Status of Vegetation Classification in Redwood Ecosystems[1]

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Abstract

Vegetation classifications, based primarily on physiognomic variability and canopy dominants and derived principally from remotely sensed imagery, have been completed for the entire redwood range (Eyre 1980, Fox 1989). However, systematic, quantitative, floristic-based vegetation classifications in old-growth redwood forests have not been completed for large portions of redwood's range. Quantitative classifications have been completed in portions of the northern (Atzet and Wheeler 1984, Becking 1967, Jimerson and Jones 2000, Lenihan 1986, Mahony 1999a, Mahony and Stuart 2000, Matthews 1986, Mendonca[4]), and extreme southern portion of redwood's range (Becking 1971, Borchert and others 1988). With the exception of very limited sampling in Marin and San Mateo Counties by Keeler-Wolf and others (2003), no quantitative classifications have been published for the central and much of the southern portion of redwood's range. Vegetation classifications are most useful if classification units are spatially represented on maps, but this is often difficult using standard remote sensing techniques. Vegetation modeling is one technique which may allow vegetation classification units to be mapped. Mahony (1999b) developed a predictive model for a portion of the northern redwood range based on a quantitative, floristic-based vegetation classification, discriminant analysis, and a Geographic Information System. Based on field verification, the model was 75 percent accurate.

Key words: old-growth, redwood, vegetation classification, vegetation modeling

Introduction

Redwood5 forests are endemic to a narrow coastal belt, one to fifty kilometers wide, from central California to southwestern Oregon (Fox 1989, Griffin and Critchfield 1972, Roy 1966). Temperature, precipitation, substrate, and other abiotic variables differ throughout redwood's range, producing tremendous diversity in species composition, stand structure, and stand dynamics.

Vegetation classification is a tool used to simplify highly complex natural ecosystems into repeatable, relatively homogeneous vegetation units for the purpose of management and communication. While there are many ways to describe and classify vegetation, systematic, quantitative, floristic-based classifications are most

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[5] Common names are used throughout the text. Corresponding scientific nomenclature follows Hickman (1993) and is included as Appendix A.

effective for vegetation conservation and management (Sawyer and Keeler-Wolf 1995). Quantitative, floristic-based classifications, such as those used by the California Native Plant Society (Sawyer and Keeler-Wolf 1995) and the California Department of Fish and Game (California Department of Fish and Game 2003), classify vegetation based on the dominant overstory species (series or alliance), in conjunction with the dominant understory species (association).

Despite the importance of classification to understanding and managing redwood ecosystems, large portions of the redwood range have not been quantitatively classified and described. Most redwood forests have been logged (Evarts and Popper 2001, Fox 1989, Sawyer and others 2000). Classification of remaining old-growth redwood is particularly important because old-growth forests are in greater equilibrium with site variables compared to rapidly changing logged forests, and represent conditions generally present prior to large scale human disturbance. Information gleaned from old-growth classification can, in addition to assisting in management and conservation of old-growth forests themselves, provide baseline data essential to restoring logged redwood ecosystems to old-growth conditions.

Classifications Conducted in Redwood Ecosystems

Vegetation classifications, based primarily on physiognomic variability and canopy dominants and derived principally from remotely sensed imagery, have been completed for the entire redwood range (Eyre 1980, Fox 1989). These efforts are crucial to understanding the geographic extent, canopy physiognomy, and ecological dynamics of redwood forests at coarse scales. However, systematic, quantitative, floristic-based vegetation classifications in old-growth redwood forests have not been completed for large portions of redwood's range.

Quantitative, floristic-based classifications have been completed in portions of the northern (Atzet and Wheeler 1984, Becking 1967, Jimerson and Jones 2000, Lenihan 1986, Mahony 1999a, Mahony and Stuart 2000, Matthews 1986, Mendonca[6]), and extreme southern portion of redwood's range (Becking 1971, Borchert and others 1988). With the exception of very limited sampling in Marin and San Mateo Counties by Keeler-Wolf and others (2003), no redwood classifications have been published for the central and much of the southern portion of the range. The three redwood range divisions described here generally follow Sawyer and others (2000).

Based on completed classifications, it is clear that redwood forests are highly variable in terms of stand structure, floristic composition, and ecosystem dynamics. Redwood forests, therefore, are not a uniform vegetation type but a highly diverse assemblage of forest associations that, with the exception of redwood trees themselves, have few floristic and structural attributes in common. This variability underscores the importance of classifying all redwood stands, particularly old-growth stands, in order to develop a complete catalogue of redwood forest associations occurring throughout the range. Moisture availability, represented by abiotic variables such as elevation, topographic position, aspect, slope angle, and coastal proximity, appears to be a dominant factor determining composition of redwood

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[6] Unpublished data on file, Humboldt State University, Arcata, California.

forests both within a particular region and throughout the range as a whole.

Northern Range

Northern redwood forests are the most extensively classified redwood forests. Becking (1967) classified redwood into alliances (=series): the Redwood-redwood sorrel alliance and Redwood-sword fern alliance. He indicated that the moist Redwood-redwood sorrel alliance occurred on lower slopes and alluvial flats, and the drier Redwood-sword fern alliance was generally found on middle and upper slopes and ridges.

Lenihan (1986) described three old-growth redwood associations occurring along a moisture gradient in the Little Lost Man Creek Research Natural Area in Redwood National Park, California: Redwood/deer fern, Redwood/little Oregon-grape, and Redwood/madrone. He considered the associations as moist, mesic, and xeric habitats, respectively.

Matthews (1986) described four series, five associations, and one phase in the Bull Creek watershed, Humboldt Redwoods State Park, California: Redwood/ redwood sorrel, Redwood-Douglas-fir/salal, Redwood-Douglas-fir/evergreen huckleberry, Redwood-Douglas-fir/madrone, and Douglas-fir/tanoak-madrone. He suggested these associations were arranged along a complex environmental gradient controlled primarily by soil moisture.

Mahony (1999a) and Mahony and Stuart (2000) classified and described six associations within the redwood series throughout the northern range of redwood in Jedediah Smith Redwoods State Park, Del Norte Coast Redwoods State Park, and northern Redwood National Park in northwestern California, and the Siskiyou National Forest in southwestern Oregon: Redwood/sword fern, Redwood-Douglas-fir/rhododendron, Redwood-western hemlock/evergreen huckleberry, Redwood-western hemlock/sword fern, Redwood-western hemlock/salmonberry, and Redwood-red alder/salmonberry. They suggested that moisture was the primary environmental variable controlling the distribution of forest associations. Discriminant analysis revealed that the physiographic factors influencing floristic associations, in decreasing order of importance, were elevation, coastal proximity, and a combination of aspect and topographic position called a Moisture Equivalency Index.

Jimerson and Jones (2000) described ten redwood associations in both old-growth and logged portions of the Headwaters Forest Reserve in central Humboldt County: Redwood-tanoak/evergreen huckleberry-salal, Redwood-tanoak/sword fern, Redwood-Douglas-fir/salal-evergreen huckleberry, Redwood-Douglas-fir/sword fern, Redwood-red alder/salmonberry, Redwood-western hemlock/evergreen huckleberry-salal, Redwood-western hemlock/salmonberry/sword fern, Redwood-western red-cedar/sword fern, Redwood-Sitka spruce/thimbleberry, and Redwood-grand fir/salal/ sword fern. Redwood associations in the Reserve were correlated with abiotic factors generally indicative of moisture availability, such as elevation, aspect, slope angle, slope position, and coastal proximity, with elevation the strongest correlated variable.

Mendonca[7] described four old-growth forest associations and two cutover forest associations in the forested portion of Prairie Creek Redwoods State Park in northern Humboldt and southern Del Norte Counties. The old-growth forest associations are: Redwood/sword fern-evergreen huckleberry-redwood sorrel, Redwood-Douglas-fir/tanoak-rhododendron/evergreen huckleberry-sword fern, Redwood-western hem-

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[7] Unpublished data on file, Humboldt State University, Arcata, California

lock-Sitka spruce/sword fern, and Red alder-Sitka spruce/salmonberry-sword fern. The associations described for cutover stands are: Sitka spruce/sword fern-salmonberry and Redwood-Sitka spruce/evergreen huckleberry-sword fern. The distribution of associations throughout the park was correlated with logging disturbance and abiotic variables such as elevation, topographic position, aspect, and coastal proximity.

Central Range

Keeler-Wolf and others (2003) described two associations in the redwood alliance (=series) in portions of Marin and San Mateo Counties based on thirteen plots: Redwood/tanoak/evergreen huckleberry and Redwood-Douglas-fir-California bay. The associations occurred throughout a variety of environmental conditions, and most showed signs of past logging disturbance.

Southern Range

Becking (1971) sampled 26 plots in Monterey County, California, which he placed in the Redwood-tanoak-Coulter pine association and the Redwood-tanoak-redwood sorrel association. He suggested that the redwood forest distribution in the area was primarily a result of soil moisture, with the former association occurring on drier sites and the latter on moister sites.

Borchert and others (1988) classified redwood in the southern part of the range in southern Monterey County, California using the USDA Forest Service ecological type classification system. They devised six associations ("ecological types") using biophysical factors such as landform and soil series: Redwood/western bracken-chain fern//Streamsides, Redwood/sword fern-western trillium//Gamboa-Sur, Redwood//Gamboa-Sur, Redwood/common man-root-common vetch//Gamboa-Sur, Redwood-bigleaf maple/California polypody//Gamboa, and Redwood-tanoak/round fruited carex-Douglas iris//Gamboa.

Vegetation Classification Modeling

Vegetation classifications are most useful if classification units are represented on maps, since management and conservation activities can then be spatially correlated and quantified. While vegetation maps exist for many redwood forests, the vegetation mapping units are not necessarily related to classification units. Vegetation maps depict visually distinct groupings of plants at some scale, but a vegetation classification lacks scale and can involve much more complex floristic or structural detail compared to what can be effectively mapped. However, the best maps are presented in the form of a classification (Sawyer and Keeler-Wolf 1995, Sawyer and others 2000), and vice-versa.

Classification units, particularly at the association level, can be difficult to map in redwood forests because: (1) classification unit boundaries are often diffuse and spatially patchy; (2) classification units may be too small to be shown at a designated map resolution; and (3) floristic variability at the series (=alliance) level is often difficult to identify from remotely sensed imagery (Sawyer and others 2000), and virtually impossible to identify at the association level in redwood forests due to dense canopy cover. Since much redwood forest variability is found at the association level, the ability to map associations can be extremely beneficial for redwood conservation and management.

Vegetation modeling is one technique which may allow vegetation classification units to be mapped across the landscape. Predictive vegetation modeling using quantitative vegetation classification and Geographic Information System (GIS) technologies is emerging as an effective method of mapping and predicting vegetation at landscape scales (Brzeziecki and others 1993; Franklin 1995, 1998; Lowell 1991).

Mahony (1999b) developed a prediction model for a portion of the northern redwood range in Jedediah Smith Redwoods State Park in Del Norte County based on a quantitative floristic classification developed by Mahony (1999a) and Mahony and Stuart (2000). The classification described three old-growth redwood forest associations in the park, and discriminant analysis correlated each forest association with abiotic variables, including elevation, coastal proximity, slope position, and aspect. Discriminant analysis is a statistical technique assessing differences between two or more groups and a set of discriminating variables (Klecka 1980). The eigenvalue (expressed in individual percentages relative to total percent) indicates how much discriminatory power each function has.

The prediction model used the following assumptions: (1) all old-growth redwood vegetation in the park consists of one of three classified associations; (2) each association has distinct correlations with the abiotic variables of elevation, coastal proximity, slope, and topographic position/aspect (in the form of a moisture equivalency index (MEI), an index of soil moisture); (3) abiotic variables can be identified on a ten-meter Digital Elevation Model (DEM); and (4) equations can be developed predicting the most likely association occupying each DEM pixel.

Equations were developed that predicted, based on an association's affinity for each abiotic variable derived from discriminant analysis, which pixel in a DEM had the strongest correlation with a particular association. After the equations were run in Arc/Info GRID, the association with the highest score for a particular pixel (the higher the score, the greater the affinity for abiotic variables found in the pixel) was the association to which the pixel was classified. With each pixel classified, a vector map was created depicting predicted associations as polygons.

To determine model accuracy, the map was field verified. Based on 296 ground samples, the map was determined to be 75 percent accurate. Using similar methods, additional models were developed for other portions of Redwood National and State Parks, with similar, though slightly less accurate, results.

While vegetation modeling has limitations, it offers a technique to depict classification units in mapped form. When classification units are mapped, they can be quantified and defined for the purposes of conservation planning and resource management. Prediction models developed over the entire redwood range can help resource managers, scientists, and conservation professionals quantify, compare, and conserve the diversity of redwood ecosystems found throughout the entire range. Since modeling predicts potential vegetation (Brzeziecki and others 1993), it can be used for second-growth management to approximate old-growth forest associations which existed prior to harvesting, and subsequently guide restoration efforts. Finally, since wildlife habitat modeling is essentially identical to vegetation modeling (Franklin 1995), wildlife managers can utilize forest association models to predict suitable wildlife habitat.

Conclusions and Recommendations

Vegetation classification offers important baseline information that can be used to understand, conserve, and manage redwood forests. Quantitative, floristic-based classifications have been completed in portions, most notably the northern part, of redwood's range, but large sections of the range have not been adequately classified and described. Unclassified old-growth redwood forests should be prioritized for quantitative, floristic-based classification in order to develop a complete redwood forest baseline. Classification information can be incorporated into vegetative models to map existing old-growth forest associations, as well as approximate pre-logging conditions in cutover forests to aid in restoration and management.

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Appendix A. *Common and scientific names for species mentioned in the text. Nomenclature for scientific names follows Hickman (1993).*

bigleaf maple	*Acer macrophyllum*
California bay	*Umbellularia californica*
California polypody	*Polypodium californicum*
chain fern	*Woodwardia fimbriata*
common man-root	*Marah fabaceus*
common vetch	*Vicia sativa* ssp. *nigra*
Coulter pine	*Pinus coulteri*
deer fern	*Blechnum spicant*
Douglas-fir	*Pseudotsuga menziesii* var. *menziesii*
Douglas iris	*Iris douglasiana*
evergreen huckleberry	*Vaccinium ovatum*
grand fir	*Abies grandis*
little Oregon grape	*Berberis nervosa*
madrone	*Arbutus menziesii*
red alder	*Alnus rubra*
redwood	*Sequoia sempervirens*
redwood sorrel	*Oxalis oregana*
rhododendron	*Rhododendron macrophyllum*
round fruited carex	*Carex globosa*
salal	*Gaultheria shallon*
salmonberry	*Rubus spectabilis*
Sitka spruce	*Picea sitchensis*
sword fern	*Polystichum munitum*
tanoak	*Lithocarpus densiflorus*
thimbleberry	*Rubus parviflorus*
western bracken	*Pteridium aquilinum* var. *pubescens*
western hemlock	*Tsuga heterophylla*
western redcedar	*Thuja plicata*
western trillium	*Trillium ovatum* ssp. *ovatum*