RELATIONSHIPS OF SHADE AND MAXIMUM STREAM TEMPERATURES ON THREE NORTHEASTERN OREGON STREAMS

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STUDY METHODS

Three Rosgen type B streams in northeastern Oregon were selected for study. Two streams were in the Snake River Ecological Province and one was in the Blue Mountain Ecological Province. A four-mile segment of each stream was selected for study. The top of the stream was near the headwaters and the bottom was near the mouth. Each stream was evaluated with ocular reconnaissance to determine where changes in cover occurred. Natural cover breaks were determined and each of the three streams was divided into four study reaches. Canopy cover was measured with hemispherical photography on twenty plots centered on each stream in each reach. The high cover stream had an average canopy cover of 85% (Table 1). Cover ranged from 81% to 87% across study reaches for the high-cover stream. The mid-cover stream had an average canopy cover of 68% and a range from 60% to 78%. The low-cover stream had an average cover of 53% that ranged from 33% to 70% across study reaches. Measurements were taken at base flow. All streams had low base flows ranging from .05 cfs to 1.1 cfs. Air temperature was recorded with stowaway data loggers at the top, middle and bottom of each stream. Stowaways were placed in the shade in small, ventilated shelters. Water temperatures were recorded with stowaway data loggers at the top of the study area, which was the beginning of reach 4 and at the beginning and end of each reach in each stream. Each stream reach was labeled from reach 1 nearest the mouth to reach 4 at the upper end of the study area. Stowaways were placed in the thalweg of the stream in a shaded location. All data loggers were tested for accuracy before and after the field season using standard protocols. Temperatures were recorded in 1 hour 20 minute increments. Shade was calculated for ten-minute increments of each day and averaged over days for each reach on each stream.

Data were analyzed by analysis of variance and linear regression within each stream for the twenty hottest days of 2001. Differences between means were analyzed with least significant difference. Temperature change was evaluated for the mid-cover stream on the hottest day of 2001 comparing temperature change from 14:00 to 15:20 in each reach with the shade present during that hour and twenty minute period. Temperature change from 64° F (or the temperature closest to that) over the subsequent hour and twenty minutes was compared to shade present during that period. No statistical analyses were conducted for the contrasts made on the hottest day of the year.

Table 1. Characteristics of three stream study areas. The mid-cover stream is in Blue Mountain Ecological Province and the other two are in Snake River Ecological Province. Percent shade was calculated for daylight hours in the twenty hottest days of 2001.

Characteristic	High-Cover				Mid-Cover				Low-Cover			
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 1	Reach 2	Reach 3	Reach 4	Reach 1	Reach 2	Reach 3	Reach 4
Base Flow (cfs)	0.05	0.14	0.14	0.07	0.47	0.56	0.53	0.52	0.19	0.83	1.10	0.79
Width (feet)	5.6 Average for all reaches				4.9 Average for all reaches				5.9 Average for all reaches			
Elevation (feet)	4500	5000	5300	5500	3325	3420	3580	3660	4500	4600	4800	5000
Length (mile)	1.7	.5	1.0	0.8	1.1	1.4	0.9	0.5	1.1	0.6	1.1	1.3
% Cover	81	87	87	85	71	60	62	78	70	70	40	33
% Shade	71	80	82	79	54	35	41	68	54	57	22	12

RESULTS AND DISCUSSION

In the high-cover stream maximum daily temperature increased significantly as the stream flowed through the upper reach (Table 2). The daily maximum temperature also significantly increased through the next downstream reach. In the next reach downstream the daily maximum temperature declined significantly. In the lowest reach the stream's maximum temperature significantly warmed. During the twenty hottest days average shade was similar in the upper reaches at about 80% and lower in the bottom reach at 71%. The daily maximum temperature of the stream was reached at 14:00 at the top of the upper reach and in the lower two reaches. The daily maximum temperatures in the upper two reaches occurred an hour and a half later in the day than at the top of the study area and in the two lower reaches of the stream.

In the mid-cover stream daily maximum temperature increased significantly from the top of the stream through the upper three reaches and was significantly lower in the bottom reach. Average daily shade among the reaches studied ranged from 68% to 35% during the 20 hottest days of 2001. Shade was lowest in the two middle reaches. The daily maximum temperature was reached at 14:00 at the top of the study area. At the end of the upper reach the daily maximum temperature was reached four hours later. The lower three reaches attained the daily maximum temperature at 16:00 or 16:30. This was 1.5 to 2 hours before the upper reach attained maximum temperature.

In the low-cover stream daily maximum temperature during the 20 hottest days of 2001 increased through the upper reach, decreased downstream in the next reach, increased downstream in the next reach and decreased as the stream flowed through the bottom reach. Shade during these days was lowest in the upper two reaches and highest in the lower reaches. The top of the stream study area and the upper two reaches attained the daily maximum temperature at 14:40. The next reach maximized temperature at 15:00 and the lowest reach at 15:30, even though the maximum temperature was 4.9 °F lower than in the reach above it.

There was no evidence of significant ground water inputs based on landform or presence of springs and seeps along all streams during this period of low flow in the late summer. The increased flow in the third reach of the low-cover stream comes from a side channel that is at the same temperature as the main channel. It was measured with the same type of thermistor and the same protocol, over five summer seasons. While there is a tendency for the streams to heat as they flow downstream, they do not heat uniformly with respect to daily stream temperature maximums. The time of reaching maximum temperature does not correlate with any pattern of uniform heating.

Relative temperature changes appear to be independent of the daily shade levels. Comparison of the percent shade over each stream reach to the change in average maximum daily temperature was not significant using linear regression, $R^2 = 3\%$ (Figure 1). There was no discernable pattern of relationship between the level of shade and the change in average daily maximum temperature for all three streams.

Table 2. Average maximum water temperature, time temperature was reached, and shade calculated for the twenty hottest days of 2001. Shade was not calculated at the top of each stream.

	Maximum Water Temperature (F)				
	High-Cover 85%				
	Reach 1	Reach 2	Reach 3	Reach 4	Top
Temperature	72.1	58.1	59.0	55.0	48.9
Shade	71%	80%	82%	79%	
Time Max. T was reached	14:00	14:00	15:30	15:30	14:00
	Mid-Cover 68%				
Temperature	69.3	70.2	67.5	64.8	64.2
Shade	54%	35%	41%	68%	
Time Max. T was reached	16:00	16:30	16:00	18:00	14:00
	Low-Cover 53%				
Temperature	68.0	72.9	67.1	71.4	64.6
Shade	54%	57%	21%	12%	
Time Max. T was reached	15:30	15:00	14:40	14:40	14:40

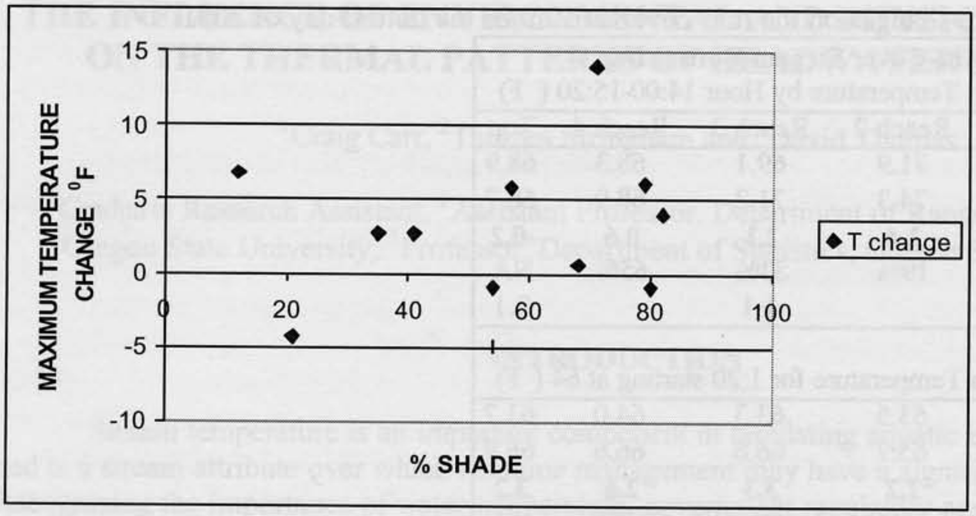

Figure 1. Non-significant relationship of percent shade to change in average daily maximum temperature over the twenty hottest days compared across all streams.

Overall, cumulative effects of physical factors on the daily maximum temperature changes were not apparent. There are many compensating factors in natural systems that can obscure expected outcomes of the interaction of ecological forces. In these streams it was apparent that shade was not a dominant force in directing maximum daily temperature change.

In order to better understand specific shade relations to maximum daily water temperature, we calculated the shade from 14:00 to 15:20 on the hottest day of the year in 2001 for the mid-cover stream. We also calculated the change that occurred in the hour and twenty minutes following the temperature closest to 64° F. The 64° F base was arbitrarily selected to be close to the maximum temperature in Oregon's water quality standards. We then compared the temperature change from 64° F to shade present during that timeframe (Table 3).

At the top of the stream study area the temperature change varied little in the hour and twenty minute time period for 14:00 to 15:20. The change of –0.3° F is at the level of accuracy of the sensors so it may reflect no change. The upper reach, with 65% shade, increased 0.6° F. The remaining reaches all increased by 1.8° F to 2.4° F and shade ranged from 19% to 43%. When we compared the increase from 64° F for the subsequent hour and twenty-minute period we found little apparent relationship between shade present and temperature increase. The temperature increase with 36% shade was higher than that for 62% shade by 0.7° F. The change for the stream under 11% shade was about the same as for 45% shade. There were no apparent relationships between level of shade and change in temperature for either a common time period or common base temperature.

Table 3. Temperature changes on the mid-cover stream for the hottest day of 2001.

Mid-Cover Stream Hottest Day					
Change in Temperature by Hour 14:00-15:20 (F)					
Time	Reach 1	Reach 2	Reach 3	Reach 4	Top
14:00	70.7	71.9	69.1	68.3	68.9
15:20	72.5	74.3	71.2	68.9	68.7
Change	**1.8**	**2.4**	**2.1**	**0.6**	**-0.2**
Shade	43%	19%	33%	65%	NA
Air Cng	0.4		1.1		3.1
Change in Temperature for 1:20 starting at 64 (F)					
Start	63.5	63.5	63.3	64.0	63.7
End	65.5	65.7	66.6	66.6	66.9
Change	**2.0**	**2.2**	**3.3**	**2.6**	**3.2**
Shade	45%	11%	36%	62%	NA
Air Cng	4.7		-0.4		3.1

Air temp ranges 94.8-100.4 at 14:00-15:20

Air temp ranges 92.1-97.7 at 64°F change

SUMMARY

Data analysis and interpretation is continuing and the findings presented in this report are preliminary. Our key interpretations of the data follow. Maximum daily and hourly temperature of the streams we studied as well as hourly change from a common temperature were not closely related to shade levels during the hottest days of the year. Many factors influence temperature of flowing water and shade is often considered a primary influence. The streams studied are small, low discharge streams that should respond quickly to influences that direct temperature change. The lack of clear response patterns suggests a high level of compensation for influences of temperature driving forces. Our study does not provide evidence that shade is a driving force in temperature change on these streams.

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