

RIPARIAN PLANT WATER RELATIONS ALONG THE NORTH FORK KINGS RIVER, CALIFORNIA¹

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Abstract: Plant water relations of five obligate riparian species were studied along California's North Fork Kings River. Diurnal stomatal conductance, transpiration, and xylem pressure potentials were measured throughout the 1986 growing season and in mid-season in 1987. Patterns were similar for all species although absolute values varied considerably. Maximum stomatal conductance occurred early in the day and season during favorable environmental conditions and decreased as air temperature and the vapor pressure difference between the leaf and air increased. Maximum transpiration rates occurred in mid-morning and mid-summer resulting in estimated daily water losses per unit sunlit leaf area of 163-328 mol H₂O m⁻². Predawn xylem pressure potentials remained high in 1986 when streamflows averaged 1.41 m³/s (50 cfs), however they were notably lower in 1987 at 0.7 m³/s (25 cfs).

Riparian systems are heavily used for recreational and human resource values, for example, streams are often diverted for water and hydroelectric power generation. These uses sometimes conflict with inherent values of riparian systems, such as providing ecosystem stability and aquatic or terrestrial habitats. The conflict between natural values and diverting instream flows in riparian areas of the Sierra Nevada, California, has sparked several recent studies. These investigations are aimed at separating riparian vegetation responses to streamflow diversion from those vegetation responses resulting from natural community dynamics.

Streamflow diversion has been found to impact riparian vegetation both positively and negatively (Jones and Stokes 1985, Taylor and Davilla 1987, Taylor and Risser 1988). Harris and others (1987) found that the relative importance of these types of impacts depends largely on channel morphology and stream reach type. Remote sensing and stable isotope studies have been used to assess the hydrology, water sources and potential evapotranspiration of Sierran watersheds with diversions (Hess and Smith 1987, Skibitzke and Associates 1987, Space and others these proceedings). These studies are providing data sets to generate a predictive model of vegetation responses to diversion.

The objectives of this study were to examine patterns of riparian plant water relations, determine how these patterns change as streamflow changes, and provide physiological data sets for a predictive model of vegetation responses to diversion. We attempted to determine if streamflow changes influence plant water relations, patterns of water use, canopy temperatures, and differential mortality of riparian individuals. We measured daily and seasonal patterns of stomatal conductance, transpiration, and plant xylem pressure potential of adult and juvenile riparian plants to determine how these patterns may be affected by diversion.

Materials and Methods

Study Sites and Species

Plant physiological measurements of riparian plants were made at two sites along the North Fork of the Kings River (36°48'N, 119°07'W, 370 m elevation). The primary site at One Mile Bar was located about 2.5 km downstream from Balch Camp where a uniformly deep, coarse, sandy substrate occurs. The second site, which was subject to less intensive sampling, was located at Balch Camp where a shallow substrate is composed of coarse sand, cobbles and boulders.

Five plant species were selected for measurement: *Alnus rhombifolia*, white alder; *Platanus racemosa*, California sycamore; *Salix gooddingii*, Goodding's willow; *S. hindsiana*, sandbar willow; and *S. laevigata*, red willow. The alder and sycamore are large trees with large, broadly ovate and palmate leaves, respectively. Goodding's and red willow are trees with large, lanceolate, and glabrous leaves, while the sandbar willow is a shrub with small, linear, and gray-villous leaves. All five species are considered to be obligate riparian plants. For each species 3-5 individuals of adults and juveniles were selected for measurement when present.

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Table 1 - Ambient air temperature, relative humidity, and streamflow at Balch Camp, and Soil moisture 2.5 km downstream from Balch Camp, North Fork Kings River, on dates of physiological measurements. Dashes indicate missing data values.

		T air (°C)		RH (%)		Stream-flow (m ³ /2)	Soil Moisture (%of dry mass)
		Date	Max	Min	Max	Min	@1.2 m depth)
21	Apr 1986	----	----	---	----	49.3	22.7
8	May 1986	24.7	4.6	88.7	34.6	33.4	22.3
22	May 1986	25.6	5.4	81.4	27.7	38.0	22.5
4	Jun 1986	29.9	13.3	85.3	39.6	86.1	saturated
18	Jun 1986	28.8	13.7	83.6	34.5	35.1	21.3
2	Jul 1986	39.0	17.0	53.9	15.9	7.7	16.5
16	Jul 1986	33.3	15.6	51.1	15.0	2.4	14.5
30	Jul 1986	37.2	16.3	62.6	17.3	1.9	14.0
13	Aug 1986	----	----	----	----	1.4	13.0
27	Aug 1986	38.8	18.4	49.3	15.0	1.1	12.5
10	Sep 1986	30.3	9.8	36.2	15.0	1.0	12.3
24	Sep 1986 ¹	18.6	14.6	89.6	80.0	3.1	----
8	Oct 1986	33.8	11.0	70.6	15.0	1.3	12.3
29	Oct 1986	----	11.2	78.7	----	1.1	12.0
30	Jul 1987	35.7	----	----	14.0	0.8	----
25	Aug 1987	33.7	----	----	12.0	0.7	----

¹ A storm on 23-24 Sep 1986 produced 8.9 mm rainfall.

Plant Water Relations

Diurnal patterns of stomatal conductance, transpiration, and leaf microclimate were determined for all plant species on given sample dates. Measurements were made biweekly from April through October, 1986, and once each in July and August, 1987. A Lambda Instruments LI-1600 steady state porometer (LI-COR, Lincoln, NE) was used at 90 minute intervals throughout each day. In general, two abaxial leaf surfaces were measured; however occasionally, measurements of adaxial surfaces were made. A Lambda Instruments LI-190S quantum sensor was used to measure incident photon flux density for individual leaves. In addition to the porometer thermocouple, an infrared thermometer (Everest Interscience, Tustin, Calif.) was used to measure leaf temperatures. A portable pressure chamber apparatus (Soil Moisture Equip. Corp., Santa Barbara, Calif.) was used to measure xylem pressure potentials of 2-3 leaves or shoots from each individual before dawn and at solar noon. In 1986, soil moisture was measured with a CPN 503 neutron hydroprobe (CPN Corp., Martinez, Calif.) at 0.3m depth intervals. Nine access tubes were arranged along three transects within the riparian corridor at One Mile Bar and five access tubes were arranged along two transects at Balch Camp.

Results and Discussion

Climate, Streamflow, and Soil Moisture

Local climate at Balch Camp during the study period is presented in table 1. In 1986, air temperatures in excess of 25°C occurred throughout the growing season with the warmest days (to 39°C) occurring in July and August. Relative humidities remained high through June and then abruptly dropped in July when maximum air temperatures increased significantly. In October at the onset of senescence, maximum air temperatures remained high while minimum temperatures regularly dropped to 6°C. Light precipitation occurred in early May and late September. In 1987, similar hot and dry climatic conditions predominated.

Streamflows for the dates of physiological measurements are given in table 1 also. Streamflows peaked in early June, rapidly decreased during June and early July, and leveled at around 1.4 m³/s for the remaining months of the 1986 season and around 0.7 m³/s for the 1987 season.

Soil moisture was highest early in the 1986 season coinciding with the time of highest streamflows (table 1). Soil moisture declined gradually at all depths throughout the summer. The lowest moisture measurements were made in September when 11.2 and 23.0 percent water content by volume were measured at 0.5 and 1.2 m depths, respectively. Rains in late September, totaling 10.9 mm, increased soil moisture throughout the profile.

Plant Water Relations

A summary of seasonal predawn xylem pressure potentials and maximum daily stomatal conductance to water vapor is provided in table 2. Seasonal predawn xylem pressure potentials were high throughout the 1986 season for all species. In late season (October) at One Mile Bar, the xylem pressure potentials of *Salix gooddingii* and *S. laevigata* at -0.95 and -0.82 MPa indicated water stress for these species. Woodhouse (1983) found that *S. laevigata* is water stressed at -0.75 MPa. However, these lowered predawn measurements were more likely a result of increased root resistance to water uptake during the onset of dormancy than from insufficient soil moisture (Larcher 1980).

We found no consistent relationships between maximum xylem pressure potentials and maximum stomatal conductance for any species. Patterns in stomatal conductance were similar for all species, but absolute values varied considerably. Maximum stomatal conductance typically occurred in early June and declined gradually thereafter with the lowest observed conductances occurring in late October. *Platanus racemosa* and *Salix laevigata* had the highest maximum conductance at 0.229

and $0.254 \text{ mol m}^{-2}\text{s}^{-1}$, respectively. *Alnus rhombifolia* and *S. gooddingii* had moderate conductance at 0.158 and $0.128 \text{ mol m}^{-2}\text{s}^{-1}$, while *S. hindsiana* had the lowest maximum conductance at $0.108 \text{ mol m}^{-2}\text{s}^{-1}$. Lower stomatal conductance in all species in April and May may have occurred because of low soil and air temperatures and incomplete leaf expansion. High stomatal conductances in June coincided with ideal climatic conditions (moderate air temperatures, high humidities, high light, and warmer soil temperatures), abundant soil water, and mature leaves. The decline in stomatal conductance later in the season may have been the result of the combination of an increased vapor pressure difference (VPD) of the atmosphere and decreased soil moisture, while leaf senescence contributed to the decline in September. The broad-leaved willows appeared to have less effective stomatal control for maintaining high xylem pressure potentials during the period of high VPD in late season.

Table 2 - Seasonal trends in predawn xylem pressure potential (MPa) and maximum stomatal conductance ($\text{mol H}_2\text{O}/(\text{m}^2\text{s})$) for adult riparian plants in 1986 along the North Fork Kings River.

One Mile Bar	<i>Alnus rhombi- folia</i> (n=3)		<i>Salix laevi- gata</i> (n=1)		<i>Salix hinsi- ana</i> (n=2)	
	XPP max	g max	XPP max	g max	XPP max	g max
Apr 10	-0.24	0.173	-0.15	0.118	-0.13	0.091
Apr 24	-0.17	0.186	-0.10	0.251	-0.12	0.135
May 8	-0.26	0.179	-0.10	0.212	-0.13	0.102
May 22	-0.21	0.115	-0.18	0.263	-0.14	0.106
Jun 4	-0.22	0.152	-0.20	0.340	-0.17	0.139
Jun 18	-0.23	0.160	-0.28	0.286	-0.26	0.124
Jul 2	-0.31	0.083	-0.25	0.336	-0.24	0.086
Jul 16	-0.24	0.095	-0.40	0.296	-0.29	0.086
Jul 30	-0.20	0.133	-0.23	0.277	-0.23	0.122
Aug 13	-0.22	0.109	-0.37	0.307	-0.28	0.085
Aug 27	-0.23	0.122	-0.30	0.252	-0.23	0.113
Sep 10	-0.26	0.091	-0.35	0.211	-0.31	0.083
Sep 24	-0.13	-----	-0.23	-----	-0.19	-----
Oct 8	-0.27	0.143	-0.82	0.213	-0.34	0.116
Oct 29	-0.22	0.207	-0.68	0.195	-0.33	0.118

Balch Camp	<i>Alnus rhombi- folia</i> (n=5)		<i>Platanus race- mosa</i> (n=3)		<i>Salix good- dingii</i> (n=1)	
	XPP max	g max	XPP max	g max	XPP max	g max
Apr 11	-0.18	0.138	-0.16	0.124	-----	-----
Apr 25	-0.21	0.180	-0.18	0.287	-----	-----
May 23	-0.25	0.221	-0.18	0.272	-----	-----
Jun 5	-0.23	0.235	-0.25	0.354	-----	-----
Jun 19	-0.23	0.288	-0.28	0.290	-----	-----
Jul 3	-0.21	0.164	-0.25	0.315	-----	-----
Jul 17	-0.20	0.154	-0.11	0.206	-----	-----
Jul 31	-0.20	0.194	-0.12	0.233	-0.20	0.269
Aug 14	-0.26	-----	-0.13	-----	-0.20	-----
Aug 28	-0.31	0.098	-0.10	0.186	-0.13	0.176
Sep 11	-0.38	0.099	-0.14	0.161	-0.18	0.190
Oct 9	-0.28	0.181	-0.17	0.168	-0.25	0.166
Oct 30	-0.29	0.161	-0.18	0.150	-0.20	0.114
Oct 8	-0.27	0.143	-0.82	0.213	-0.34	0.116
Oct 29	-0.22	0.207	-0.68	0.195	-0.33	0.118

Patterns of integrated daily transpiration rates were very similar for all species at the beginning and end of the season, but values diverged for each species during the mid-summer period of significant water consumption (data not shown). The greatest daily transpirational water losses occurred from mid-June through August corresponding with the period of greatest VPD. Mean integrated transpiration was relatively high for *Platanus racemosa* and *Salix laevigata* at 239 and $328 \text{ mol m}^{-2}\text{d}^{-1}$, respectively. In contrast, *Alnus rhombifolia*, *S. gooddingii*, and *S. hindsiana* had relatively low integrated transpiration at 157 , 170 , and $177 \text{ mol m}^{-2}\text{d}^{-1}$.

Diurnal trends in photosynthetic photon flux density (PPFD), VPD, stomatal conductance to water vapor, and transpiration are shown for adult *Alnus rhombifolia* on three dates in figure 1. These trends were similar for all species measured. Typically, PPFD increased and levelled to a long midday maximum while VPD increased gradually and remained high until late in the day.

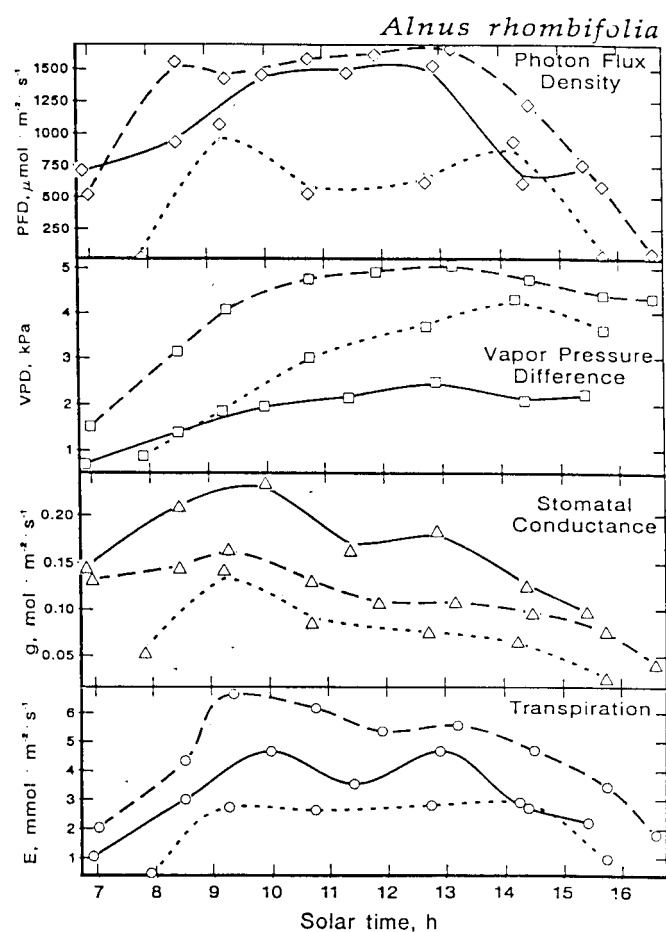


Figure 1. Diurnal patterns in photon flux density, vapor pressure difference, stomatal conductance, and transpiration for *Alnus rhombifolia* in June (—), July (---), and October (...) 1986.

Figure 1- Diurnal patterns in photon flux density, vapor pressure difference, stomatal conductance, and transpiration for *Alnus rhombifolia* in June (—), July (---), and October (...) 1986.

Stomatal conductance reached maximum values in mid-morning and gradually decreased during the remainder of the day. We found no consistent relationships between stomatal conductance and PPFD nor between stomatal conductance and VPD. Nevertheless, a decline in conductance as a result of increasing VPD is a well established relationship (Schulze 1986).

Diurnal transpiration patterns mirrored stomatal conductance with maximum transpiration occurring in conjunction with maximum stomatal conductance because leaf temperatures were close to air temperatures. Transpiration rates declined or levelled during midday even though VPD remained high, except for *Salix hindsiiana* which typically increased transpiration rates to afternoon maxima.

Diurnal xylem pressure potential patterns showed a rapid decline by mid-morning coinciding with maximum transpiration (data not shown). The prolonged midday minimums in conjunction with increasing VPD probably triggered partial stomatal closure resulting in the observed decrease in transpiration rates.

In 1987, air temperatures and VPD were slightly less than in 1986. Measurements of stomatal conductance and transpiration were slightly less also. Both predawn and midday xylem pressure potentials in 1987 were notably lower than in 1986, however insufficient data were obtained to test significance. In 1986, we found that the riparian plants had an adequate moisture supply and were capable of absorbing sufficient water to compensate for their large transpirational water losses. In late summer of 1987, the internal water status of the plants indicated that they may not have had sufficient soil moisture available to offset transpirational losses. Further physiological measurements in conjunction with soil moisture measurements at low streamflows would help to clarify the lower water limits of these riparian plants.

Conclusions

The patterns of water relations in five riparian species along the North Fork Kings River showed similar diurnal and seasonal trends. Stomatal conductance was greatest early in the season when climatic conditions were mild. All species had reduced stomatal conductance during the late season low flow periods. In contrast, transpiration was greatest in mid-summer when air temperatures and VPD were greatest also. Predawn xylem pressure potentials indicated that plants were able to fully recover internal plant water status at night given the 1986 streamflows $1.4\text{m}^3/\text{s}$. Xylem pressure potential data collected in 1987 are insufficient to draw conclusions from at streamflows of $0.7\text{m}^3/\text{s}$.

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