RIPARIAN COMMUNITIES OF THE SIERRA NEVADA AND THEIR ENVIRONMENTAL RELATIONSHIPS[1]

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Abstract: Data on riparian community composition and environmental conditions were collected on over 20 streams in the Sierra Nevada as part of hydropower licensing studies. Over 1,000 samples were analyzed using two-way indicator species analysis (TWINSPAN), to determine riparian dominance types. Ordination techniques were applied to evaluate associations between environmental conditions and community characteristics. Results indicate that at least 15 communities are found in riparian settings at altitudes ranging from 300 to 3000 m on eastern and western slopes of the Sierra Nevada. These communities are arranged in the landscape in apparent response to climatic and geomorphic gradients.

The published literature contains few descriptions of riparian communities in California montane settings. In recent years, these communities have been subject to intensive ecological investigations performed in conjunction with agency permit requirements for hydroelectric development. Reports of these investigations fall into that elusive category of "grey" literature which is rarely accessible to scientists and managers. Fragments have been published in the refereed literature (Harris and others 1987; Harris 1988) and symposia proceedings (Harris and others 1985; Taylor and others 1987).

The purpose of this paper is to summarize some of the ecological studies conducted by consultants to Pacific Gas and Electric Company (PG and E) and Southern California Edison Company (SCE) with the specific aim of presenting an overview of the physical and botanical characteristics of riparian communities in the Sierra Nevada. These consultant studies encompass many of the communities occurring at altitudes from 300 to 3000 m in the central Sierra Nevada. Because field studies and analysis techniques were to some degree standardized, the results represent a valuable data base on montane riparian communities of the region. This data base is available to other scientists who may be stimulated by the introductory materials contained in this paper.

Methods

Study Area Location

Detailed ecological studies were conducted by PG and E, SCE and other hydropower developers throughout California's central Sierra Nevada Mountains. This paper is confined to the results of studies undertaken by Jones and Stokes Associates (1984,1985) and Taylor and Davilla (1985,1986). Jones and Stokes Associates (1984) sampled existing streamflow diversion sites from Fresno County north to Plumas County to analyze effects of existing hydropower projects on riparian communities. They also conducted an intensive field study in the upper Kings River basin, Fresno County. Taylor and Davilla (1985,1986) conducted intensive studies in Madera and Fresno Counties, respectively, in the upper San Joaquin and Kings River basins. Thus, the data base includes both extensive and intensive sampling programs.

Jones and Stokes Associates (1985) sampled existing SCE hydropower sites and unregulated stream reaches in the eastern Sierra Nevada from Bishop north to Lee Vining (Inyo and Mono Counties). Although numerous other hydropower developments have been proposed in the eastern Sierra Nevada, data collection efforts have not been coordinated except in the case of SCE projects.

Field Sampling Techniques

Field techniques used by Jones and Stokes Associates (1984, 1985) were described by Harris and others (1987) and more recently by Harris (1988). Except for an additional procedure described below, the same techniques were used by Taylor and Davilla (1985, 1986). Briefly, the initial step was to stratify streams into reaches using physiographic and hydrologic criteria. Typical criteria included stream order, altitude, valley geomorphology and substrate. After field reconnaissance, sample sites were selected in stratified reaches. Sample sites were homogeneous with respect to vegetation and geomorphology, as subjectively judged in the field.

Two sampling procedures were used. Jones and Stokes Associates (1984,1985) used transects perpendicular to channels and spanning the floodplain to collect

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vegetation and environmental data. Taylor and Davilla (1985,1986) also used transects but complemented the transect sampling with a plotless stand survey sampling scheme i.e. releves, (Mueller-Dombois and Ellenberg 1974).

In transect sampling, plant cover values were measured, while in releves they were estimated by using a scale. In either method, various environmental data were collected at each sample site. The releve method was advantageous for rapid collection of compositional data from an extensive area. The transect method was most useful for obtaining detailed data to study community-environmental relationships.

Further information on sampling procedures may be obtained from published accounts and reports available from the sponsoring utility companies. Considering all studies conducted by Jones and Stokes Associates and Taylor and Davilla, a total of 851 transects and 392 releves were sampled. Only 105 of the transects were sampled in the eastern Sierra Nevada.

Data Analysis Methods

Vegetation and environmental data were analyzed using univariate, bivariate and multivariate methods. Only techniques relevant to the presented results will be noted. To identify patterns of vegetation variation in relation to environmental conditions, combined ordination-classification techniques were used (Gauch 1982). Two-way indicator species analysis –TWINSPAN (Hill 1979a) was utilized to classify vegetation samples of equivalent floristic and compositional structure. Detrended correspondence analysis (Hill 1979b) and multiple regression were applied to investigate patterns in vegetation correlated with environmental conditions.

Results And Discussion

Riparian Community Types

The dominant environmental controls on riparian community composition in the Sierra Nevada are climate and stream valley geomorphology. Communities initially segregate by aspect, i.e. east or west slope of the range. On either slope, they are further distinguished by altitude. Both aspect and altitude are strongly correlated with climate (Major 1977). At a given altitude on either slope, community composition and structure are strongly affected by geomorphic factors such as steam size (order), floodplain development and surficial geology.

Jones and Stokes Associates (1984) classify west-slope communities at altitudes ranging from 1200 to 2500 m into five dominance types. Lower altitude communities (less than 1600 m) are dominated by *Alnus rhombifolia,* often in association with *Rhododendron occidentale* and *Fraxinus latifolia.* Mid-altitude streams (1600 to 2200 m) support communities dominated by *Alnus incana* ssp *tenuifolia* or *Salix lasiolepis* or mixtures of *Cornus stolinifera* and *Salix lasiolepis.* At higher altitudes, *Pinus contorta* var *murrayana* and *Spiraea densiflora* often dominate riparian communities, particularly in meadow-like settings.

The general classification presented by Jones and Stokes Associates (1984) was derived from data obtained throughout the central Sierra Nevada and is applicable to many perennial streams in the region. The work of Taylor and Davilla (1985, 1986) considerably expands understanding of communities existing at altitudes of 300 to 2200 m in the Fresno-Madera County area. Taylor and Davilla (1985) distinguish 20 community types in their watershed-study area. Nine are variants of the *Alnus rhombifolia* community separated on the basis of shrub and/or herb associates. Three additional community types are dominated by *Fraxinus latifolia.* Six are classified as dominated by conifers (*Abies magnifica* or *A. concolor*). These would be comparable to the shrub-dominated types of Jones and Stokes Associates (1984) in which the riparian community is bordered by, or in part composed of non-obligate conifers. In the latter work, non-obligate conifers were excluded as a basis for naming types. The remaining two types are identified as an *Alnus incana* ssp *tenuifolia* community and another dominated by *Populus balsamifera* var *trichocarpa.*

Taylor and Davilla (1986) classify streamside communities in their study area into four types; two dominated by *Alnus rhombifolia* and two by *Alnus rhombifolia* and *Fraxinus latifolia.* All of these were reported in their previous work.

Differences between the classifications of Jones and Stokes Associates and Taylor and Davilla are due to the objectives of each study, choice of classification level, choice of indicator species (in the case of conifers) and geographical area covered. Taylor and Davilla's work may be considered a finer resolution classification applicable to a watershed rather than a region. Considering all studies, there appear to be seven major dominance types that characterize west-slope riparian communities (table 1). These may be subdivided into variants on the basis of associated shrub and herb species, as demonstrated by Taylor and Davilla (1985, 1986). The need for subdivision, of course, depends on the objectives of the investigator. It is probable that intensive evaluation within the major dominance types at other locations would reveal additional floristic variation and associates.

Table 1 — Riparian Dominance Types of the Western Sierra Nevada

Dominance Type	Dominant Tree/Shrub	Indicator Shrub/Herb
Pinus contorta var *murrayana*	*Pinus contorta* var *murrayana*	*Spirea densiflora, Carex fracta, Deschampsia elongata*
Abies magnifica	*Abies magnifica*[1] *Salix lasiolepis*	*Salix drummondiana, Cornus stolinifera, Senecio triangularis, Athyrium filix-femina*
Alnus incana ssp *tenuifolia*	*Alnus incana* ssp *tenuifolia*[2]	*Rhododendron occidentale, Glyceria striata*
Populus balsamifera var *trichocarpa*	*Populus balsamifera* var *trichocarpa*	*Rhododendron occidentale*
Abies concolor[3]	*Abies concolor* *Cornus stolinifera,* *Salix lasiolepis*	*Rhododendron occidentale, Ribes nevedense, Rubus parviflorus, Boykinia major, Athyrium filix-femina*
Alnus rhombifolia[4]	*Alnus rhombifolia*	Many shrubs and herbs. See Taylor and Davilla (1985).
Fraxinus latifolia	*Fraxinus latifolia* *Alnus rhombifolia*	Many shrubs and herbs. See Taylor and Davilla (1985).

[1] *Abies magnifica* may be absent (*Salix lasiolepis* type of Jones and Stokes 1984).

[2] *Abies concolor* on valley slopes may provide substantial cover.

[3] *Abies concolor* is a facultative riparian species. Obligate riparian shrubs dominate near-stream cover.

[4] *Mixed conifer* forest dominates zonal vegetation. Subdivided into variants by Taylor and Davilla (1985).

In the eastern Sierra Nevada, Jones and Stokes Associates (1985) distinguish eight community types at altitudes ranging from 1200-3000 m. Streams on alluvial fans at lower altitudes are dominated by a *Chrysothamnus nauseosus* - *Artemisia tridentata* association and streams at highest altitudes are dominated by a *Pinus contorta* var *murrayana* - meadow community. The other six types (table 2) do not sort out simply along an altitudinal gradient. Their occurrence seems dependent on geomorphic and land use factors. They include communities dominated by *Populus balsamifera* var *trichocarpa, Populus tremuloides, Betula occidentalis* and *Salix* spp. The work of Jones and Stokes Associates (1985) focused on a fairly narrow range of streams and is not a comprehensive classification for the region.

Taylor (1982) presents a preliminary classification for eastern Sierra Nevada riparian communities. Taylor (1982) recognizes 18 "habitat types" divided into lower altitude, middle altitude and upper altitude communities. These include 5 dominated by *Salix* spp., 6 dominated by herbs, 4 dominated by conifers and 3 dominated by other deciduous trees or shrubs. Superficially, some of his communities appear similar to those of Jones and Stokes Associates (1985). Differences in objectives, methods, nomenclature and perhaps, taxonomy impair direct comparisons between the classifications. In particular, Jones and Stokes Associates (1985) did not encounter herb and conifer-dominated communities. Additional studies are needed in this region to derive a comprehensive classification.

Environmental Relationships of Dominance Types

Western Sierra Nevada riparian communities array themselves along an altitudinal/climatic gradient from the crest to the foothills. In addition to strong correlations between species' dominance and altitude, there is a strong negative correlation between altitude and percent tree cover and a strong positive correlation between altitude and herb cover (Jones and Stokes Associates

Table 2 – Riparian Dominance Types of the Eastern Sierra Nevada

Dominance Type	Dominant Tree/Shrub	Indicator Shrub/Herb
Pinus contorta var *murrayana* - meadow[1]	*Pinus contorta var murrayana, Salix* spp.	*Alium validum, Carex* spp.
Salix - Glyceria	*Salix* spp.	*Salix geyeriana*
Populus tremuloides	*Populus tremuloides Salix* spp.	*Elymus triticoides,*
Salix - Cornus[2]	*Salix* spp. *Cornus stolinifera*	*Equisetum, Deschampsia*
Betula - Saliz[3]	*Betula occidentalis Salix* spp.	*caespitosa, Carex lanuginosa*
Populus tremuloides -	*Populus tremuloides*	*Salix lasiolepis,*
Populus balsamifera var *trichocarpa*[4]	*Populus balsamifera* var *trichocarpa*	*Cornus stolinifera, Carex lanuginosa*
Populus - Rosa	*Populus balsamifera* var *trichocarpa Rosa woodsii*	*Salix exigua, Artemisia tridentata*
Chrysothamnus - Artemisia[5]	*Chrysothamnus nauseosus Artemisia tridentata*	*Salix exigua, Betula occidentalis, Phragmites australis*

[1]Comparable to higher altitude pine type of western Sierra Nevada.

[2]0ccasional *Populus balsamifera* var *trichocarpa* or *Pinus jeffreyi* may occur.

[3]Dominated by *Salix lasiolepis* according to Taylor (1982). Occasional large *Pinus jeffreyi* may occur.

[4]Complex vertical structure often with reduced herb cover.

[5]*Salix exigua* and *Betula occidentalis* typically dominate near-stream cover.

1984). Total canopy cover decreases with increasing altitude (Taylor and Davilla 1985).

Gradient i.e. channel slope, substrate and stream power are also correlated with occurrence of communities or with community structure (Jones and Stokes Associates 1984; Taylor and Davilla 1985,1986). In general, as gradient increases and substrate coarsens, communities tend to simplify. At the extreme, steep bedrock channels usually have little if any riparian cover. For example, of over 46 km of streams in the upper Kings River basin studied by Jones and Stokes Associates (1984) over 15 km were completely barren of vegetation. Canopy cover increases on gentle gradient reaches, especially with gravel and sand substrates (Taylor and Davilla 1985).

Particular riparian dominants are also associated with specific substrates or positions on floodplains (Jones and Stokes Associates 1984; Taylor and Davilla 1985; Harris and others 1985). Willows and some common riparian herbs (*Glyceria striata* and *Pteridium aquilinum*) are often associated with sand and cobble substrates. Many species can be grouped into classes based on their position of occurrence relative to the stream channel. *Alnus rhombifolia, Alnus incana* ssp *tenuifolia* and *Salix lasiolepis* all tend to occur immediately adjacent to channels (Jones and Stokes Associates 1984; Taylor and Davilla 1985). Conversely, *Abies concolor* and oaks are often associated with peripheral, outer floodplain locations. Intermediate positions on floodplains are occupied by facultative riparian conifers, principally pines, and *Calocedrus decurrens* (Taylor and Davilla 1985).

The effects of streamflow diversions on western Sierra Nevada riparian communities vary depending on site-specific environmental conditions (Harris and others 1987). Taylor and Davilla (1985) observed a general trend for increased canopy cover on diverted reaches relative to undiverted reaches in the upper San Joaquin watershed. Harris and others (1987) saw similar responses on some western Nevada streams but also found decreased cover on other streams. Investigators have also noted changes in community structure and density and sizes of riparian dominants on diverted reaches relative to comparable undiverted reaches.

Environmental relationships of eastern Sierra Nevada riparian communities have been described elsewhere (Harris 1988). Stream valley geomorphology i.e. valley shape and surficial geology, floodplain geomorphology and substrate show significant associations with different dominance types. Correlations between altitude and geomorphic conditions cause the gradient to be complex on the eastern slope and associations between communities and altitude are not as clear as on the western slope. Instead, communities tend to be associated with valley environments occurring at various altitudes. For example, glaciated bedrock streams at higher altitudes are vegetated by the *Pinus contorta* var *murrayana* - meadow community if the channel is incised with sand or cobble substrate. In the same valley type, if the channel is braided in gravel, the *Salix* spp - *Glyceria striata* community tends to dominate (Harris 1988).

Land uses such as grazing, tree cutting and streamflow diversion have also profoundly affected the areal extent and composition of riparian communities in the eastern Sierra Nevada (Taylor 1982; Harris and others 1987). The severe climate in this region, especially at arid lower altitudes, may affect the ability of a community to recover after disturbance or may exacerbate impacts. Streamflow diversions, in particular, have been responsible for extensive losses of riparian habitat on low-altitude, arid alluvial fans (Taylor 1982). The presence of the *Chrysothamnus nauseosus* - *Artemisia tri dentata* community on alluvial fans may reflect compositional changes from obligate riparian dominants to facultative riparian species due to diversions and other land use impacts (Harris and others 1987).

Additional analyses, and in the eastern Sierra Nevada particularly, additional data are needed to clarify environmental relationships with riparian dominants. Also, the ecological functions and successional processes of these communities have not been studied to date.

Management Implications

The resource values of riparian dominance types in the Sierra Nevada vary, depending on the composition and structure of the community at a specific location. Riparian communities should be considered multiple re-source settings. It is reasonable to expect the greatest number and diversity of values (i.e. wildlife habitat, fisheries, aesthetics, economics and recreation) to be associated with the most complex and diverse communities. Included in the western Sierra Nevada might be communities dominated by *Alnus rhombifolia* with well-developed shrub and herb layers. In the eastern Sierra Nevada, communities dominated by *Populus* may have highest resource values. Communities comprised exclusively of shrubs or dominated by conifers which have simple structure and low species diversity may not have the same range or magnitudes of resource values. They nevertheless are critical for specific ecological functions and deserve careful management and protection. Obviously, greater knowledge of resources associated with montane riparian communities is required before sound management prescriptions can be developed and impacts avoided.

Development of the classification presented here was possible because of standardized data collection and analysis techniques. Valuable data that could be used to enhance classification and management has been and continues to be collected by other investigators. This classification is a starting point for developing a regional riparian typology at a scale suitable for management. For the western Sierra Nevada, the range of occurrence of known dominance types and their environmental relationships need to be better understood. It is possible that additional major types might be disclosed by further field sampling. The need for refinement of major types into floristic variants, as was done by Taylor and Davilla (1985) could be determined by potential users and accommodated within a hierarchical system. In the eastern Sierra Nevada there has not been additional standardized sampling for expansion and refinement of the classification proposed by Jones and Stokes Associates (1985). There are undoubtedly dominance types in the region which were not included in their sample. The standardized format and methods used by prior investigators and documented in the literature cited should be used for future sampling if the value of the extensive existing data base is to be realized.

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