*	24	-0.0804	-0.0607	0.1271	0.0990	0.1502	-0.0052	-0.0069	-0.0401	-0.0037	-0.0588
Ponderosa Pine	*Comandra umbellata*	24	-0.0686	-0.0696	0.0777	0.1314	0.0282	0.0257	0.0821	-0.0146	-0.0470	-0.0505
Ponderosa Pine	*Yucca angustissima*	24	-0.0660	-0.0505	0.1162	0.1379	0.0550	-0.0337	-0.0226	-0.0629	-0.0344	-0.0521
Douglas Fir-White Fir	*Quercus gambelii*	86	-0.0835	-0.2123	-0.0259	0.0354	0.0422	0.1792	0.1804	0.1418	0.0666	-0.0480
Douglas Fir-White Fir	*Pachystima myrsinites*	71	-0.0573	-0.1407	-0.0118	0.0118	0.0706	0.2096	0.1310	0.0248	0.1121	-0.0386
Douglas Fir-White Fir	*Carex rossii*	57	-0.0335	-0.1431	-0.0482	0.0505	0.1222	0.2114	0.1553	0.1027	0.0042	-0.0554
Douglas Fir-White Fir	*Abies concolor*	52	-0.0226	-0.0893	-0.0770	-0.0559	0.0865	0.0603	0.0229	0.1859	0.2236	0.0410
Douglas Fir-White Fir	*Symphoricarpos oreophilus*	52	-0.0154	-0.1199	-0.0154	-0.0492	-0.0478	0.1381	0.1700	0.2005	-0.0018	-0.0198
Douglas Fir-White Fir	*Pseudotsuga menziesii*	48	-0.0476	-0.0849	-0.0415	-0.0183	0.1328	0.0553	0.0042	0.0309	0.2559	0.0212
Douglas Fir-White Fir	*Vicia americana*	48	-0.0117	-0.0951	-0.0621	-0.0652	-0.0499	0.0806	0.1074	0.2497	0.0347	0.0130
Douglas Fir-White Fir	*Acer grandidentatum*	43	-0.0556	-0.0988	-0.0451	-0.0489	0.0587	0.0312	0.0003	0.1139	0.2614	0.0429
Douglas Fir-White Fir	*Draba asprella*	38	-0.0516	-0.0823	0.0124	0.0971	0.2068	0.0802	0.0067	-0.0115	0.1409	-0.0142
Douglas Fir-White Fir	*Haplopappus scopulorum*	38	-0.0620	-0.0438	0.1804	0.0711	0.0046	0.0255	0.0324	-0.0509	-0.0055	-0.0515
Douglas Fir-White Fir	*Mahonia repens*	38	-0.0231	-0.0947	-0.0511	-0.0508	-0.0046	0.1614	0.0969	0.0752	0.1310	0.0000

APPENDIX 4. Continued.

Vegetation Type	Modal Species	% Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Douglas Fir-White Fir	*Holodiscus dumosus*	33	-0.0356	-0.0921	-0.0438	0.0077	0.3078	-0.0046	-0.0308	-0.0027	0.1947	-0.0222
Douglas Fir-White Fir	*Fraxinus anomala*	29	-0.0588	0.0431	0.2408	-0.0204	0.0183	0.0824	0.0020	-0.0571	-0.0092	-0.0520
Douglas Fir-White Fir	*Heuchera rubescens*	29	-0.0292	-0.0709	-0.0461	-0.0292	0.1744	0.0382	-0.0019	0.0476	0.2533	-0.0007
Douglas Fir-White Fir	*Stellaria jamesiana*	29	0.0048	-0.0822	-0.1064	-0.0712	-0.0308	0.0271	0.0497	0.3314	0.0534	0.0380
Douglas Fir-White Fir	*Juniperus scopulorum*	24	-0.0178	-0.0775	-0.0461	-0.0170	-0.0283	0.0539	0.0409	0.1754	0.0134	0.0109
Hanging Gardens	*Adiantum capillus-veneris*	89	-0.0154	-0.0290	-0.0466	-0.0340	-0.0028	-0.0352	-0.0308	0.0132	0.1540	-0.0025
Hanging Gardens	*Calamagrostis scopulorum*	79	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	0.0179	-0.0085
Hanging Gardens	*Aster welshii*	72	-0.0269	-0.0449	-0.0609	-0.0507	-0.0144	-0.0372	-0.0375	0.0224	0.1633	0.1134
Hanging Gardens	*Lobelia cardinalis*[2]	56	--	--	--	--	--	--	--	--	--	--
Hanging Gardens	*Aquilegia chrysantha*	50	-0.0109	-0.0204	-0.0368	-0.0240	-0.0163	-0.0248	-0.0217	-0.0127	0.0179	-0.0085
Hanging Gardens	*Aquilegia formosa*	50	-0.0189	-0.0355	-0.0509	-0.0269	0.0919	-0.0250	-0.0232	-0.0163	0.0585	-0.0070
Hanging Gardens	*Dodecatheon pulchellum*	44	-0.0154	-0.0290	-0.0469	-0.0340	-0.0108	-0.0123	-0.0086	-0.0025	0.0387	-0.0025
Hanging Gardens	*Apocynum androsaemifolium*	40	-0.0154	-0.0290	-0.0414	-0.0189	0.0270	0.0152	-0.0030	0.0476	0.2110	0.0817
Hanging Gardens	*Aster glaucodes*	40	-0.0269	-0.0144	0.0115	-0.0389	-0.0091	-0.0054	-0.0173	0.0135	0.1160	0.1156
Hanging Gardens	*Eupatorium herbaceum*	40	-0.0081	-0.0709	-0.0670	-0.0391	0.1492	0.0054	-0.0365	0.0630	0.3612	0.0462
Hanging Gardens	*Solidago velutina*	40	0.0085	-0.1190	-0.0889	0.0046	0.1890	0.0614	0.1036	0.0889	0.1476	-0.0134
Hanging Gardens	*Erigeron utahensis*	39	-0.0341	0.1342	0.2246	0.0464	-0.0274	-0.0700	-0.0681	-0.0713	-0.0588	-0.0560
Hanging Gardens	*Petrophytum caespitosum*	39	-0.0385	-0.0612	-0.0582	0.0268	0.3143	0.0020	-0.0243	-0.0130	0.1274	0.0088
Hanging Gardens	*Muhlenbergia thurberi*	33	-0.0174	-0.0610	-0.0526	0.0809	0.2838	-0.0207	-0.0274	-0.0274	0.0811	-0.0182
Hanging Gardens	*Smilacina stellata*	33	-0.0189	-0.0355	-0.0640	-0.0334	-0.0215	0.0102	-0.0142	0.0284	0.0379	-0.0060
Hanging Gardens	*Agrostis stolonifera*	28	-0.0109	-0.0183	-0.0329	-0.0240	-0.0163	-0.0248	-0.0217	0.0068	0.0093	0.2268
Hanging Gardens	*Carex curatorum*[2]	28	--	--	--	--	--	--	--	--	--	--
Hanging Gardens	*Cirsium arizonicum*	26	0.0236	-0.0538	0.0075	0.0434	0.1052	0.0028	-0.0078	0.0262	0.0954	0.0911
Hanging Gardens	*Antennaria rosulata*	20	-0.0189	-0.0276	-0.0021	-0.0057	0.0238	0.0195	0.0148	0.0635	0.1447	0.0540
Riparian	*Mimulus cardinalis*	72	-0.0154	-0.0260	-0.0466	-0.0340	-0.0231	-0.0282	-0.0252	0.0007	0.1183	0.0442
Riparian	*Acer negundo*	63	-0.0226	-0.0711	-0.0929	-0.0678	0.0736	-0.0447	-0.0579	0.0499	0.3163	0.2513
Riparian	*Artemisia ludoviciana*	42	-0.0089	0.0007	0.1161	0.0261	0.0346	-0.0376	-0.0201	0.0195	0.0962	0.1026
Riparian	*Bromus diandrus*	42	0.0312	-0.0336	-0.0857	-0.0613	-0.0407	-0.0734	-0.0647	-0.0126	0.0071	0.3353

APPENDIX 4. Continued.

Vegetation Type	Modal Species	% Occ.	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
Riparian	*Bromus ciliatus*	37	0.0293	-0.0670	-0.0665	-0.0486	0.0757	-0.0176	-0.0460	0.0473	0.2602	0.0995
Riparian	*Senecio spartioides*	37	-0.0242	-0.0684	-0.0308	0.0456	0.0257	-0.0538	-0.0629	0.0085	0.1054	0.0200
Riparian	*Fraxinus velutina*	32	-0.0169	-0.0349	-0.0638	-0.0478	-0.0313	-0.0546	-0.0496	-0.0130	0.0263	0.1862
Riparian	*Populus fremontii*	32	-0.0139	-0.0177	-0.0756	-0.0534	-0.0362	-0.0613	-0.0487	0.0008	0.0149	0.3936
Riparian	*Equisetum hyemale*	26	0.0242	-0.0422	-0.0812	-0.0464	-0.0190	-0.0501	-0.0537	0.0372	0.1603	0.3744
Riparian	*Zauschneria latifolia*	26	-0.0160	-0.0558	-0.0283	0.0005	0.2515	-0.0038	-0.0293	0.0217	0.1956	-0.0039
Riparian	*Cystopteris fragilis*	21	0.0155	-0.0505	-0.0547	-0.0311	0.0833	-0.0160	-0.0366	0.0764	0.3184	0.0691
Riparian	*Poa pratensis*	21	-0.0045	-0.0598	-0.0991	-0.0276	-0.0409	-0.0455	-0.0258	0.2466	0.0391	0.2027
Riparian	*Tamarix chinensis*	21	-0.0245	-0.0253	-0.0696	-0.0476	-0.0322	-0.0559	-0.0489	0.0066	0.0266	0.4269
Riparian	*Thelypodium laxiflorum*	21	-0.0291	-0.0363	0.0363	-0.0046	0.0139	-0.0327	-0.0249	0.0083	0.1166	0.0474

[1]The species of *Gutierrezia* listed in Harper et al. (2001) were lumped in the coalition group analysis due to identification uncertainties.
[2]*Carex curatorum* and *Lobelia cardinalis* were present in supplemental hanging garden data used by Harper et al. (2001) but not used in coalition group analysis.

APPENDIX 5. Associations of the U.S. National Vegetation Classification System at Zion National Park, Utah, as recognized by Cogan et al. (2004), placed within an alternative classification hierarchy based on affinities to coalition groups (see Fig. 7 in paper). Affinity values (right 10 columns) are in units of the phi coefficient. The values are calculated for each species in relation to each coalition group (see Appendix 3) and then averaged across plots and associations. Green shading by cell value is scaled separately for each column.

XXx. Alternative Classification Hierarchy NVC Association	**Lowland Flats**	**Arid Lowlands**	**Rocky Slopes**	**Upland Sands**	**Slickrock**	**Lower Mesa Top**	**Upper Mesa Top**	**High Plateau**	**Crevice Canyon**	**Stream-bank**
A. XERIC ZION VEGETATION										
A1. Mesa Top / Upland Sands / Slickrock / Rocky Slopes										
A1a. Mesa Top - Forest / Woodland / Shrubland										
Ponderosa Pine / Gambel Oak Woodland	-0.0295	-0.0601	0.0136	0.0478	0.0331	0.0531	0.0639	0.0427	0.0121	-0.0214
White Fir / Greenleaf Manzanita Forest	-0.0442	-0.0862	0.0015	0.0176	0.0408	0.1158	0.0961	0.0639	0.0486	-0.0254
Mexican Manzanita Shrubland	-0.0425	-0.0717	0.0225	0.0303	0.0317	0.0921	0.0651	0.0242	0.0246	0.0039
Ponderosa Pine / Black Sagebrush Woodland	-0.0296	-0.0548	0.0250	0.0294	0.0106	0.0564	0.0747	0.0357	-0.0105	-0.0261
Two-needle Pinyon / Curl-leaf Mountain-mahogany Woodland	-0.0329	-0.0587	0.0439	0.0305	-0.0002	0.0817	0.0847	0.0195	-0.0217	-0.0407
Basin Big Sagebrush / Western Wheatgrass - (Streamside Wild Rye) Shrubland	0.0223	-0.0711	-0.0104	-0.0127	-0.0312	0.0902	0.0811	0.0420	-0.0170	-0.0268
A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse										
Mountain-mahogany Rock Pavement Sparse Vegetation	-0.0364	-0.0268	0.0768	0.0301	-0.0053	0.0845	0.0628	-0.0280	-0.0347	-0.0565
Two-needle Pinyon - Juniper species / Mountain-mahogany Woodland	-0.0374	-0.0230	0.0898	0.0229	-0.0176	0.1039	0.0808	-0.0317	-0.0461	-0.0622
Gambel Oak - Mountain-mahogany / (Geyer's Sedge) Shrubland	-0.0360	-0.0304	0.0604	0.0140	-0.0058	0.0699	0.0632	0.0114	-0.0143	-0.0427
Gambel Oak / Utah Serviceberry Shrubland	-0.0297	-0.0211	0.0641	0.0343	-0.0032	0.0363	0.0460	0.0101	-0.0178	-0.0286
Two-needle Pinyon - Juniper species / Gambel Oak Woodland	-0.0449	-0.0447	0.0714	0.0486	0.0052	0.0814	0.0761	-0.0107	-0.0215	-0.0477
Two-needle Pinyon - Utah Juniper / Greenleaf Manzanita Woodland	-0.0542	-0.0407	0.0953	0.0627	0.0079	0.0983	0.0780	-0.0313	-0.0351	-0.0663
Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland	-0.0488	-0.0501	0.0729	0.0715	0.0263	0.0718	0.0665	-0.0080	-0.0201	-0.0521
Ponderosa Pine / Greenleaf Manzanita Woodland	-0.0408	-0.0507	0.0357	0.0660	0.0309	0.0768	0.0651	-0.0049	-0.0160	-0.0431
Black Sagebrush / Muttongrass Dwarf-shrubland	-0.0180	-0.0101	0.0468	0.0361	0.0215	0.0340	0.0580	-0.0037	-0.0318	-0.0450
Singleleaf Pinyon - Utah Juniper / Mountain-mahogany - Gambel Oak Woodland	-0.0517	-0.0051	0.1151	0.0158	-0.0391	0.0742	0.0598	-0.0393	-0.0561	-0.0758
Two-needle Pinyon - Utah Juniper / Stansbury Cliff-rose Woodland	-0.0407	0.0065	0.0965	0.0272	-0.0123	0.0577	0.0410	-0.0386	-0.0391	-0.0528
Mountain Big Sagebrush / Needle-and-Thread Shrubland	0.0025	-0.0072	0.0392	0.0313	-0.0221	0.0264	0.0523	0.0116	-0.0272	-0.0307
A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse										
Blue Grama - Needle-and-Thread Herbaceous Vegetation	-0.0229	-0.0197	0.0485	0.0965	0.0109	-0.0001	0.0182	-0.0117	-0.0223	-0.0308
Greenleaf Manzanita - Mountain Big Sagebrush Shrubland	-0.0460	-0.0387	0.0579	0.1264	0.0219	0.0062	0.0230	-0.0183	-0.0314	-0.0416
Big Sagebrush / Blue Grama Shrubland	-0.0199	-0.0280	0.0227	0.0956	-0.0022	-0.0099	0.0041	0.0164	-0.0227	-0.0190
Gambel Oak / Muttongrass Shrubland	-0.0330	-0.0376	0.0558	0.0686	0.0304	0.0241	0.0486	0.0113	-0.0024	-0.0228
Greenleaf Manzanita Shrubland	-0.0444	-0.0437	0.0560	0.0912	0.0425	0.0383	0.0363	-0.0125	-0.0169	-0.0399
Gambel Oak / Big Sagebrush Shrubland	-0.0139	-0.0193	0.0503	0.0458	-0.0108	0.0085	0.0166	0.0083	-0.0183	-0.0196
Black Sagebrush / Needle-and-Thread Dwarf-shrubland	-0.0031	0.0230	0.0704	0.0474	-0.0041	-0.0101	0.0143	-0.0194	-0.0382	-0.0356

APPENDIX 5. Continued.

XXx. Alternative Classification Hierarchy NVC Association	**Lowland Flats**	**Arid Lowlands**	**Rocky Slopes**	**Upland Sands**	**Slickrock**	**Lower Mesa Top**	**Upper Mesa Top**	**High Plateau**	**Crevice Canyon**	**Stream-bank**
Two-needle Pinyon - Juniper species / Big Sagebrush Woodland	-0.0224	0.0012	0.0675	0.0806	-0.0180	0.0112	0.0186	-0.0387	-0.0479	-0.0470
Ponderosa Pine Slickrock Sparse Vegetation	-0.0389	-0.0118	0.0941	0.0791	0.0381	0.0123	0.0204	-0.0354	-0.0271	-0.0409
Stansbury Cliff-rose - Greenleaf Manzanita Shrubland	-0.0464	-0.0157	0.0903	0.0913	0.0418	0.0244	0.0246	-0.0432	-0.0422	-0.0622
Two-needle Pinyon - Utah Juniper / Littleleaf Mountain-mahogany Woodland	-0.0395	0.0053	0.1013	0.0582	0.0180	0.0221	0.0184	-0.0448	-0.0344	-0.0436
Littleleaf Mountain-mahogany Slickrock Sparse Vegetation	-0.0428	-0.0225	0.0572	0.0899	0.1010	-0.0043	-0.0008	-0.0417	-0.0082	-0.0362
(Sandhill Muhly, Mountain Muhly) - Hairy Goldenaster Herbaceous Vegetation	-0.0305	-0.0153	0.0481	0.1097	0.0557	-0.0134	-0.0024	-0.0167	-0.0156	-0.0148
A1 outlier										
Needle-and-Thread Great Basin Herbaceous Vegetation	0.0212	-0.0171	0.0041	0.0385	-0.0086	0.0052	0.0350	0.0378	-0.0027	-0.0083
A2. Lowlands / Rocky Slopes / Upland Sands										
A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse										
Sand Dropseed Great Basin Herbaceous Vegetation	0.0686	0.0819	0.0181	0.0175	-0.0301	-0.0995	-0.0820	-0.0563	-0.0374	0.0469
Arrow-weed Seasonally Flooded Shrubland	0.0752	0.0821	0.0137	-0.0194	-0.0465	-0.0718	-0.0485	-0.0096	-0.0181	0.0424
Nevada Joint-fir / Lichen Sparse Vegetation	0.1295	0.1541	-0.0038	-0.0627	-0.0608	-0.0967	-0.0827	-0.0556	-0.0430	-0.0127
Fourwing Saltbush - Big Sagebrush Shrubland	0.0954	0.1107	0.0064	-0.0267	-0.0576	-0.0758	-0.0631	-0.0460	-0.0461	-0.0115
Fourwing Saltbush Shrubland	0.0864	0.1379	0.0241	-0.0258	-0.0509	-0.0783	-0.0648	-0.0620	-0.0524	-0.0251
Nevada Joint-fir Basalt Shrubland	0.0961	0.1486	0.0207	-0.0204	-0.0509	-0.0852	-0.0684	-0.0517	-0.0405	-0.0139
James' Galleta Herbaceous Vegetation	0.0877	0.1470	0.0421	-0.0409	-0.0600	-0.1016	-0.0797	-0.0669	-0.0596	-0.0165
A2b. Arid Lowlands - Woodland / Shrubland / Sparse										
Blackbrush Shrubland	0.0591	0.1692	0.0466	-0.0290	-0.0600	-0.0745	-0.0595	-0.0695	-0.0605	-0.0327
Blackbrush / James' Galleta Shrubland	0.0477	0.2037	0.0586	-0.0488	-0.0706	-0.0861	-0.0701	-0.0675	-0.0653	-0.0432
Crispleaf Wild Buckwheat Badlands Sparse Vegetation	0.0203	0.1338	0.0527	-0.0180	-0.0422	-0.0599	-0.0491	-0.0555	-0.0478	-0.0289
Snakeweed - (Prickly-pear species) / James' Galleta Dwarf-shrubland	0.0557	0.1171	0.0503	-0.0068	-0.0471	-0.0661	-0.0451	-0.0542	-0.0540	-0.0204
Singleleaf Pinyon - Utah Juniper / Blackbrush Woodland	0.0036	0.1322	0.0856	-0.0079	-0.0693	-0.0479	-0.0263	-0.0647	-0.0696	-0.0471
Utah Juniper / Big Sagebrush Woodland	0.0212	0.1489	0.0947	0.0031	-0.0698	-0.0558	-0.0336	-0.0754	-0.0844	-0.0563
Singleleaf Pinyon - Utah Juniper / Big Sagebrush Woodland	0.0131	0.1264	0.0825	-0.0170	-0.0564	-0.0555	-0.0398	-0.0604	-0.0604	-0.0389
Sand Sagebrush Colorado Plateau Shrubland	0.0276	0.0861	0.0369	0.0103	-0.0316	-0.0690	-0.0525	-0.0511	-0.0421	-0.0004
Big Sagebrush - (Rubber Rabbitbrush) / Cheatgrass Semi-natural Shrubland	0.0364	0.0781	0.0419	0.0151	-0.0469	-0.0660	-0.0445	-0.0430	-0.0477	-0.0074
A2 outliers										
Coyote Willow / Barren Shrubland	0.0100	0.0450	0.0273	0.0545	-0.0368	-0.0746	-0.0713	-0.0464	-0.0204	0.0710
Green Rabbitbrush / Kentucky Bluegrass Semi-natural Shrub Herbaceous Vegetation	0.0508	0.0253	-0.0073	0.0057	-0.0382	-0.0465	-0.0258	0.0349	-0.0229	0.0275

APPENDIX 5. Continued.

XXx. Alternative Classification Hierarchy NVC Association	Lowland Flats	Arid Lowlands	Rocky Slopes	Upland Sands	Slickrock	Lower Mesa Top	Upper Mesa Top	High Plateau	Crevice Canyon	Stream-bank
A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse										
Rubber Rabbitbrush Sand Deposit Sparse Vegetation	0.0115	0.0194	0.0318	0.0634	0.0060	-0.0492	-0.0413	-0.0293	-0.0184	0.0072
Rubber Rabbitbrush / Cheatgrass Semi-natural Shrubland	0.0036	0.0489	0.0925	0.0697	-0.0269	-0.0668	-0.0495	-0.0707	-0.0537	-0.0201
Gray Horsebrush - Mormon-tea Shrubland	-0.0231	0.0029	0.0589	0.0993	0.0032	-0.0324	-0.0125	-0.0380	-0.0328	-0.0212
Black Sagebrush / Bottlebrush Dwarf-shrubland	0.0176	0.0195	0.0215	0.0238	0.0094	-0.0173	0.0052	-0.0082	-0.0248	-0.0219
A2d. Rocky Slopes - Woodland / Shrubland										
Singleleaf Pinyon - Utah Juniper / Turbinella Live Oak Woodland	-0.0164	0.0753	0.1121	0.0272	-0.0245	-0.0365	-0.0259	-0.0569	-0.0490	-0.0373
Singleleaf Pinyon - Utah Juniper / (Roundleaf Buffaloberry, Utah Serviceberry) Woodland	-0.0236	0.0722	0.1224	0.0204	-0.0195	-0.0223	-0.0156	-0.0549	-0.0480	-0.0474
Singleleaf Pinyon - Utah Juniper / Sparse Understory Woodland	-0.0152	0.0704	0.1077	0.0154	-0.0413	-0.0129	-0.0002	-0.0555	-0.0598	-0.0531
Singleleaf Pinyon - Utah Juniper / Black Sagebrush Woodland	-0.0010	0.0719	0.0775	-0.0188	-0.0448	-0.0180	0.0019	-0.0356	-0.0543	-0.0459
Turbinella Live Oak - (Utah Serviceberry) Colluvial Shrubland	-0.0223	0.0281	0.0948	0.0332	-0.0017	-0.0055	-0.0012	-0.0287	-0.0253	-0.0274
Single-leaf Ash Woodland	-0.0310	0.0288	0.0902	0.0149	-0.0133	-0.0076	-0.0074	-0.0109	-0.0067	-0.0141
B. MESIC ZION VEGETATION										
B1. High Plateau / Crevice Canyon										
B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous										
Bigtooth Maple / Gambel Oak Forest	-0.0266	-0.0669	-0.0086	0.0090	0.0228	0.0316	0.0282	0.0782	0.0703	0.0274
White Fir / Bigtooth Maple Forest	-0.0367	-0.0767	-0.0156	-0.0019	0.0521	0.0524	0.0347	0.0785	0.1288	0.0213
Beaked Sedge Herbaceous Vegetation	-0.0211	-0.0347	-0.0341	0.0063	0.0144	-0.0080	-0.0145	0.0198	0.0569	0.1332
Douglas-fir / Mountain Snowberry Forest	-0.0345	-0.0557	0.0114	0.0082	0.0298	0.0635	0.0536	0.0520	0.0551	0.0000
White Fir / Gambel Oak Forest	-0.0408	-0.0982	-0.0198	-0.0006	0.0440	0.0957	0.0788	0.1057	0.0897	-0.0068
Douglas-fir / Gambel Oak Forest	-0.0461	-0.0697	0.0161	0.0117	0.0477	0.0662	0.0436	0.0487	0.0855	-0.0095
Ponderosa Pine / Northern Bracken Woodland	-0.0297	-0.0532	-0.0254	0.0398	0.0498	0.0049	0.0077	0.0707	0.0378	0.0218
Ponderosa Pine / Smooth Brome Semi-natural Woodland	-0.0197	-0.0553	-0.0214	0.0371	0.0429	0.0145	0.0337	0.0901	0.0337	0.0368
Box-elder / Tasselflower Brickelbush Woodland	-0.0029	-0.0499	-0.0443	-0.0152	0.0506	-0.0146	-0.0206	0.0869	0.1435	0.0664
Douglas-fir / Bigtooth Maple Forest	-0.0368	-0.0773	-0.0487	-0.0182	0.0594	0.0435	0.0067	0.0481	0.1910	0.0634
Rocky Mountain Juniper - Gambel Oak Woodland	-0.0309	-0.0325	0.0252	0.0206	0.0073	0.0133	0.0170	0.0282	0.0380	0.0585
B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous										
Kentucky Bluegrass Semi-natural Seasonally Flooded Herbaceous Alliance	0.0581	-0.0225	-0.0411	-0.0045	-0.0025	-0.0113	0.0234	0.1086	0.0064	0.0341
Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	0.0931	-0.0306	-0.0070	-0.0175	-0.0124	0.0173	0.0624	0.0717	0.0021	0.0174
Quaking Aspen - White Fir / Kentucky Bluegrass Semi-natural Forest	0.0062	-0.0447	-0.0404	-0.0046	0.0024	0.0100	0.0221	0.1285	0.0457	0.0400
Quaking Aspen / Mountain Snowberry / Tall Forbs Forest	-0.0067	-0.0594	-0.0505	-0.0256	-0.0049	0.0256	0.0391	0.1860	0.0609	0.0457

APPENDIX 5. Continued.

XXx. Alternative Classification Hierarchy NVC Association	**Lowland Flats**	**Arid Lowlands**	**Rocky Slopes**	**Upland Sands**	**Slickrock**	**Lower Mesa Top**	**Upper Mesa Top**	**High Plateau**	**Crevice Canyon**	**Stream-bank**
Quaking Aspen / Gambel Oak / Mountain Snowberry Forest	0.0108	-0.0644	-0.0556	-0.0237	0.0001	0.0270	0.0497	0.1635	0.0604	0.0600
Intermediate Wheatgrass Semi-natural Herbaceous Vegetation	-0.0087	-0.0432	-0.0174	-0.0190	-0.0147	0.0089	0.0349	0.1599	0.0408	0.0487
Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland	0.0232	-0.0419	-0.0253	0.0102	-0.0092	0.0036	0.0253	0.1238	0.0096	0.0214
Gambel Oak / Mountain Snowberry Shrubland	-0.0133	-0.0650	-0.0049	0.0096	-0.0003	0.0521	0.0683	0.1088	0.0207	0.0038
White Fir / Mountain Snowberry Forest	-0.0206	-0.0714	-0.0223	-0.0081	0.0001	0.0594	0.0731	0.1542	0.0412	0.0061
Quaking Aspen - White Fir / Mountain Snowberry Forest	-0.0183	-0.0708	-0.0318	-0.0087	0.0165	0.0517	0.0589	0.1266	0.0659	0.0104
Utah Serviceberry Shrubland	-0.0105	-0.0158	0.0184	-0.0081	-0.0245	0.0201	0.0253	0.0651	0.0168	0.0181
B2. Streambank / High Plateau										
B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous										
Nebraska Sedge Herbaceous Vegetation	-0.0169	-0.0402	-0.0439	0.0096	0.0197	-0.0189	-0.0137	0.0671	0.0526	0.1606
Baltic Rush Herbaceous Vegetation	0.0144	-0.0256	-0.0491	-0.0162	-0.0073	-0.0267	-0.0133	0.0801	0.0315	0.1540
Fremont Cottonwood / Water Birch Wooded Shrubland	-0.0225	-0.0277	-0.0108	-0.0128	0.0009	-0.0014	0.0005	0.0448	0.0421	0.1064
Strapleaf Willow / Beaked Sedge Shrubland	-0.0110	-0.0392	-0.0578	-0.0118	-0.0030	-0.0084	-0.0126	0.1070	0.0733	0.1149
Box-elder / Disturbed Understory Woodland	0.0062	-0.0197	-0.0053	0.0110	-0.0027	-0.0242	-0.0165	0.0434	0.0480	0.0505
B2b. Streambank - Forest / Woodland / Shrub / Herb										
Emory Seepwillow Shrubland	-0.0004	-0.0124	-0.0214	-0.0201	-0.0025	-0.0408	-0.0396	0.0225	0.0431	0.2246
Coyote Willow / Mesic Graminoids Shrubland	-0.0075	-0.0222	-0.0435	-0.0036	-0.0087	-0.0315	-0.0250	0.0180	0.0475	0.2544
(Field Horsetail, Variegated Scouringrush) Herbaceous Vegetation	-0.0020	-0.0023	-0.0227	0.0133	-0.0139	-0.0569	-0.0468	0.0297	0.0219	0.2354
Fremont Cottonwood - Velvet Ash Woodland	-0.0040	-0.0014	-0.0135	-0.0234	-0.0161	-0.0414	-0.0400	-0.0128	0.0370	0.1710
Fremont Cottonwood / Emory Seepwillow Woodland	-0.0036	0.0135	0.0023	0.0057	-0.0152	-0.0474	-0.0355	-0.0098	0.0046	0.1466
Fremont Cottonwood / Coyote Willow Forest	0.0077	0.0214	-0.0014	-0.0056	-0.0186	-0.0471	-0.0381	-0.0114	0.0069	0.1520

APPENDIX 6. Vegetation units of the U.S. National Vegetation Classification at Zion National Park, Utah, as recognized by Cogan et al. (2004), and their placement in alternative classes based on coalition group affinities (see Fig. 7 in paper).

Alliance	Association	Alternative class based on coalition group affinities
X. CLASS		
X.X. Subclass		
X.X.X. Formation Group		
X.X.X.X.x. Formation		
I. FOREST		
I.A. evergreen forest		
I.A.8. needle-leaved evergreen forest		
I.A.8.N.c. Conical-crowned temperate or subpolar needle-leaved evergreen forest		
White Fir Forest Alliance	White Fir / Bigtooth Maple Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	White Fir / Greenleaf Manzanita Forest	A1a. Mesa Top - Forest / Woodland / Shrubland
	White Fir / Gambel Oak Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	White Fir / Mountain Snowberry Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Douglas-fir Forest Alliance	Douglas-fir / Bigtooth Maple Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	Douglas-fir / Gambel Oak Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	Douglas-fir / Mountain Snowberry Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
I.B. deciduous forest		
I.B.2. cold-deciduous forest		
I.B.2.N.b. Montane or boreal cold-deciduous forest		
Bigtooth Maple Montane Forest Alliance	Bigtooth Maple / Gambel Oak Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Quaking Aspen Forest Alliance	Quaking Aspen / Mountain Snowberry / Tall Forbs Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
I.B.2.N.d. Temporarily flooded cold-deciduous forest		
Quaking Aspen Temporarily Flooded Forest Alliance	Quaking Aspen / Gambel Oak / Mountain Snowberry Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Fremont Cottonwood Temporarily Flooded Forest Alliance	Fremont Cottonwood / Coyote Willow Forest	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
I.C. mixed evergreen - deciduous forest		
I.C.3. mixed needle-leaved evergreen - cold-deciduous forest		
I.C.3.N.a. Mixed needle-leaved evergreen - cold-deciduous forest		
White Fir - Quaking Aspen Forest Alliance	Quaking Aspen - White Fir / Kentucky Bluegrass Semi-natural Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
	Quaking Aspen - White Fir / Mountain Snowberry Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous

APPENDIX 6. Continued. X. Class ◆ X.X. Subclass ◆ X.X.X. Formation Group ◆ X.X.X.X.x. Formation.

Alliance	Association	Alternative class based on coalition group affinities
II. WOODLAND		
II.A. evergreen woodland		
II.A.4. needle-leaved evergreen woodland		
II.A.4.N.a. Rounded-crowned temperate or subpolar needle-leaved evergreen woodland		
Two-needle Pinyon - (Juniper species) Woodland Alliance	Two-needle Pinyon - Utah Juniper / Greenleaf Manzanita Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Two-needle Pinyon - Utah Juniper / Littleleaf Mountain-mahogany Woodland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
	Two-needle Pinyon - Utah Juniper / Stansbury Cliff-rose Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Two-needle Pinyon - Juniper species / Big Sagebrush Woodland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
	Two-needle Pinyon - Juniper species / Mountain-mahogany Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Two-needle Pinyon - Juniper species / Gambel Oak Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Two-needle Pinyon / Curl-leaf Mountain-mahogany Woodland	A1a. Mesa Top - Forest / Woodland / Shrubland
Ponderosa Pine Woodland Alliance	Ponderosa Pine / Greenleaf Manzanita Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Ponderosa Pine / Black Sagebrush Woodland	A1a. Mesa Top - Forest / Woodland / Shrubland
	Ponderosa Pine / Smooth Brome Semi-natural Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	Ponderosa Pine / Northern Bracken Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	Ponderosa Pine / Gambel Oak Woodland	A1a. Mesa Top - Forest / Woodland / Shrubland
Utah Juniper Woodland Alliance	Utah Juniper / Big Sagebrush Woodland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Singleleaf Pinyon - (Utah Juniper) Woodland Alliance	Singleleaf Pinyon - Utah Juniper / (Roundleaf Buffaloberry, Utah Serviceberry) Woodland	A2d. Rocky Slopes - Woodland / Shrubland
	Singleleaf Pinyon - Utah Juniper / Black Sagebrush Woodland	A2d. Rocky Slopes - Woodland / Shrubland
	Singleleaf Pinyon - Utah Juniper / Big Sagebrush Woodland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
	Singleleaf Pinyon - Utah Juniper / Mountain-mahogany - Gambel Oak Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Singleleaf Pinyon - Utah Juniper / Blackbrush Woodland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
	Singleleaf Pinyon - Utah Juniper / Snakeweed / James' Galleta Woodland	unclassified (plot data unavailable)
	Singleleaf Pinyon - Utah Juniper / Needle-and-Thread Woodland	unclassified (plot data unavailable)
	Singleleaf Pinyon - Utah Juniper / Turbinella Live Oak Woodland	A2d. Rocky Slopes - Woodland / Shrubland
	Singleleaf Pinyon - Utah Juniper / Sparse Understory Woodland	A2d. Rocky Slopes - Woodland / Shrubland
Rocky Mountain Juniper Woodland Alliance	Rocky Mountain Juniper - Gambel Oak Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
II.B. deciduous woodland		
II.B.2. cold-deciduous woodland		
II.B.2.N.a. Cold-deciduous woodland		
Russian-olive Semi-natural Woodland Alliance	Russian-olive Semi-natural Woodland	unclassified (plot data unavailable)

APPENDIX 6. Continued. X. Class ◆ X.X. Subclass ◆ X.X.X. Formation Group ◆ X.X.X.X.x. Formation.

Alliance	Association	Alternative class based on coalition group affinities
II.B.2.N.b. Temporarily flooded cold-deciduous woodland		
Box-elder Temporarily Flooded Woodland Alliance	Box-elder / Tasselflower Brickelbush Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
	Box-elder / Disturbed Understory Woodland	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Fremont Cottonwood Temporarily Flooded Woodland Alliance	Fremont Cottonwood - Velvet Ash Woodland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
	Fremont Cottonwood / Emory Seepwillow Woodland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
Single-leaf Ash Temporarily Flooded Woodland Alliance	Single-leaf Ash Woodland	A2d. Rocky Slopes - Woodland / Shrubland
III. SHRUBLAND		
III.A. evergreen shrubland		
III.A.2. broad-leaved evergreen shrubland		
III.A.2.N.c. Sclerophyllous temperate broad-leaved evergreen shrubland		
Greenleaf Manzanita Shrubland Alliance	Greenleaf Manzanita - Mountain Big Sagebrush Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
	Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Greenleaf Manzanita Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Mexican Manzanita Shrubland Alliance	Mexican Manzanita Shrubland	A1a. Mesa Top - Forest / Woodland / Shrubland
Turbinella Live Oak Shrubland Alliance	Turbinella Live Oak - (Utah Serviceberry) Colluvial Shrubland	A2d. Rocky Slopes - Woodland / Shrubland
III.A.2.N.h. Seasonally flooded temperate broad-leaved evergreen shrubland		
Arrow-weed Seasonally Flooded Shrubland Alliance	Arrow-weed Seasonally Flooded Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
III.A.4. microphyllous evergreen shrubland		
III.A.4.N.a. Lowland microphyllous evergreen shrubland		
Big Sagebrush Shrubland Alliance	Big Sagebrush - (Rubber Rabbitbrush) / Cheatgrass Semi-natural Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
	Big Sagebrush / Blue Grama Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Basin Big Sagebrush Shrubland Alliance	Basin Big Sagebrush / Western Wheatgrass - (Streamside Wild Rye) Shrubland	A1a. Mesa Top - Forest / Woodland / Shrubland
Mountain Big Sagebrush Shrubland Alliance	Mountain Big Sagebrush / Needle-and-Thread Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
(Stansbury Cliff-rose, Mexican Cliff-rose) Shrubland Alliance	Stansbury Cliff-rose - Greenleaf Manzanita Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Rubber Rabbitbrush Shrubland Alliance	Rubber Rabbitbrush / Cheatgrass Semi-natural Shrubland	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
Sand Sagebrush Shrubland Alliance	Sand Sagebrush Colorado Plateau Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
III.A.4.N.c. Temporarily flooded microphyllous shrubland		
Salt-cedar species Semi-natural Temporarily Flooded Shrubland Alliance	Salt-cedar species Temporarily Flooded Shrubland	unclassified (plot data unavailable)

APPENDIX 6. Continued. X. Class ◆ X.X. Subclass ◆ X.X.X. Formation Group ◆ X.X.X.X.x. Formation.

Alliance	Association	Alternative class based on coalition group affinities
III.A.5. extremely xeromorphic subdesert shrubland		
III.A.5.N.a. Broad-leaved and microphyllous evergreen extremely xeromorphic subdesert shrubland		
Nevada Joint-fir Shrubland Alliance	Nevada Joint-fir Basalt Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Mormon-tea Shrubland Alliance	Gray Horsebrush - Mormon-tea Shrubland	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
III.A.5.N.b. Facultatively deciduous extremely xeromorphic subdesert shrubland		
Blackbrush Shrubland Alliance	Blackbrush / James' Galleta Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
	Blackbrush Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Fourwing Saltbush Shrubland Alliance	Fourwing Saltbush - Big Sagebrush Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
	Fourwing Saltbush Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
III.B. deciduous shrubland		
III.B.2. cold-deciduous shrubland		
III.B.2.N.a. Temperate cold-deciduous shrubland		
Mountain Snowberry Shrubland Alliance	Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Utah Serviceberry Shrubland Alliance	Utah Serviceberry Shrubland	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Gambel Oak Shrubland Alliance	Gambel Oak - Mountain-mahogany / (Geyer's Sedge) Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Gambel Oak / Utah Serviceberry Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
	Gambel Oak / Big Sagebrush Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
	Gambel Oak / Muttongrass Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
	Gambel Oak / Mountain Snowberry Shrubland	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
III.B.2.N.d. Temporarily flooded cold-deciduous shrubland		
Water Birch Temporarily Flooded Shrubland Alliance	Fremont Cottonwood / Water Birch Wooded Shrubland	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Strapleaf Willow Temporarily Flooded Shrubland Alliance	Strapleaf Willow / Beaked Sedge Shrubland	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
(Coyote Willow, Sandbar Willow) Temporarily Flooded Shrubland Alliance	Coyote Willow / Barren Shrubland	A2. Lowlands / Rocky Slopes / Upland Sands (outlier)
	Coyote Willow / Mesic Graminoids Shrubland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous

APPENDIX 6. Continued. X. Class ◆ X.X. Subclass ◆ X.X.X. Formation Group ◆ X.X.X.X.x. Formation.

Alliance	Association	Alternative class based on coalition group affinities
IV.A. evergreen dwarf-shrubland		
IV.A.2. extremely xeromorphic evergreen subdesert dwarf-shrubland		
IV.A.2.N.a. Extremely xeromorphic evergreen subdesert dwarf-shrubland		
Black Sagebrush Dwarf-shrubland Alliance	Black Sagebrush / Bottlebrush Dwarf-shrubland	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
	Black Sagebrush / Needle-and-Thread Dwarf-shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
	Black Sagebrush / Muttongrass Dwarf-shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
IV.B. deciduous dwarf-shrubland		
IV.B.2. cold-deciduous dwarf-shrubland		
IV.B.2.N.a. Caespitose cold-deciduous dwarf-shrubland		
Snakeweed Dwarf-shrubland Alliance	Snakeweed - (Prickly-pear species) / James' Galleta Dwarf-shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
V. HERBACEOUS VEGETATION		
V.A. perennial grassland		
V.A.5. temperate or subpolar grassland		
V.A.5.N.c. Medium-tall sod temperate or subpolar grassland		
Intermediate Wheatgrass Semi-natural Herbaceous Alliance	Intermediate Wheatgrass Semi-natural Herbaceous Vegetation	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
V.A.5.N.d. Medium-tall bunch temperate or subpolar grassland		
Mountain Muhly Herbaceous Alliance	(Sandhill Muhly, Mountain Muhly) - Hairy Goldenaster Herbaceous Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Needle-and-Thread Bunch Herbaceous Alliance	Needle-and-Thread Great Basin Herbaceous Vegetation	A1. Mesa Top / Upland Sands / Slickrock / Rocky Slopes (outlier)
Smooth Brome Semi-natural Herbaceous Alliance	Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Sand Dropseed Herbaceous Alliance	Sand Dropseed Great Basin Herbaceous Vegetation	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
V.A.5.N.e. Short sod temperate or subpolar grassland		
James' Galleta Herbaceous Alliance	James' Galleta Herbaceous Vegetation	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Blue Grama Herbaceous Alliance	Blue Grama - Needle-and-Thread Herbaceous Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
V.A.5.N.k. Seasonally flooded temperate or subpolar grassland		
Baltic Rush Seasonally Flooded Herbaceous Alliance	Baltic Rush Herbaceous Vegetation	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Kentucky Bluegrass Semi-natural Seasonally Flooded Herbaceous Alliance	Kentucky Bluegrass Semi-natural Seasonally Flooded Herbaceous Alliance	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
(Swollen-beak Sedge, Beaked Sedge) Seasonally Flooded Herbaceous Alliance	Beaked Sedge Herbaceous Vegetation	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Nebraska Sedge Seasonally Flooded Herbaceous Alliance	Nebraska Sedge Herbaceous Vegetation	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous

APPENDIX 6. Continued. X. Class ◆ X.X. Subclass ◆ X.X.X. Formation Group ◆ X.X.X.X.x. Formation.

Alliance	Association	Alternative class based on coalition group affinities
V.A.7. temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer		
V.A.7.N.e. Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer		
Green Rabbitbrush Shrub Herbaceous Alliance	Green Rabbitbrush / Kentucky Bluegrass Semi-natural Shrub Herbaceous Vegetation	A2. Lowlands / Rocky Slopes / Upland Sands (outlier)
V.B. perennial forb vegetation		
V.B.2. temperate perennial forb vegetation		
V.B.2.N.e. Semipermanently flooded temperate perennial forb vegetation		
(Field Horsetail, Variegated Scouringrush) Semipermanently Flooded Herbaceous Alliance	(Field Horsetail, Variegated Scouringrush) Herbaceous Vegetation	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
V.D. annual grassland		
V.D.2. temperate annual grassland		
V.D.2.N.d. Short temperate annual grassland		
Cheatgrass Semi-natural Herbaceous Alliance	Cheatgrass Herbaceous Semi-natural Alliance	unclassified (plot data unavailable)
VII. SPARSE VEGETATION		
VII.A. sparse vascular vegetation		
VII.A.1. cliffs with sparse vascular vegetation		
VII.A.1.N.a. Cliffs with sparse vascular vegetation		
Wooded Bedrock Sparsely Vegetated Alliance	Ponderosa Pine Slickrock Sparse Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
VII.A.2. pavement with sparse vascular vegetation		
VII.A.2.N.a. Pavement with sparse vascular vegetation		
Littleleaf Mountain-mahogany Sparsely Vegetated Alliance	Littleleaf Mountain-mahogany Slickrock Sparse Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
VII.C. slopes		
VII.C.3. dry slopes		
VII.C.3.N.b. Dry slopes		
Mountain-mahogany Sparsely Vegetated Alliance	Mountain-mahogany Rock Pavement Sparse Vegetation	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Painted Desert Sparsely Vegetated Alliance	Nevada Joint-fir / Lichen Sparse Vegetation	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
	Crispleaf Wild Buckwheat Badlands Sparse Vegetation	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
HIERARCHY PLACEMENT UNDETERMINED		
Emory Seepwillow Shrubland [provisional]	Emory Seepwillow Shrubland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
Rubber Rabbitbrush Sand Deposit Sparse Vegetation [provisional]	Rubber Rabbitbrush Sand Deposit Sparse Vegetation	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse

APPENDIX 7. Associations of the U.S. National Vegetation Classification (NVC) at Zion National Park, Utah (Cogan et al. 2004), arranged according to the revised classification heirarchy (FGDC 2008), and their placement in alternative classes based on coalition group affinities (see Fig. 7 in paper). NVC classes were obtained or inferred from NatureServe (2013) or USNVC (2013).

X - Class
X.X - Subclass
X.X.X - Formation
X.X.X.Xx - Division
Macrogroup
Group

Association	Alternative class based on coalition group affinities
1 - Forest to Open Woodland	
1.B - Temperate & Boreal Forest	
1.B.2 - Cool Temperate Forest	
1.B.2.Nb - Rocky Mountain Cool Temperate Forest	
Central Rocky Mountain Dry Lower Montane & Foothill Forest	
Pseudotsuga menziesii Middle Rocky Mountain Montane Forest & Woodland Group	
Douglas-fir / Mountain Snowberry Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Rocky Mountain Subalpine & High Montane Conifer Forest	
Populus tremuloides Rocky Mountain Forest & Woodland Group	
Quaking Aspen / Mountain Snowberry / Tall Forbs Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Quaking Aspen / Gambel Oak / Mountain Snowberry Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Southern Rocky Mountain Lower Montane Forest	
Abies concolor - Picea pungens - Pseudotsuga menziesii Mesic Southern Rocky Mountain Forest Group	
Bigtooth Maple / Gambel Oak Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Douglas-fir / Bigtooth Maple Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Quaking Aspen - White Fir / Kentucky Bluegrass Semi-natural Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Quaking Aspen - White Fir / Mountain Snowberry Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
White Fir / Bigtooth Maple Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
White Fir / Mountain Snowberry Forest	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Abies concolor - Pseudotsuga menziesii Southern Rocky Mountain Dry Forest Group	
Douglas-fir / Gambel Oak Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
White Fir / Gambel Oak Forest	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
White Fir / Greenleaf Manzanita Forest	A1a. Mesa Top - Forest / Woodland / Shrubland

APPENDIX 7. Continued. X - Class ◆ X.X Subgrass ◆ X.X.X - Formation ◆ X.X.X.Xx - Division ◆ Macrogroup ◆ Group.

Association	Alternative class based on coalition group affinities
Pinus ponderosa Southern Rocky Mountain Forest & Woodland Group	
Ponderosa Pine / Black Sagebrush Woodland	A1a. Mesa Top - Forest / Woodland / Shrubland
Ponderosa Pine / Gambel Oak Woodland	A1a. Mesa Top - Forest / Woodland / Shrubland
Ponderosa Pine / Greenleaf Manzanita Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Ponderosa Pine / Northern Bracken Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Ponderosa Pine / Smooth Brome Semi-natural Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
1.B.2.Nc - Western North American Cool Temperate Woodland & Scrub	
Intermountain Singleleaf Pinyon - Utah Juniper - Western Juniper Woodland	
Juniperus osteosperma Woodland & Savanna Group	
Rocky Mountain Juniper - Gambel Oak Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Utah Juniper / Big Sagebrush Woodland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Pinus edulis - Juniperus osteosperma Woodland Group	
Two-needle Pinyon - Juniper species / Big Sagebrush Woodland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Two-needle Pinyon - Juniper species / Gambel Oak Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Two-needle Pinyon - Juniper species / Mountain-mahogany Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Two-needle Pinyon - Utah Juniper / Greenleaf Manzanita Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Two-needle Pinyon - Utah Juniper / Littleleaf Mountain-mahogany Woodland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Two-needle Pinyon - Utah Juniper / Stansbury Cliff-rose Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Two-needle Pinyon / Curl-leaf Mountain-mahogany Woodland	A1a. Mesa Top - Forest / Woodland / Shrubland
Pinus monophylla - Juniperus osteosperma Woodland Group	
Singleleaf Pinyon - Utah Juniper / (Roundleaf Buffaloberry, Utah Serviceberry) Woodland	A2d. Rocky Slopes - Woodland / Shrubland
Singleleaf Pinyon - Utah Juniper / Big Sagebrush Woodland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Singleleaf Pinyon - Utah Juniper / Black Sagebrush Woodland	A2d. Rocky Slopes - Woodland / Shrubland
Singleleaf Pinyon - Utah Juniper / Blackbrush Woodland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Singleleaf Pinyon - Utah Juniper / Mountain-mahogany - Gambel Oak Woodland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Singleleaf Pinyon - Utah Juniper / Sparse Understory Woodland	A2d. Rocky Slopes - Woodland / Shrubland
Singleleaf Pinyon - Utah Juniper / Turbinella Live Oak Woodland	A2d. Rocky Slopes - Woodland / Shrubland

APPENDIX 7. Continued. X - Class ◆ X.X Subgrass ◆ X.X.X - Formation ◆ X.X.X.Xx - Division ◆ Macrogroup ◆ Group.

Association	Alternative class based on coalition group affinities
1.B.3 - Temperate Flooded & Swamp Forest	
1.B.3.Nc - Rocky Mountain & Great Basin Flooded & Swamp Forest	
Rocky Mountain & Great Basin Riparian Forest	
Populus deltoides ssp. wislizeni - Alnus rubra - Alnus rhombifolia Riparian Woodland Group	
Box-elder / Disturbed Understory Woodland	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Box-elder / Tasselflower Brickelbush Woodland	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Fremont Cottonwood / Coyote Willow Forest	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
Single-leaf Ash Woodland	A2d. Rocky Slopes - Woodland / Shrubland
Fremont Cottonwood / Water Birch Wooded Shrubland	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
1.B.3.Nd - Southwestern North American Flooded & Swamp Forest	
Warm Southwest Riparian Forest	
Populus deltoides ssp. wislizeni - Platanus wrightii - Juglans major Warm Desert Riparian Scrub Group	
Fremont Cottonwood - Velvet Ash Woodland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
Fremont Cottonwood / Emory Seepwillow Woodland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
2 - Shrubland & Grassland	
2.B - Temperate & Boreal Grassland & Shrubland	
2.B.2 - Temperate Grassland, Meadow & Shrubland	
2.B.2.Na - Western North American Grassland & Shrubland	
Rocky Mountain-Vancouverian Subalpine & High Montane Mesic Grass & Forb Meadow	
Festuca arizonica - Festuca thurberi - Muhlenbergia montana Grassland Group	
(Sandhill Muhly, Mountain Muhly) - Hairy Goldenaster Herbaceous Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Southern Rocky Mountain Montane Shrubland	
Cercocarpus montanus - Amelanchier utahensis - Rhus trilobata Foothill Shrubland Group	
Littleleaf Mountain-mahogany Slickrock Sparse Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Utah Serviceberry Shrubland	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Quercus gambelii - Amelanchier spp. - Prunus virginiana Southern Rocky Mountain Montane Shrubland Group	
Gambel Oak - Mountain-mahogany / (Geyer's Sedge) Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Gambel Oak / Big Sagebrush Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Gambel Oak / Mountain Snowberry Shrubland	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous

APPENDIX 7. Continued. X - Class ◆ X.X Subgrass ◆ X.X.X - Formation ◆ X.X.X.Xx - Division ◆ Macrogroup ◆ Group.

Association	Alternative class based on coalition group affinities
Gambel Oak / Muttongrass Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Gambel Oak / Utah Serviceberry Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Greenleaf Manzanita - Gambel Oak - (Utah Serviceberry) Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Mountain Snowberry / Kentucky Bluegrass Semi-natural Shrubland	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
unknown macrogroup & group	
Intermediate Wheatgrass Semi-natural Herbaceous Vegetation	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
2.B.2.Nd - Western North American Interior Sclerophyllous Chaparral Shrubland	
Cool Interior Chaparral	
Arctostaphylos patula - Arctostaphylos nevadensis - Ceanothus velutinus Montane Sclerophyll Scrub Group	
Stansbury Cliff-rose - Greenleaf Manzanita Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Greenleaf Manzanita - Mountain Big Sagebrush Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Greenleaf Manzanita Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Warm Interior Chaparral	
Quercus turbinella - Ceanothus greggii - Arctostaphylos pungens Chaparral Group	
Mexican Manzanita Shrubland	A1a. Mesa Top - Forest / Woodland / Shrubland
Turbinella Live Oak - (Utah Serviceberry) Colluvial Shrubland	A2d. Rocky Slopes - Woodland / Shrubland
2.B.6.Nb - Western North American Freshwater Shrubland, Wet Meadow & Marsh	
Great Plains Mixedgrass Prairie & Shrubland	
Schizachyrium scoparium - Bouteloua curtipendula - Pascopyrum smithii Mixedgrass Prairie Group	
Smooth Brome - (Western Wheatgrass) Semi-natural Herbaceous Vegetation	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous
Western North American Montane & Subalpine Wet Shrubland & Wet Meadow	
Carex spp. - Calamagrostis spp. Montane Wet Meadow Group	
Beaked Sedge Herbaceous Vegetation	B1a. High Plateau / Crevice Canyon - Forest / Woodland / Herbaceous
Baltic Rush Herbaceous Vegetation	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Nebraska Sedge Herbaceous Vegetation	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Salix spp. Riparian & Seep Shrubland Group	
Strapleaf Willow / Beaked Sedge Shrubland	B2a. Streambank / High Plateau - Forest / Woodland / Shrubland / Herbaceous
Kentucky Bluegrass Semi-natural Seasonally Flooded Herbaceous Alliance	B1b. High Plateau - Forest / Woodland / Shrubland / Herbaceous

APPENDIX 7. Continued. X - Class ◆ X.X Subgrass ◆ X.X.X - Formation ◆ X.X.X.Xx - Division ◆ Macrogroup ◆ Group.

Association	Alternative class based on coalition group affinities
Western North American Temperate Lowland Wet Shrubland, Wet Meadow & Marsh	
Deschampsia beringensis - Argentina egedii - Carex obnupta Vancouverian Freshwater Coastal Marsh & Meadow Group	
(Field Horsetail, Variegated Scouringrush) Herbaceous Vegetation	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
Salix exigua - Crataegus spp. - Forestiera pubescens Rocky Mountain & Great Basin Riparian & Seep Shrubland Group	
Coyote Willow / Mesic Graminoids Shrubland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
2.B.6.Nc - Southwestern North American Warm Desert Freshwater Marsh	
Warm Desert Freshwater Shrubland, Meadow & Marsh	
Prosopis glandulosa - Baccharis spp. North American Warm Desert Riparian Low Bosque & Shrubland Group	
Arrow-weed Seasonally Flooded Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
2.B.6 - Temperate & Boreal Freshwater Marsh, Wet Meadow & Shrubland	
Coyote Willow / Barren Shrubland	A2. Lowlands / Rocky Slopes / Upland Sands (outlier)
Emory Seepwillow Shrubland	B2b. Streambank - Forest / Woodland / Shrubland / Herbaceous
3 - Desert & Semi-Desert	
3.B - Cool Semi-Desert Scrub & Grassland	
3.B.1 - Cool Semi-Desert Scrub & Grassland	
3.B.1.Ne - Western North American Cool Semi-Desert Scrub & Grassland	
Great Basin & Intermountain Dry Shrubland & Grassland	
Chrysothamnus viscidiflorus - Ericameria nauseosa - Krascheninnikovia lanata Shrubland Group	
Rubber Rabbitbrush Sand Deposit Sparse Vegetation	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
Green Rabbitbrush / Kentucky Bluegrass Semi-natural Shrub Herbaceous Vegetation	A2. Lowlands / Rocky Slopes / Upland Sands (outlier)
Rubber Rabbitbrush / Cheatgrass Semi-natural Shrubland	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
Snakeweed - (Prickly-pear species) / James' Galleta Dwarf-shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Coleogyne ramosissima - Ephedra cutleri - Ephedra torreyana Colorado Plateau Shrubland Group	
Blackbrush / James' Galleta Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Blackbrush Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Sand Sagebrush Colorado Plateau Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse

APPENDIX 7. Continued. X - Class ◆ X.X Subgrass ◆ X.X.X - Formation ◆ X.X.X.Xx - Division ◆ Macrogroup ◆ Group.

Association	Alternative class based on coalition group affinities
Pleuraphis jamesii - Achnatherum hymenoides - Hesperostipa comata Semi-Desert Grassland Group	
Blue Grama - Needle-and-Thread Herbaceous Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
James' Galleta Herbaceous Vegetation	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Needle-and-Thread Great Basin Herbaceous Vegetation	A1. Mesa Top / Upland Sands / Slickrock / Rocky Slopes (outlier)
Sand Dropseed Great Basin Herbaceous Vegetation	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Great Basin & Intermountain Dwarf Sage Shrubland & Steppe	
Artemisia arbuscula - Artemisia bigelovii - Artemisia nova Shrubland & Steppe Group	
Black Sagebrush / Bottlebrush Dwarf-shrubland	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
Black Sagebrush / Muttongrass Dwarf-shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Black Sagebrush / Needle-and-Thread Dwarf-shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Great Basin & Intermountain Tall Sagebrush Shrubland & Steppe	
Artemisia tridentata - Artemisia tripartita - Purshia tridentata Big Sagebrush Steppe Group	
Basin Big Sagebrush / Western Wheatgrass - (Streamside Wild Rye) Shrubland	A1a. Mesa Top - Forest / Woodland / Shrubland
Artemisia tridentata ssp. spiciformis - Artemisia tridentata ssp. vaseyana - Artemisia cana ssp. viscidula Tall Shrubland & Steppe Group	
Mountain Big Sagebrush / Needle-and-Thread Shrubland	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Artemisia tridentata ssp. wyomingensis - Artemisia tridentata ssp. tridentata Tall Sagebrush Group	
Big Sagebrush - (Rubber Rabbitbrush) / Cheatgrass Semi-natural Shrubland	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Big Sagebrush / Blue Grama Shrubland	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse
Great Basin Saltbrush Scrub	
Atriplex confertifolia - Atriplex canescens - Krascheninnikovia lanata Scrub Group	
Fourwing Saltbush - Big Sagebrush Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Fourwing Saltbush Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Gray Horsebrush - Mormon-tea Shrubland	A2c. Upland Sands / Rocky Slopes - Shrubland / Sparse
6 - Rock Vegetation	
6.C - Desert & Semi-Desert Rock Vegetation	
6.C.1 - Warm Semi-Desert Cliff, Scree & Rock Vegetation	
6.C.1.Na - North American Warm Semi-Desert Cliff, Scree & Rock Vegetation	
North American Warm Semi-Desert Cliff, Scree & Rock Vegetation	
Nevada Joint-fir Basalt Shrubland	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse

APPENDIX 7. Continued. X - Class ◆ X.X Subgrass ◆ X.X.X - Formation ◆ X.X.X.Xx - Division ◆ Macrogroup ◆ Group.

Association	Alternative class based on coalition group affinities
6.C.2 - Cool Semi-Desert Cliff, Scree & Other Rock Vegetation	
6.C.2.Na - North American Cool Semi-Desert Cliff, Scree & Rock Vegetation	
Intermountain Basins Cliff, Scree & Badland Sparse Vegetation	
Atriplex spp. - Cercocarpus spp. - Ephedra spp. Intermountain Basins Sparse Vegetation Group	
Mountain-mahogany Rock Pavement Sparse Vegetation	A1b. Mesa Top / Rocky Slopes - Woodland / Shrubland / Sparse
Crispleaf Wild Buckwheat Badlands Sparse Vegetation	A2b. Arid Lowlands - Woodland / Shrubland / Sparse
Nevada Joint-fir / Lichen Sparse Vegetation	A2a. Arid Lowlands / Lowland Flats - Woodland / Shrubland / Herbaceous / Sparse
Ponderosa Pine Slickrock Sparse Vegetation	A1c. Upland Sands / Slickrock / Rocky Slopes - Woodland / Shrubland / Herbaceous / Sparse

APPENDIX 8. Numbers of associations of the U.S. National Vegetation Classification (NVC) at Zion National Park, Utah (Cogan et al. 2004), classified to land cover classes and ecological systems (obtained or inferred from NatureServe 2013) and alternative classes based on coalition group affinities (see Fig. 7 in paper).

		# of Associations in Alternative Class (see Fig. 7)										
Land Cover Class	**Ecological System**	**A1a**	**A1b**	**A1c**	**A2a**	**A2b**	**A2c**	**A2d**	**B1a**	**B1b**	**B2a**	**B2b**
Barren	Colorado Plateau Mixed Bedrock Canyon and Tableland		1	3	1							
Barren	Inter-Mountain Basins Active and Stabilized Dune			1		1	1					
Barren	Inter-Mountain Basins Cliff and Canyon		1	2				1				
Barren	Inter-Mountain Basins Shale Badland				1	1						
Barren	Inter-Mountain Basins Volcanic Rock and Cinder Land				1							
Forest and Woodland	Colorado Plateau Pinyon-Juniper Woodland	1	4	2		1			1			
Forest and Woodland	Great Basin Pinyon-Juniper Woodland		1			2		4				
Forest and Woodland	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland									2		
Forest and Woodland	Rocky Mountain Aspen Forest and Woodland									2		
Forest and Woodland	Rocky Mountain Bigtooth Maple Ravine Woodland								2			
Forest and Woodland	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	1							3	1		
Forest and Woodland	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	1							4	1		

APPENDIX 8. Continued.

Land Cover Class	Ecological System	# of Associations in Alternative Class (see Fig. 7)										
		A1a	A1b	A1c	A2a	A2b	A2c	A2d	B1a	B1b	B2a	B2b
Forest and Woodland	Southern Rocky Mountain Ponderosa Pine Woodland	2	1						2			
Herbaceous	Inter-Mountain Basins Semi-Desert Grassland			2	2					2		
Herbaceous Wetland	Rocky Mountain Alpine-Montane Wet Meadow								1		2	
Herbaceous Wetland	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland							1	1	2	4	4
Shrubland	Colorado Plateau Blackbrush-Mormon-Tea Shrubland					3						
Shrubland	Colorado Plateau Mixed Low Sagebrush Shrubland		1	1			1					
Shrubland	Colorado Plateau Pinyon-Juniper Shrubland	1	3	1								
Shrubland	Great Basin Xeric Mixed Sagebrush Shrubland		1	1			1					
Shrubland	Inter-Mountain Basins Big Sagebrush Shrubland	1		1		1	2					
Shrubland	Inter-Mountain Basins Mixed Salt Desert Scrub				2							
Shrubland	Mogollon Chaparral	1	1	2				1				
Shrubland	Rocky Mountain Gambel Oak-Mixed Montane Shrubland		3	2					1	2		
Shrubland	Rocky Mountain Lower Montane-Foothill Shrubland									2		
Shrubland	Southern Colorado Plateau Sand Shrubland						1					
Steppe/Savanna	Inter-Mountain Basins Big Sagebrush Steppe	1										
Steppe/Savanna	Inter-Mountain Basins Montane Sagebrush Steppe		2	1								
Steppe/Savanna	Inter-Mountain Basins Semi-Desert Shrub-Steppe			1		1						
Woody Wetland	North American Warm Desert Lower Montane Riparian Woodland and Shrubland										1	2
Woody Wetland	North American Warm Desert Riparian Woodland and Shrubland				1							3
Woody Wetland	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland							1	1	2	4	4
Woody Wetland	Rocky Mountain Subalpine-Montane Riparian Shrubland							1			1	
Woody Wetland	Rocky Mountain Subalpine-Montane Riparian Woodland									1		