

RIPARIAN VEGETATION BASE-LINE ANALYSIS AND MONITORING ALONG BISHOP CREEK, CALIFORNIA¹

Janet L. Nachlinger, Carl A. Fox and Patricia A. Moen²

Abstract: A base-line analysis and long-term monitoring study of the riparian system along California's Bishop Creek is being conducted to measure the effects that planned increases in streamflow may have on riparian vegetation and associated wildlife. Six sites located in different major physiographic valley types have been selected for study. Biotic, climatologic, hydrologic, geomorphologic, and edaphic response parameters are being measured to evaluate streamflow and riparian vegetation relationships. Biotic parameters being monitored include stand structural parameters, species composition and importance values (density, cover, and basal area), as well as productivity, growth, and regeneration characteristics.

Riparian vegetation responds to changes in streamflow in various ways. Changes in riparian plant cover, growth, density, composition, and aerial extent all have been attributed in some degree to increases or decreases in streamflow. Highly variable responses in the relationship between historical changes in streamflow (from diversion projects) and existing riparian vegetation characteristics have been demonstrated on the eastside of the Sierra Nevada (Harris and others 1987; Jones and Stokes 1985; Taylor 1982). Stream reach physiography (local geomorphology and hydrology), elevation and substrate characteristics appear to be important in determining riparian vegetation characteristics along these eastside stream courses (Kondolf and others 1987; Southern California Edison 1986). Unless site specific environmental information is known, predicting the responses of riparian vegetation could be difficult because these streams have been found to respond individually to changes in streamflow.

On Bishop Creek in Inyo County, California, Southern California Edison Company (SCE) is planning the release of additional water from all diversions to assure the maintenance and enhancement of the existing riparian vegetation. While actual increases in streamflow are yet to be determined, total streamflow in all reaches is likely to be maintained at 0.28 - 0.57 m³/s (10-20 cfs).

To address the long-term effects of the anticipated increase in streamflow, SCE has initiated a monitoring study along Bishop Creek. The overall objective of this study is to measure the effects that the increase in streamflow will have on riparian vegetation and asso-

ciated wildlife. Because of the difficulty in interpreting results of wildlife studies, the emphasis is on monitoring riparian vegetation and streamflow relationships.

Characteristics of the Bishop Creek riparian system expected to change as a result of increased flows include horizontal and vertical stand structure, species composition, species importance, productivity, growth rates, and regeneration patterns. Stand structural characteristics, including riparian canopy coverage and leaf area index are expected to increase, as well as the riparian zone width, where it is not limited by geomorphological constraints (Harris and others 1987). Species composition within the riparian zone is expected to change over the long term by an increase in the numbers of obligate riparian and associated wetland species and a decrease in the numbers of upland species within the riparian corridor. Increases in riparian species importance, for example, increases in relative densities, relative cover, and relative frequencies of plants, are expected. Increases in riparian plant biomass, seedling survival patterns, and possibly growth rates are expected also (Smith and Nachlinger 1987). Although a diversity of community-level responses are expected to occur as a result of increasing the Bishop Creek streamflow, selection of community parameters and methodologies for measurement have been limited to those that provide relatively easy spatial and temporal comparisons to meet the overall objective of the study.

The monitoring study is envisioned to span a thirty-year period and is structured in two phases. The first phase is to establish a base line and involves three consecutive years of sampling. The objective of this initial phase work is to define the existing riparian system under present streamflow conditions. The second phase begins after streamflows are increased and involves monitoring riparian community parameters for changes at approximately five-year intervals. The objective of this phase is to detect spatial and temporal changes in riparian community structure and dynamics, as well as to measure changes in the physical setting, that may be attributed to the increased flows. Effects that may result from chance events, time, or inherent variability in study sites necessarily are being considered. This paper describes the monitoring sites and parameters selected for monitoring, and outlines the data collection and analysis methods that are being used in the study.

¹ Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

² Staff Plant Ecologist, Executive Director, and Research Assistant, Biological Sciences Center, Desert Research Institute, Reno, Nevada.

Materials and Methods

Monitoring Study Sites

The study area is located along Bishop Creek, southwest of the town of Bishop, in Inyo County, California (fig. 1). It encompasses the stretch of Bishop Creek between SCE Plant #6 at 1400 m elevation and SCE Intake #2 along the Middle Fork of Bishop Creek at 2440 m elevation. Three primary study sites and three potentially "sensitive" study sites have been selected for monitoring. Site selection and measurements of the responses of riparian vegetation to the proposed increased streamflows are being viewed within the context of the physical factors (stream reach physiography, elevation, and substrate characteristics) that generally determine the extent and characteristics of the riparian vegetation community. Three primary sites and three "sensitive" sites have been selected for monitoring. The three primary sites correspond to three major physiographic valley types present along Bishop Creek: U-shaped glacial valley, V-shaped glacial valley, and alluvial valley fan. The three sensitive sites are areas judged to be sensitive to changes in streamflow or have vegetation (or wildlife) of special interest. The primary site plots are 0.5 ha in size and are being monitored relatively more intensively than the sensitive site plots which are 0.25 ha in size. Three to six transects have been placed perpendicular to the stream at regular intervals within each site plot to aid in measuring some of these parameters. Site locations are shown in fig. 1. General site characteristics of the six monitoring sites are summarized in table 1.

Field Methods

To monitor potential changes in the Bishop Creek riparian system, several physical and biological parameters are being observed or measured at the study sites. Table 2 lists fifteen physical site parameters that are being measured at different intervals depending on the parameter. All of the edaphic and geomorphologic, and two of the hydrologic parameters (reach type and active channel width), were measured in summer 1988 when the sites were set up. They will be remeasured at the end of the study period to detect changes in these physical site characteristics that may be attributable to increased streamflows.

Soil water content and depth to the water table are being measured monthly during the April-October growth season. At the primary sites, soil water content is being determined gravimetrically on samples collected at 10 cm depth intervals at three points along a transect from streamside to upland locations (Donahue and

others 1983). Depth to the water table will be measured in wells proposed for drilling at the primary sites during the first year of sampling. Three wells will be drilled along the streamside to upland gradient at these sites. Ground water depths will be recorded at each well providing important hydrologic information especially during the spring recharge period.

Streamflow and several climatologic parameters already are being monitored daily at several locations along Bishop Creek. Streamflow data are being obtained from SCE gaging stations. Climatologic data from stations near the monitoring sites are being obtained from SCE, as well as from the National Climate Data Center and the California Data Exchange Center.

Table 3 lists the biological parameters selected for monitoring on an annual or monthly basis. Stand structural parameters (canopy cover, canopy height, and leaf area index) are being estimated annually at peak production before plant senescence commences. Canopy cover of trees and shrubs are being estimated using the crown-diameter method (Mueller Dombois and Ellenberg 1974). All individual tree and shrub heights are being estimated by triangulation or measured directly using meter sticks. Leaf area index (LAI) is being estimated for riparian trees and shrubs by sampling representative individuals within the plots. Three methods for estimating LAI are being tested during the initial field season: 1) point (rod)-intercept (MacArthur and MacArthur 1961); 2) fish-eye photography (Anderson 1971); and 3) destructive harvesting (allometric relationships). The method that proves to be the most precise and efficient will be used in the future. Additionally, width of the riparian zone is being measured directly along the transects within each plot.

The relative importance of riparian trees and shrubs are being determined at all sites. Tree density is being tallied for an entire plot, while shrub density is being sampled in subplots. Measurements of trunk diameters at breast height (DBH) are being made and then converted to basal area for all trees present in the plot. Since the DBH of multi-stemmed individuals can be difficult to assess, only the number of stems of multi-stemmed shrubs are being tallied in the subplots. Tree cover is being determined for the entire plot, while cover of shrubs and herbaceous plants are being measured by sampling along 7-12 line transects perpendicular to the stream. Cover of all species in three strata (trees, shrubs and herbaceous) is being estimated using the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974). The frequency of species in all strata will be determined by calculating the number of plots or subplots that contain at least one individual.

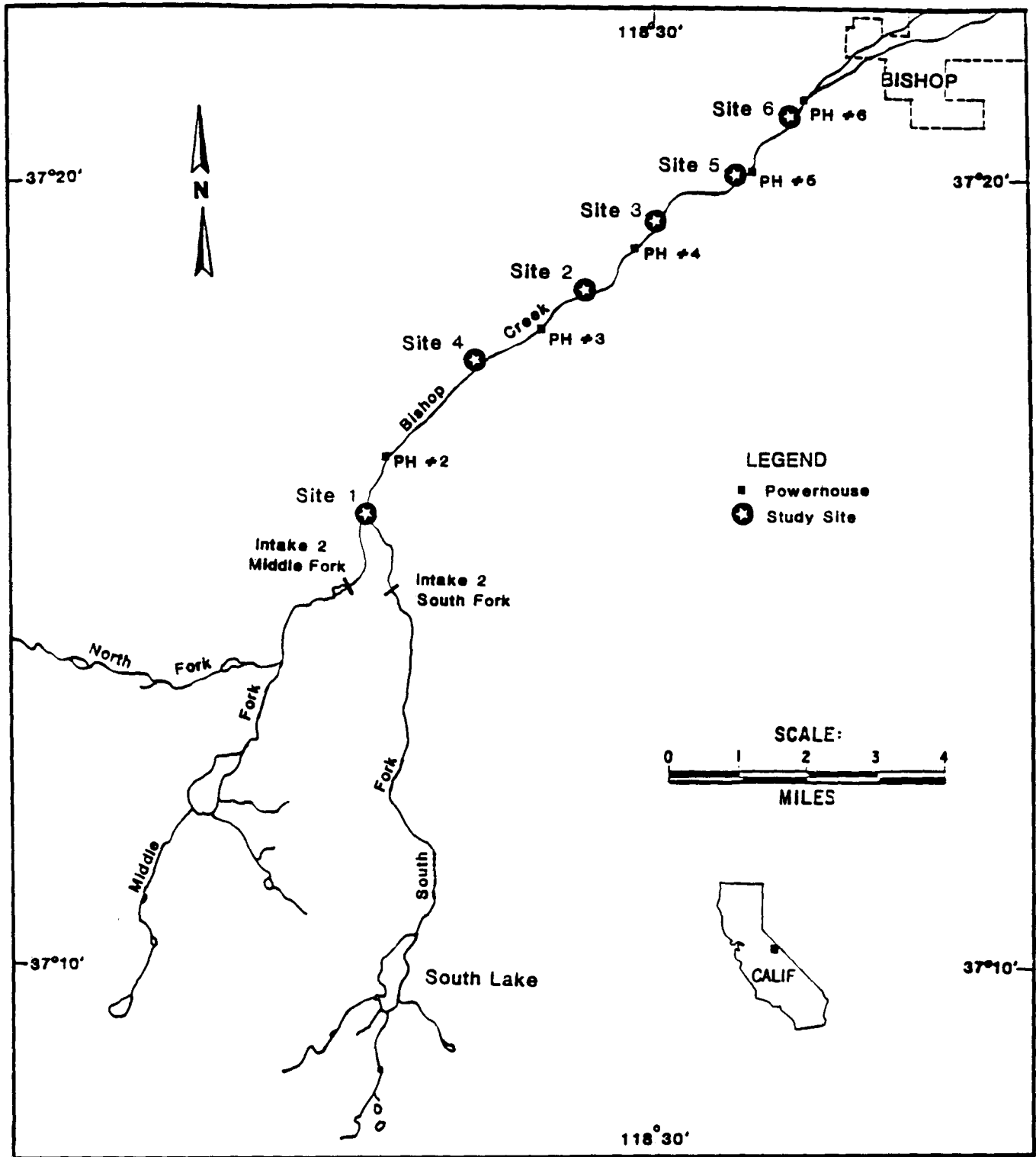


Figure 1 — Map of monitoring study site locations along Bishop Creek.

Table 1. General locations and characteristics of the selected primary and sensitive sites along Bishop Creek.

Site	General location	Elevation	Physiographic valley type	Vegetation type
<i>Primary</i>				
1	At the confluence of the South and Middle Forks adjacent to USDA Forest Service Big Trees Campground, and 1 km upstream from Plant #2	7400 ft 2255 m	U-shaped glacial valley	<i>Betula occidentalis</i> - <i>Salix lutea</i>
2	On the Main Fork, upstream of the confluence of Coyote Creek, and 1.8 km upstream from Plant #4	5640 ft 1720 m	V-shaped glacial valley	<i>Populus trichocarpa</i> - <i>Rosa woodsii</i>
3	On the Main Fork, at the head of the alluvial fan, and 1.8 km downstream from Plant #4	4920 ft 1500 m	Alluvial valley fan	<i>Populus trichocarpa</i> - <i>Rosa woodsii</i>
<i>Sensitive</i>				
4	On the Main Fork, 1.4 km upstream from Plant #3	6560 ft 2000 m	V-shaped glacial valley	<i>Betula occidentalis</i> - <i>Salix lutea</i>
5	On the Main Fork, 0.2 km upstream from Plant #5	4790 ft 1460 m	Alluvial valley fan	<i>Chrysothamnus nauseosus</i> - <i>Artemisia tridentata</i>
6	On the Main Fork, 0.5 km upstream from Plant #6	4575 ft 1395 m	Alluvial valley fan	<i>Chrysothamnus nauseosus</i> - <i>Artemisia tridentata</i>

Table 2. Physical parameters being measured or observed along Bishop Creek.

Parameter	Definition	Units	Sampling Frequency
<i>Climatologic</i>			
Air temperature	Maximum, minimum, and mean ambient temperature	Degrees C.	Daily
Precipitation	Total	Millimeters	Daily
Relative humidity	Maximum, minimum, and mean humidity	Percent	Daily
Wind speed	Mean wind speed	Meters/second	Daily
<i>Edaphic</i>			
Soil profile description	Description of soil horizon characteristics including color, structure, texture, and degree of alkalinity or acidity		Initially and at end of study
Surface substrate	Classification of substrate by size of particles (e.g. silt, sand, gravel, cobbles, boulders, and bedrock)		Initially and at end of study
<i>Geomorphologic</i>			
Physiographic valley type	Classification of valley types based on landform features (e.g. U-shaped glacial valley or alluvial fan)		Initially and at end of study
Elevation	Altitude above mean sea level	Meters	Initially and at end of study
Channel gradient	Slope of stream channel along length of stream	Degrees	Initially and at end of study
Valley slope	Slope of gently sloping surfaces perpendicular to the stream and beyond the active channel edge	Degrees	Initially and at end of study
<i>Hydrologic</i>			
Reach type	Classification of stream as gaining, losing, or in equilibrium		Initially and at end of study
Active channel width	Width across stream at height where the relatively steep bank slope breaks to a more gently sloping surface beyond the channel edge	Meters	Initially and at end of study
Streamflow	Volume of water in the channel passing a given location per unit time	Cubic meters/second	Daily
Soil water content	Percentage of water weight per unit soil weight	Percent	Monthly
Depth to water	Distance below ground surface to top table of saturated zone	Meters	Monthly (possibly daily)

Table 3. Biotic parameters being measured or estimated within the riparian corridor along Bishop Creek. These parameters are being sampled annually at the period of peak production, except for litter accumulation, seedling growth, seedling survival, and midday xylem pressure potential, which are being measured monthly during the growth season.

Parameter	Definition	Units
<i>Stand Structure</i>		
Canopy cover	Percentage of plot covered by tree and shrub canopies	Percent
Canopy height	Mean height of individual tree and shrub canopies	Meters
Leaf area index	Total leaf area (one surface only) per unit ground area	Meters ² per Meters ²
Riparian zone width	Width of riparian vegetation perpendicular to stream and excluding the channel width	Meters
<i>Relative Importance</i>		
Tree diameter at breast height	Diameter of tree trunk 1.3 meters above the ground	Meters
Tree, shrub and seedling density	Number of individuals per unit area	Number per hectare
Tree and shrub height	Height of individual shrubs in the plot	Meters
Shrub stem number	Number of stems of multi-stemmed shrubs	Number
Absolute cover	Percentage of plot (or subplots) covered by a given species	Percent
Frequency	Percentage of total plots (or subplots) which contains at least one individual of a given species	Percent
<i>Productivity</i>		
Shrub and herbaceous biomass	Dry weight of plant material per unit area per year	Kilograms per hectare
Litter accumulation	Dry weight of litter per unit area	Kilograms per hectare
<i>Growth and Survival</i>		
Tree and shrub branch growth rate	Rate of branch elongation during a growth season	Meters per year
Seedling height growth rate	Rate of seedling stem elongation during a growing season	Meters per year
Seedling survival rate	Rate of seedling survival per unit area	Number per hectare
<i>Species Composition</i>		
<i>Species Richness</i>	Identification of species present	
	Total number of species present	Number
<i>Water Relations</i>		
Midday xylem pressure potential	Leaf or branchlet xylem pressure measured at solar noon	Megapascals

At the primary sites, annual measurements of riparian plant biomass and litter accumulation are being taken at the primary sites to monitor productivity (Chapman 1976). Biomass samples are being acquired at peak productivity using destructive sampling techniques, and are being done in conjunction with the LAI harvests for trees and shrubs. Subplots, totalling 50 m² (approximately 0.01 of each total plot) are being used to sample the herbaceous component. To sample litter accumulation, 16-18 wire and cloth litter traps, have been placed randomly along the transects. Plant materials in the traps are being collected monthly during the growth season, and then weighed and totalled for seasonal accumulation values.

Annual measurements of plant growth are being determined at all sites for riparian trees, shrubs, and seedlings. Branch elongation is being measured on five lateral branches of three individuals per species of riparian trees and shrubs. To determine seedling spatial patterning, current seedlings of riparian dominants have been located and identified. Seedlings are being measured in 5-9 1 m² subplots regularly placed along the length of the stream near the channel edge. Seedling shoot growth

is being determined by measuring the heights of main shoots of all individuals present in the subplots.

Species composition and species richness also are being determined annually. Composition is determined at each site by identifying all species present and classifying them as riparian (wetland) or upland.

A few biotic parameters are being sampled monthly during the growth season, including midday (assumed minimum) xylem pressure potential, seedling survival rates, and litter accumulation rates. Xylem pressure potentials are being measured to monitor riparian plant water status. Selected adult and juvenile individuals of riparian tree and shrub species are being measured at midday (the assumed time of minimum water potential) using a pressure chamber apparatus (Scholander and others 1965). These measurements may provide useful information on general periods of water stress. Seedling survival rates are being measured monthly at all sites so that survivorship curves can be constructed. These curves will be useful tools to monitor patterns of riparian plant regeneration (Begon and Mortimer 1981). Also, monthly rates of litter accumulation will provide information on patterns of riparian plant productivity.

To aid in monitoring long term changes, a site map is being drawn annually to delineate existing vegetation with respect to the locations of all transects and subplots for monitoring shrubs, herbaceous plants, and riparian plant seedlings.

In conjunction with this ground monitoring program, some aerial monitoring is being conducted. Aerial photographs are being taken by SCE once annually for the first three years and then every five years thereafter to help document changes in the riparian community.

Data Analysis

To define the physical and biological variables at a given site for a given year, we will use descriptive statistical procedures. These analyses will provide information on central tendencies and their dispersion, thus yielding comparisons among the six sites and three physiographic valley types. To compare mean values of physical and biological variables among sites grouped by physiographic valley type in a given year, ordinary t-tests and a one way analysis of variance will be used, unless assumptions of equal variances cannot be met. If the latter, appropriate nonparametric tests for independent samples, such as the Kruskal-Wallis test, will be used.

Allometric relationships between DBH, basal area, or crown cover and LAI in a given year, will be determined using multiple regression and correlation analysis. Scatterplots will be used to visualize these relationships and correlation coefficients will be determined to test the strength of the relationships. These analyses will help determine which method of measuring LAI will be used in future sampling.

For temporal comparisons of physical and biological variables at a given site or valley type at different streamflow regimes and at different intervals since change of flows, analysis of variance (ANOVA) will be used with data having enough replicates. ANOVA will be used to test for significant changes in biological variables resulting from increasing the streamflow in V-shaped valley and alluvial valley fan settings. Since only one site (site #1) is being measured at a U-shaped glacial valley type site, no statistical procedures can be used to test for significant change in biological variables as a result of altering the streamflow regime. Only descriptions of any changes measured, without tests of significance, are possible. However, this site has been divided into three subplots on the South Fork, Middle Fork, and Main Fork of Bishop Creek for sampling, so we may be able to analyze the data by separating the subplots.

Conclusions

Measurement and analysis of the biotic and abiotic parameters included in the Bishop Creek study is expected to provide an improved understanding of the relationship between streamflow and riparian vegetation community dynamics. Collection of data over the next thirty years will result in an evaluation of the effects of streamflow alteration on the riparian ecosystem on a time scale more suitable for ecological interpretation.

References

- Anderson, M.C. 1971. Radiation and crop structure. In: Sestak, Z.; Catsky, J.; Jarvis, P.G. eds. Plant photosynthetic production: manual of methods. The Hague: Dr. W. Junk; 412-466.
- Begon, M.; Mortimer, M. 1981. Population ecology, a unified study of animals and plants. London: Blackwell Sci. Publ.; 200 p.
- Chapman, S.B. 1976. Production ecology and nutrient budgets. In: Chapman, S.B. ed. Methods in plant ecology. New York: Halsted Press; 157-228.
- Donahue, R.L.; Miller, R.W.; Shickluna, J.C. 1983. Soils, an introduction to soils and plant growth. New Jersey: Prentice-Hall; 667 p.
- Harris, R.R.; Fox, C.A.; Risser, R.J.; 1987. Impacts of hydroelectric development on riparian vegetation in the Sierra Nevada region, California, USA. *Environ. Manage.* 11: 519-527.
- Jones and Stokes Associates. 1985. Analysis of riparian vegetation on the eastside Sierra Nevada, California. Report 85-RD-59. Rosemead: Southern California Edison Company Research and Development Department; 71 p.
- MacArthur, R.H.; MacArthur, J.W. 1961. On bird species diversity. *Ecology* 42: 594-598.
- Mueller-Dombois, D.; Ellenberg H. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons; 547 p.
- Scholander, P.F.; Hammel, D.T.; Bradstreet, E.D.; Hemmingsen, A. 1965. Sap pressure in vascular plants. *Science* 148: 339-346.
- Smith, S.D.; Nachlinger, J.L. 1987. Water relations of riparian vegetation along Bishop Creek and North Fork Kings River, Sierra Nevada, California. Report 87-RD-68. Rosemead: Southern California Edison Company Research and Development Department; 69 p.
- Southern California Edison Company. 1986. Bishop Creek application for new license project no. 1394. Submitted to FERC, Washington, D.C. March 28, 1986.
- Taylor, D.W. 1982. Riparian vegetation of the eastern Sierra: ecological effects of stream diversions. *Contrib. No. 6, Mono Basin Res. Group, Lee Vining, California*, 56 p.