Environmental Relationships of Native Garry Oak (*Quercus garryana*) Communities at Their Northern Margin[1]

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Abstract

Knowledge of relationships among plant communities and environmental variables can be used in restoration, ecological assessments, predictive mapping and conservation planning. This information would be particularly important in the conservation of endangered ecosystems, such as those of Garry oak in British Columbia. To investigate relationships, sixteen environmental variables were examined for a plant community framework using Detrended Correspondence Analysis and interpretive graphing. Overall, the variables and the degree of differentiation were adequately represented by the framework of 26 native communities. Most of the environmental multivariate space from DCA was covered by the communities, but not all communities were associated with variables. Fifteen communities were distinct, and many of the remaining eleven had special circumstances. Thirteen of the variables were associated with particular communities, a total of 26 times. Most important were site mineral soil exposure, soil coarse fragments and geographic area. The results could be used to develop environmental keys to plant community sites for practical field application.

Introduction

Garry oak (*Quercus garryana* Dougl.) ecosystems are at their northern margin of their range in British Columbia (B.C.). They are among the most unique and threatened in Canada (Erickson 1993, 2000). Native stands have been reduced by urban development and threats such as invasions by alien species. While some Garry oak plant communities in the Pacific Northwest have been described (Riegel and others 1992, Sugihara and others 1987, Thilenius 1968), relationships with environmental factors have not been fully investigated. Further understanding could improve predictive ability and strengthen assessments for conservation and management of the Garry oak habitat.

I studied Garry oak stands on Vancouver Island and the Gulf Islands and developed a plant community classification framework (Erickson 1996). Twenty-six native communities are addressed in this study, including the mosaic of small patch communities and subcommunities. Added to previous, gradient-level work (Erickson 1996, 2000) are individual, community-scale environmental variables.

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This research was intended to determine the following:

- Are native plant communities adequately represented and differentiated?
- Is there a strong relationship between communities and particular ecological variables?
- Which are the most important variables to the Garry oak communities?

Methods

Environmental attributes were described along with Garry oak vegetation on 299 plots using standard methodologies (Walmsley and others 1980). The sample covered a wide array of representative sites and geographic areas (Erickson 1996). The database was scaled or transformed as required (e.g., Frank and Lee 1966 for solar values) and a total of 16 environmental variables were developed *(table 1).* The following variables used the inverse: elevation, downed wood cover, *Ah* horizon depth (depth of the organically enriched surface mineral soil), depth to bedrock, Garry oak cover, and Douglas-fir (*Pseudotsuga menziesii*)/Arbutus (*Arbutus menziesii*) cover.

Table 1—*Environmental variables analyzed.*

Abbreviation/ symbol	**Variable name**	**Values**
geog area	Geographic areas	5 Saanich Peninsula, 4 S. Gulf Islands, 3 western shore, 2 Duncan-Nanaimo, 1 N. Gulf Islands
adjinv elev	Adjusted Inverse of Elevation	Values reversed around the mean elevation
solar ind	Solar Index	Frank & Lee (1966) Solar Beam Irradiation Tables for slope and aspect, May 3
topo drain	Topographic drainage	Slope class times surface shape class
m regime	Moisture regime	Numeric values for field assigned classes from wettest (1) to driest (14)
site exp	Site exposure	Sum of numeric values for field notations (wind, saltspray, etc.)
R geol	Bedrock geology	Classes from fine, shale (1) to coarse, granite (7)
site R&r	Site bedrock & rock exposure	Summed cover values for bedrock, shallow humus over bedrock and rock
site min	Site mineral soil exposure	Cover values
soil text	Soil texture	Numeric classes assigned to field textures, from fine to coarse (highest values)
soil cfr	Soil coarse fragments	Percent: field estimates
invDW	Inverse of Downed Wood: cover	Class values
invAh dp	Inverse of Ah horizon depth	Depth in cm.
invRdp	Inverse of depth to Bedrock	Depth in cm.
invQg	Inverse of Garry oak cover	Sum of tree layer cover plus _ the shrub layer cover
invFd&Arb	Inverse of Douglas-fir and arbutus cover	Class values summed

Detrended Correspondence Analysis (DCA) (Hill and Gauch 1980) was undertaken on the variable means for each community within four organizational categories: early-season; bedrock outcrops and rocky; “other native”; and “wet native” *(table 2)*.

Table 2—*Native Garry oak plant communities.*

No.	Community name	Ct[1]	T[2]
c37a	*Quercus garryana – Camassia quamash*	E	s
c35a	*Quercus garryana- Camassia quamash- Erythronium oregonum*	E	s
c35b	*Quercus garryana – Camassia quamash – Dodecatheon hendersonii*	E	s
c37b	*Quercus garryana – Camassia quamash – Ranunculus occidentalis*	E	s
c36	*Quercus garryana – Camassia leichtlinii*	E	c
c48	*Quercus garryana – Montia perfoliata*	E	c
c51	*Quercus garryana – Dicranum scoparium – Plectritus congesta*	E	c
c52	*Quercus garryana – Dicranum scoparium*	B	s
c11	*Quercus garryana – Dicranum scoparium – Montia parvifolia*	B	s
c45	*Quercus garryana – Dicranum scoparium – Sedum spathulifolium*	B	s
c46	*Quercus garryana – Rhacomitrium canescens – Selaginella wallacei*	B	c
c26	*Quercus garryana – Mahonia aquifolium*	ON	c
c16a	*Quercus garryana – Lonicera hispidula*	ON	c
c20	*Quercus garryana – Festuca idahoensis*	ON	s
c25	*Quercus garryana – Festuca idahoensis – Cerastium arvense*	ON	s
c27	*Quercus garryana – Festuca idahoensis – Trifolium microcephalum*	ON	s
c42	*Quercus garryana – Festuca idahoensis – Vicia americana*	ON	s
c41	*Quercus garryana – Lathyrus nevadensis*	ON	c
c43	*Quercus garryana – Bromus carinatus*	ON	c
c47	*Quercus garryana – Elymus glaucus*	ON	c
c14	*Quercus garryana – Carex inops*	WN	c
c13	*Quercus garryana – Melica subulata*	WN	c
c15	*Quercus garryana – Holodiscus discolor – Symphoricarpos albus – Polypodium glycyrrhiza*	WN	s
c10	*Quercus garryana – Holodiscus discolor – Symphoricarpos albus – Rhytidiadephus triquetris*	WN	s
c8	*Quercus garryana – Symphoricarpos albus – Rosa nutkana – Lonicera ciliosa*	WN	s
c9	*Quercus garryana – Symphoricarpos albus – Rosa nutkana – Oemleria cerasiformis*	WN	s

[1] Ct (categories): E=early season, B=bedrock outcrops, ON=other native plant communities, WN=wet native plant communities.

[2] T (type): c=communities, s=subcommunities.

DCA is a multivariate method that simultaneously ordinates scores against subjects (in this case environmental data against communities), and vice-versa, using chi-squared distances. Axis (vector) solutions represent the most variation in the dataset. Communities are separated in multivariate space and referenced relative to the de-trended and re-scaled axes. DCA has been used in identifying vegetation/ environment relationships for a number of oak woodland settings (Borchert and others 1993, Maranon and others 1999, Nowacki and Abrams 1992).

Output graphs of communities and variables were scaled in common and combined. For graphical interpretation, a proportional circle was positioned to frame each community on axis 1 against 2, then 1 against 3. The adequacy of community differentiation and the strength of an association with a particular variable were judged separately by the extent of conjunction in the community circles *(table 3, fig. 1)*, but across the two axis combinations.

Table 3—*Graphical interpretative classes.*

Community differentiation	
Associated	A conjunction of the variable and the community circle
Distinct	Community circle does not overlap with another community
Strongly differentiated	Community is distinct on both axis combinations
Moderately differentiated	Distinct on one axis combination
Weakly differentiated	Separate from adjacent communities across the two axis combinations, overlaps with each only on one axis.
Environmental Variable associations	
Uniquely associated	Community is solely associated with the same variable on both axis combinations, and vice-versa
Strongly associated	Community is associated with the same variable on both axis combinations, but shares this association with other, overlapping communities
Moderately associated	Community is associated with a variable on one axis combination and obviously influencing its distribution on the second

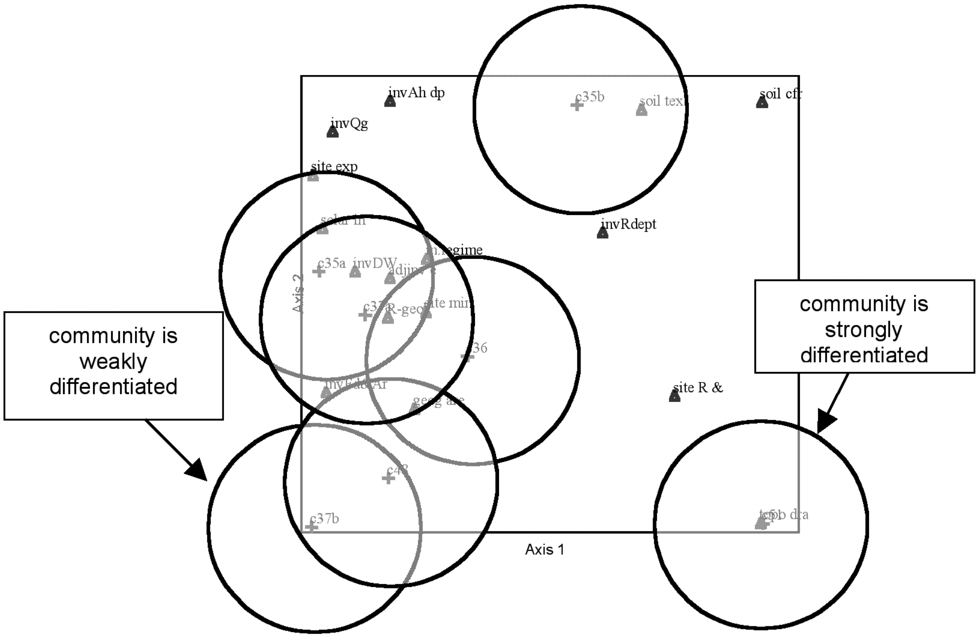

Figure 1 Example of interpretative categories: environmental factors for early season plant communities, axis 1 vs. 2. (Legend for *figures 1-8:* Symbols for each plant community (center of each circle marked with +) are found in *table 1.* Symbols for the environmental variables (scattered throughout the graphs and marked with a triangle) are found in *table 2.*

Results

Plant Community Differentiation

Most of the environmental multivariate space from DCA was covered by communities, when considered across the two axis combinations *(figs. 1-8)*. Three exceptions can be attributed to a lack of intermediate values. In the early season category, Ah horizon depth and soil coarse fragments were not associated with communities on either axis *(figs. 1, 2)*. In the wet native category, considerable space was not covered, but it did not correspond to the location of environmental variables *(figs. 7, 8)*.

Three Garry oak communities were strongly differentiated: *Dicranum scoparium-Plectritus congesta (figs. 1, 2)*; *Carex inops*; and *Holodiscus discolor-Symphoricarpos albus-Polypodium glycyrrhiza (figs. 7, 8)*, of which the first was associated with an environmental variable.

Five other Garry oak communities were moderately differentiated and associated with variables: *Camassia quamash-Dodecatheon hendersonii (figs. 1, 2)*; *Lonicera hispidula*; *Dicranum scoparium-Montia parviflorum (figs. 3, 4)*; *Festuca idahoensis-Trifolium microcephalum*; and *Bromus carinatus (figs. 5, 6)*; the first four of these uniquely so. One community, *Racomitrium canescens-Selaginella wallacei (figs. 3, 4)*, was moderately differentiated but not associated with a particular variable.

Four Garry oak communities: *Camassia quamash-Erythronium oregonum (figs. 1, 2)*; *Dicranum scoparium-Sedum spathulifolium (figs. 3, 4)*; *Festuca idahoensis-Vicia americana (figs. 5, 6)* and *Symphoricarpos albus-Rosa nutkana-Oemleria cerasiformis (figs. 7, 8)* were weakly differentiated, but uniquely associated with variables. Two others: *Lathyrus nevadensis (figs. 5, 6)* and *Holodiscus discolor-Symphoricarpos albus-Rhytidiadelphus triquetris (figs. 7, 8)* were weakly differentiated and not associated with a variable.

Many Garry oak communities (11, or 42 percent) were not differentiated in that they overlapped with adjacent ones on both axis combinations, four of these strongly so. Included were two of the subcommunities which can be identical or have only slight differences in their environmental factors, in that they are separated primarily for their vegetation characteristics. Nevertheless, many (9) of the overlapping communities still had variables associated with them; for most, uniquely so. For example, the *Montia perfoliata (figs. 1, 2)* community was not distinct from adjacent communities, but was associated with the variable, geographic area, on both combinations.

Most (19, or 73 percent) of the communities were also associated with variables on one axis combination. Differentiation for subcommunities (10) exceeded that for communities (5).

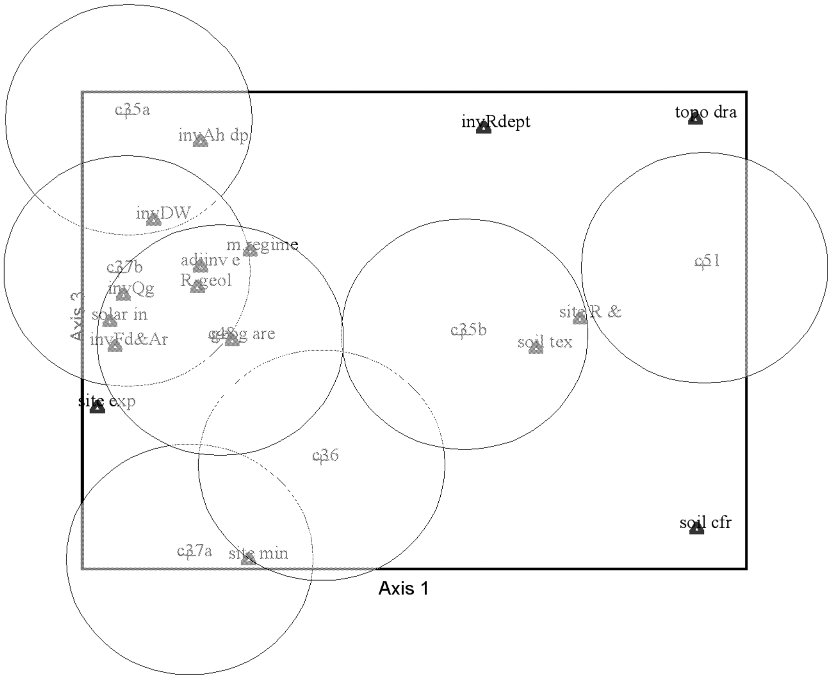

Figure 2 Environmental factors for early season plant communities: axis 1 vs. 3.

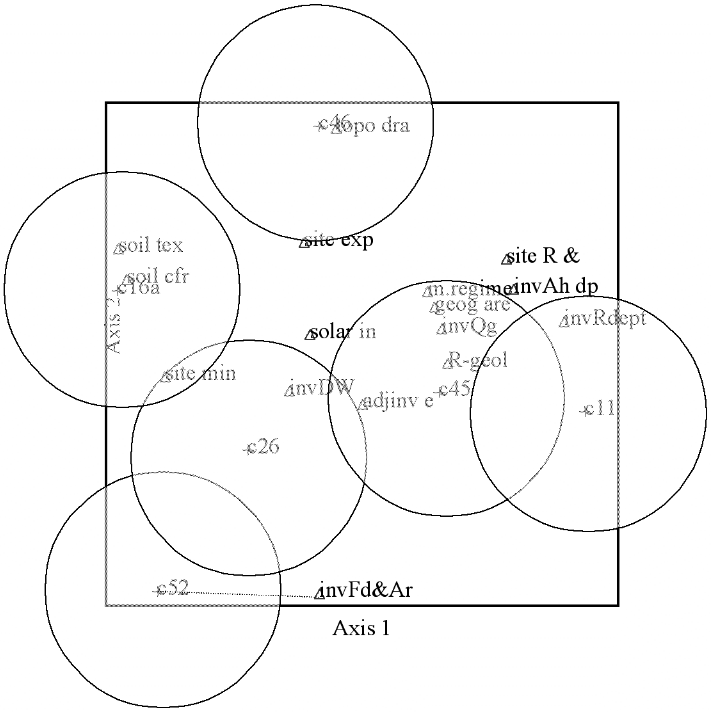

Figure 3 Bedrock outcrop and rocky plant communities and environmental variables: axis 1 vs 2.

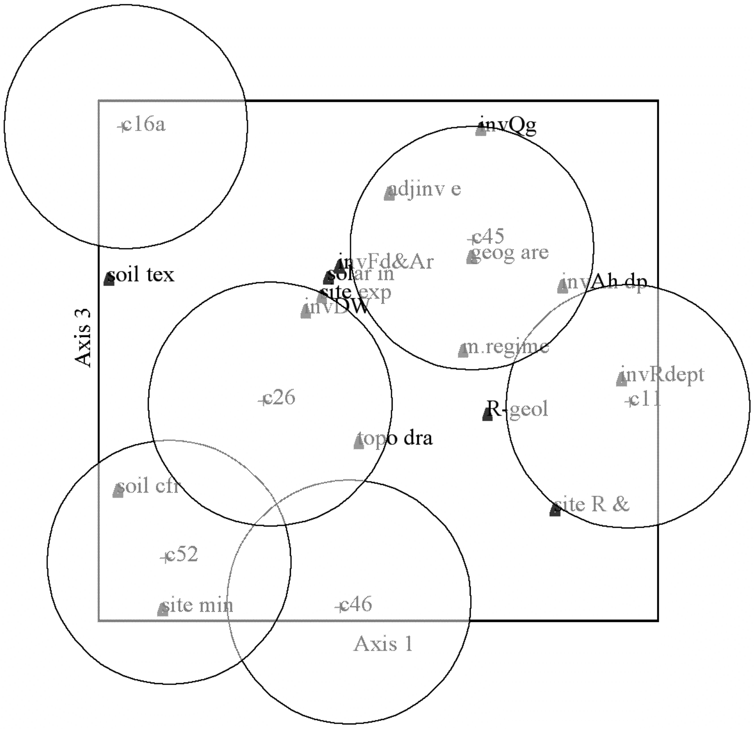

Figure 4 Bedrock outcrop and rocky plant communities and environmental variables: axis 1 vs. 3.

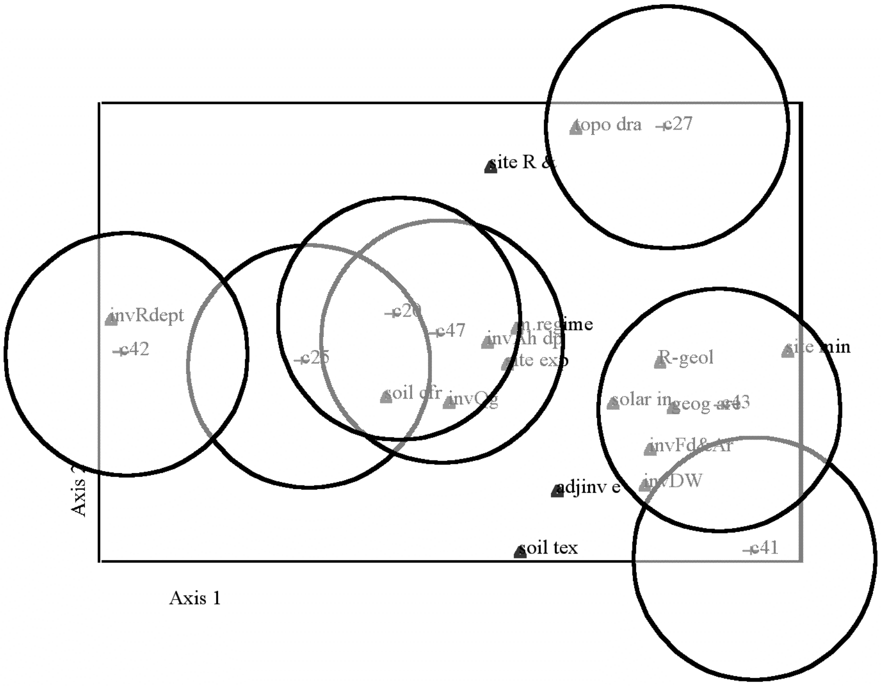

Figure 5 Other native plant communities and environmental variables: axis 1 vs 2.

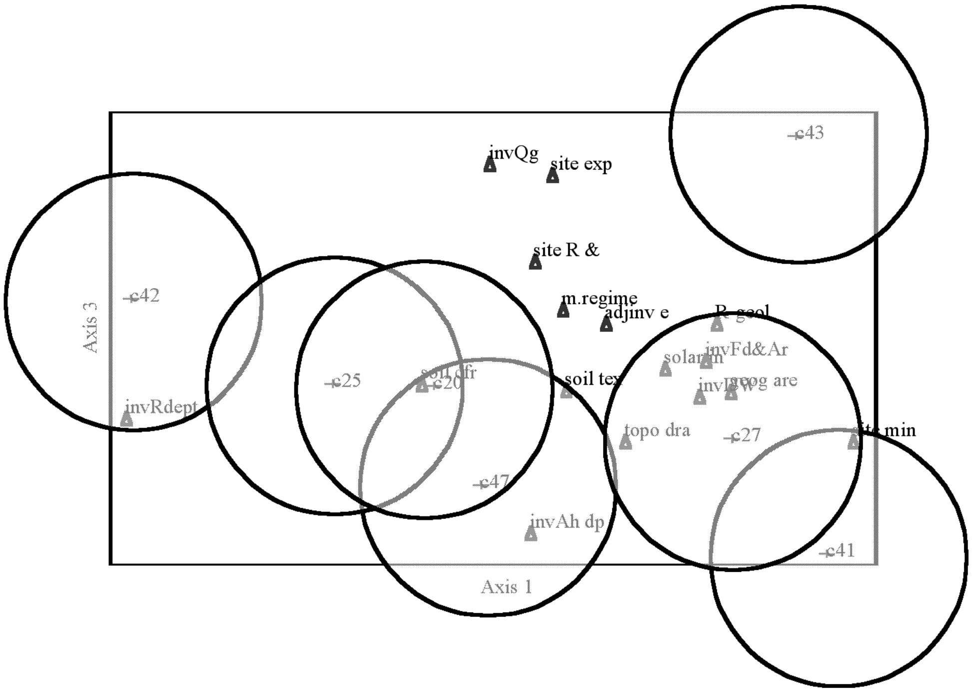

Figure 6 Other native plant communities and environmental variables: axis 1 vs. 3.

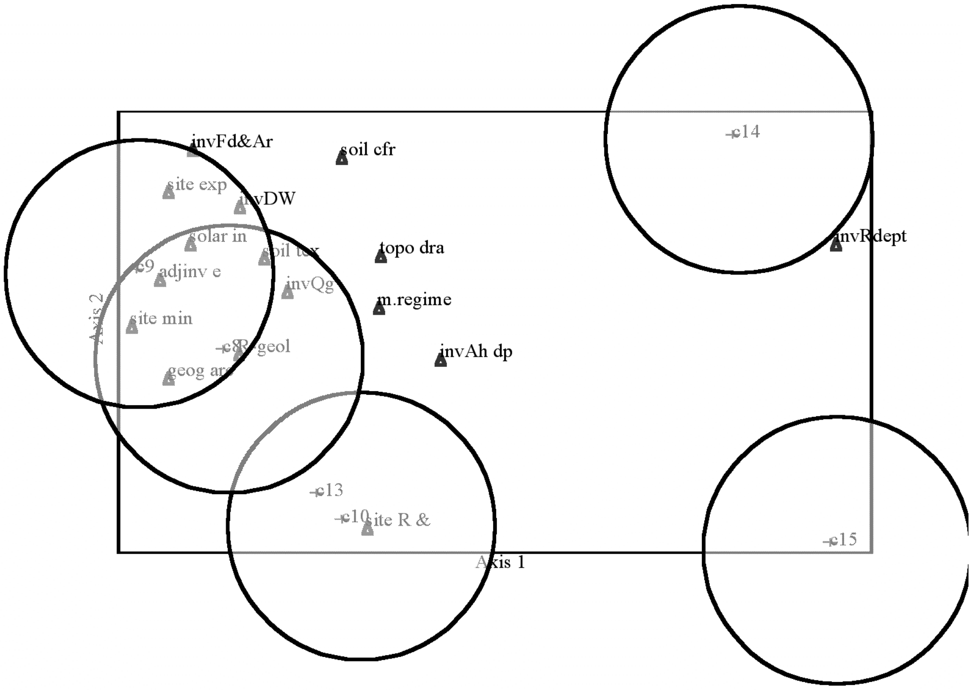

Figure 7 Wet native plant communities and environmental variables: axis 1 vs. 2.

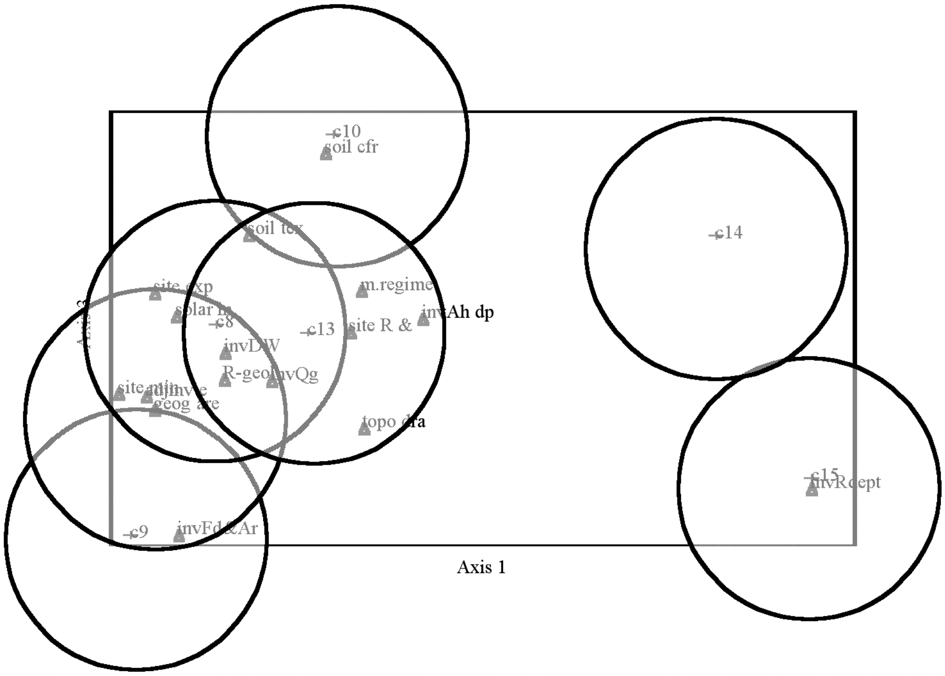

Figure 8 Wet native plant communities and environmental variables: axis 1 vs 3.

Environmental Variables Associated with Individual Communities

Twenty-six associations of environmental variables occurred with particular communities *(figs. 1-8)*, including 13 of the variables. Missing were site exposure, *Ah* horizon depth, and moisture regime. Highest among these, each with five, were associations of site mineral soil exposure, and soil coarse fragments with communities. Geographic area had three associations. A number of variables had two: topographic drainage, soil texture, downed wood, depth to bedrock, elevation, and Garry oak cover.

Site mineral soil exposure was associated with five Garry oak communities (4 unique associations and 1 strong), all with high values: *Camassia quamash* Typic *(figs. 1, 2); Dicranum scoparium* Typic; *Mahonia aquifolium (figs. 3, 4); Bromus carinatus (figs. 5, 6);* and *Symphoricarpos albus-Rosa nutkana-Lonicera ciliosa (figs. 7, 8).*

Soil percent coarse fragments was also associated with five Garry oak communities (3 unique associations and 2 strong): *Dicranum scoparium* Typic; *Lonicera hispidula (figs. 3, 4); Festuca idahoensis*; and *Festuca idahoensis-Cerastium arvense (figs. 5, 6):* each with high values in the data; and *Elymus glaucus (figs. 5, 6),* with moderate values.

Geographic area was strongly associated with three Garry oak communities: *Dicranum scoparium-Sedum spathulifolium (figs. 3, 4)* and *Montia perfoliata (figs. 1, 2),* with high values; and *Symphoricarpos albus-Rosa nutkana-Lonicera ciliosa (figs. 7, 8),* with moderate values in the data. High values indicate a more south-easterly (warmer, drier) distribution; moderate values a more mixed distribution; and for both: probably also biogeographic differences associated with a history on the main island.

Topographic drainage was strongly or moderately associated with two Garry oak communities: *Dicranum scoparium-Plectritus congesta (figs. 1, 2)* (on convex sites which rapidly shed soil moisture); and *Festuca idahoensis-Trifolium microcephalum (figs. 5, 6),* both of which had high values.

Soil texture was strongly associated with two Garry oak communities: *Camassia quamash-Dodecatheon hendersonii (figs. 1, 2),* and *Lonicera hispidula (figs. 3, 4),* both of which had high values (coarse soils).

Depth to bedrock was strongly associated with two Garry oak communities: *Dicranum scoparium-Montia parviflorum (figs. 3, 4)* and *Festuca idahoensis-Vicia americana (figs. 5, 6),* both with high values for their shallow soils relative to others within their category.

Downed wood was strongly or moderately associated with two Garry oak communities: *Camassia quamash-Erythronium oregonum (figs. 1, 2)* and *Mahonia aquifolium (figs. 3, 4),* both of which had low cover in their community means.

Elevation was uniquely or strongly associated with two Garry oak communities: *Symphoricarpos albus-Rosa nutkana-Lonicera ciliosa (figs. 7, 8)* and *Dicranum scoparium-Sedum spathulifolium (figs. 3, 4),* both of which had low elevations. The same two communities also had a relationship with Garry oak cover (high covers on the former, low on the latter).

Douglas-fir and Arbutus cover was strongly associated with one Garry oak community, *Symphoricarpos albus-Rosa nutkana-Oemleria cerasiformis*, with a relative deficiency of cover for these trees. These sites are multi-layered, deciduous shrub thickets.

Site bedrock and rock exposure was strongly associated with one Garry oak community: *Melica subulata (figs. 7, 8),* which had moderately high values.

The remaining variables in this set, bedrock geology and solar insolation, were strongly associated with one Garry oak community, *Symphoricarpos albus-Rosa nutkana-Lonicera ciliosa (figs. 7, 8),* which also had one variable (geographic area) above. Their high values suggest sites with coarse, nutrient poor bedrock on steep south and southwesterly-facing slopes, relative to others within the “wet” category.

All 16 variables were found in conjunction with communities on one axis combination, except depth to bedrock (which had several strong associations).

Discussion

The results indicate an adequate degree of differentiation in the community framework. Fifteen communities were distinct in the interpretive graphing. Of those not differentiated, two were subcommunities not expected to differ in their environmental relationships, six were uniquely associated with environmental variables, leaving three communities not accounted for. However, communities may not correspond to extreme values of any particular variable, especially if they have intermediate moisture relations. The Garry oak-*Elymus glaucus* community, for example, was found with moderate values of soil coarse fragments; low values for moisture regime, site exposure and Garry oak cover; and moderate values for soil texture; the latter four variables all on one axis combination.

Differentiation for subcommunities (10) exceeded that for communities (5), suggesting that subcommunities may not be sharing the same ecological sites. Short temporal-scale, within-community plant succession may characterize recovery after minor disturbance in these subcommunities. For example, in Garry oak habitat, *Festuca idahoensis-Trifolium microcephalum* may lead to *Festuca idahoensis-Cerastium arvense* and then to a *Festuca idahoensis* subcommunity (Erickson 1996). There could be corresponding site-level environmental changes, such as decreasing bare mineral soil exposure. The results on differentiation could be used to modify the concepts or placement of subcommunities. Either site differences and moderate vegetation differences could be recognized, or the more distinct subcommunities could be elevated to communities. The differentiation results on their own do not compellingly suggest classification changes, but they could contribute to a review which includes vegetation comparisons.

The environmental variables were adequately represented by the community framework, with most of the environmental multivariate space covered by communities. In the early season category, *Ah* horizon depth and soil coarse fragments were not covered, suggesting potential additions of communities with intermediate values for these variables. In the wet native category, considerable space was not covered, but it did not correspond to the location of environmental variables. Instead, these gaps seem to result from the fact that the values for depth to bedrock were strongly skewed in both directions. Compensating factors, such as the inflow of soil moisture from bedrock, might also mask a vegetation response to intermediate values.

The strength of the associations for these variables does not present evidence for a 1:1 relationship between sites and communities. Environmentally-distinct communities with single identified variables comprise about 58 percent of the total. Plant communities have been taken as the integrators of site conditions. However, with subtle site differences and variations in biogeographic and disturbance histories, it is unlikely there will ever be total predictability. Many communities may respond to a suite of environmental variables, rather than to one outstanding variable.

Soil coarse fragments, site mineral soil exposure, and geographic area were the most important variables in the community framework, followed by topographic drainage, soil texture, depth to bedrock, percent downed wood, and elevation. The remaining variables were associated with only one or with no communities. These results differ from previous gradient-level multiple regression work (Erickson 1996, 2000), but this is attributed to the difference in scale. The present work addresses small-patch communities scattered in a mosaic, as may be appropriate for discontinuous distributions at a range margin.

Applying the environmental relationships from this study could advance both site and vegetation assessments in preservation initiatives, and predictive ability for restoration work in Garry oak habitat. With the addition of numeric thresholds, an environmental key could be developed which would allow ecological sites to be assigned to plant communities in the absence of vegetation information. These relationships could be applied in broad ecological surveys, such as predictive mapping. A tested, refined, and more ecosystematic plant community classification should stimulate wider application and therefore encourage the conservation of these important elements of biodiversity.

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