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Water temperature in irrigation return flow from the Upper Snake Rock watershed

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ABSTRACT

The temperature of water can increase as it flows in irrigation canals, ditches and furrow irrigated fields, potentially increasing the temperature of irrigation return flow water. The objective of this study was to compare water temperature of irrigation return flow with the irrigation water diverted from the Snake River. Water temperature was measured weekly in the main irrigation canal and 23 return flow streams from 2005 to 2008 in the Upper Snake Rock (USR) watershed in Southern Idaho, USA. The USR is an 82,000 ha watershed with about 60% of the crop land surface irrigated and the remaining area sprinkler irrigated. Median annual water temperatures in irrigation return flow streams were not greater than the water diverted from the river, suggesting that water temperature does not increase as water flowed through the canal system and furrow irrigated fields. Water in 7 of the 13 return flow streams that received flow from subsurface drains had significantly lower temperatures than the main canal in at least two years of the four years. Median water temperature in July in seven return flow streams was also lower than the main canal. Results of this study indicate that water can be diverted from a river for irrigation without increasing the temperature of the irrigation return flow.

1. Introduction

A primary beneficial use in many rivers in the western part of the United States is supporting cold water aquatic life. Elevated water temperatures can alter stream ecology and inhibit native fish species (Poole and Berman, 2001; U.S. EPA, 2003). Many rivers in the western U.S. also support irrigated agriculture by conveying water to irrigated watersheds and receiving irrigation return flow. A portion of the diverted irrigation water typically returns to the rivers because diversions do not exactly match irrigation needs, and because surface and subsurface drainage occur in the watershed.

The temperature of water flowing in streams or man-made channels can increase when the air temperature is greater than the water temperature. Sprague (2005) showed that water temperature was significantly greater at forested sites during a drought than agricultural and urban sites. They attributed this difference to smaller streams in the forested areas and cooler water discharged from reservoirs and point sources in agricultural and urban areas. Stream water temperature typically increases linearly with air temperature from about 0° to 20 °C (Mohseni and Stefan, 1999). In surface irrigated fields, water temperature can increase as water flows over the soil. Duke (1992) measured a 2 to 3 °C increase in water temperature when crops shaded the irrigation furrows and up to 22 °C increase when crops provided little shading on hot sunny days (air temperature > 30 °C). On a watershed scale, hydrology can impact stream water temperatures. Stringham et al. (1998) found that daily maximum water temperatures in an irrigated reach were 1 to 3 °C cooler than the non-irrigated reach upstream during mid-July to August. Water temperature was similar between the two reaches from May to mid-July. They attributed the cooler water temperature to subsurface return flow in the irrigated meadow.

The Upper Snake Rock (USR) watershed, located in Southern Idaho, USA, has 82,000 ha of irrigated cropland with about 60% of the watershed irrigated by furrow irrigation. The remaining farm land is sprinkler irrigated. Irrigation water is diverted from the Snake River and approximately 40% flows back to the river through furrow irrigation runoff, unused irrigation water, and subsurface drainage (Bjorneberg et al., 2008). A beneficial use for the Snake River in this area is supporting cold water biota. Irrigation return flow from the USR could increase the temperature of the Snake River due to the high amount of furrow irrigation in the watershed. Therefore, the objective of this study was to determine if water temperature in irrigation return flow was greater than in the irrigation water diverted from the Snake River. This study did not attempt

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to quantify the impacts of reduced flow in the Snake River due to irrigation diversion. It only compared the temperature of the water returning to river with water diverted from the river.

2. Materials and methods

Water quality monitoring in the USR watershed began in 2005. Irrigation water, supplied by the Twin Falls Canal Company (TFCC) from April to mid-October, flows in canals, ephemeral streams and coulees as it is delivered to fields or flows back to the Snake River. The watershed is approximately 45 km by 15 km. The main canal flows approximately 90 km following the topography, forming the east and south boundary of the watershed. Return flow streams generally flow north to the Snake River (Fig. 1). Many streams only convey irrigation return flow and therefore have no flow from November to April, while other streams flow all year due to subsurface drain tiles and tunnels located sporadically throughout the watershed. Drain tunnels are 1.2 m wide by 1.8 m high tunnels that were dug horizontally into the basalt bedrock to remove excess groundwater that percolated up to the soil surface after irrigation began in this watershed. Rock Creek is the only stream that flows into the watershed. It is ephemeral upstream from the watershed; typically only flowing in spring and early summer from snowmelt in the mountains as rain seldom causes runoff in this area.

Water temperature was measured with a hand held thermocouple once per week at 24 sites (Fig. 1) from April 2005 to November 2008 when water samples were collected. All sites were sampled the same day between 9:00 am to 3:00 pm. The sampling route was reversed each week to alter sampling times at the sites (i.e. first site was last, last site was first). Flow rates at all sites were measured with weirs or calculated from stage-discharge relationships. Water flow rates were automatically recorded on data loggers at 13 sites that had higher flow rates. Flow stage at the remaining 11 sites was manually measured once a week.

Median annual water temperature in the main irrigation canal was compared to temperatures measured in the 23 return flow streams. Only water temperature data from April to October were used because water only flows in the main canal during this time period. Irrigation return flow from November to March was entirely from subsurface drainage. Median water temperature in July was also compared between the main canal and the return flow streams. Statistical differences were determined by the Mann–Whitney U test ($P < 0.05$) using the NPAR1WAY Procedure with Wilcoxon Scores in SAS (SAS Institute, 2008).

3. Results and discussion

Irrigation water diverted from the Snake River is the main source of water in the USR watershed, contributing 70 to 80% of the water input into the watershed and 40 to 50 times more water than Rock Creek (Bjorneberg et al., 2008). Rain events are typically <10 mm and seldom cause runoff. From 2005 to 2008, only six precipitation events exceeded 20 mm with five of these events occurring in 2005 when precipitation was 20% greater than the annual average of 270 mm (Bjorneberg et al., 2015).

Ten of the irrigation return flow streams did not receive any water from subsurface drains. These streams only convey irrigation water and irrigation return flow. Median water temperature in these ten streams was not significantly different from the water temperature in the main irrigation canal (Table 1). This suggests that the temperature of the water did not increase as water flowed through the canal system and furrow irrigated fields. The canals and return flow streams were not shallow, slow flowing streams that could easily gain heat. Water depth was about 3 m in the main canal and 1 to 2 m in irrigation laterals and return flow streams. Mohseni

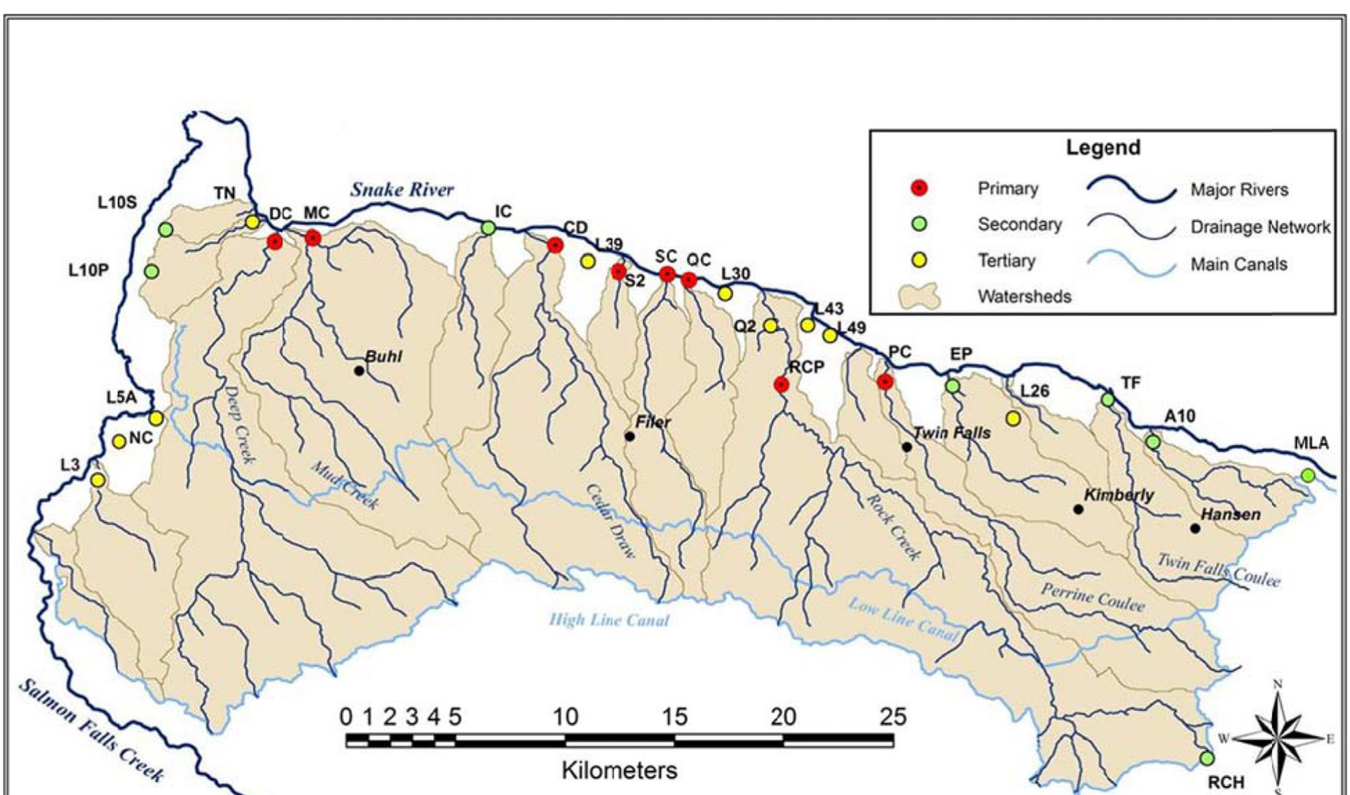

Fig. 1. Monitoring sites in the Upper Snake Rock Watershed in southern Idaho, USA. Site L10P was not included in the analysis because water did not flow at that site during the irrigation season.

and Stefan (1999) also noted that high air temperatures cause the vapor pressure deficit above the water surface to increase, causing evaporative cooling that reduces the water temperature increase.

The median annual water temperatures in the streams with subsurface drainage were frequently less than the water temperature in the main irrigation canal (Table 1). Seven of the 13 streams with flow from subsurface drains had significantly lower temperatures than the main canal in at least two years. Median water temperatures were generally 2 to 4 °C less in these streams. Water temperatures in only three return flow streams with subsurface drains were not significantly different from the main canal for any year.

More return flow streams had lower median temperatures in 2006 and 2007 than 2005 and 2008 (Table 1). Summing the total degree days from April 1 to October 31 for mean daily air temperature measured at the Twin Falls AgriMet site (USBR, 2014) indicated that 2006 (3354 °C-day) and 2007 (3403 °C-day) were warmer than 2005 (3165 °C-day) or 2008 (3148 °C-day). Higher air temperatures would not affect the temperature of subsurface drain water which could increase the cooling effect in these streams when air temperatures were higher.

There was no indication that water temperatures were greater in return flow streams where the water flowed farther in the canal system. For example, water flowed about 10 km from the main canal monitoring site to A10 and 90 km to NC. The median temperature was numerically higher at A10 for 2006 and 2008 (Table 1), but the median annual temperatures were not statistically different for any year.

Since water temperatures and irrigation demand were greatest in July, median July water temperatures in return flow was compared to the main irrigation canal. Seven of the return flow streams, all with subsurface drains, had significantly lower water temperatures than the main canal (Table 1). Median July water temperatures in irrigation return flow streams were never significantly greater than the temperature in the main irrigation canal.

Approximately 30% of the water volume diverted into the watershed during the irrigation season returned to the Snake River in the return flow streams (Table 2). The exception was 2006 when return flow volume was 39% of the main canal volume. Return flow in streams with subsurface drains accounted for 93 to 95% of the total return flow volume during the irrigation season. The amount of return flow associated with streams that had significantly lower water temperatures was 4, 48, 52 and 16% of the total return flow volume in 2005, 2006, 2007 and 2008, respectively.

It is important to note that the median temperatures in this study could be biased because water temperature was only measured once per week during the day when water samples were collected. These point measurements did not capture diurnal fluctuations in water temperature like a daily mean of hourly values. Temperature probes were added to two sites (DC and NC) in 2008 to record water temperature hourly. DC was a larger return flow stream, with flow rate varying from 1.5 to 5.5 $m^3\,s^{-1}$, that received flow from subsurface drains. NC did not have flow from subsurface

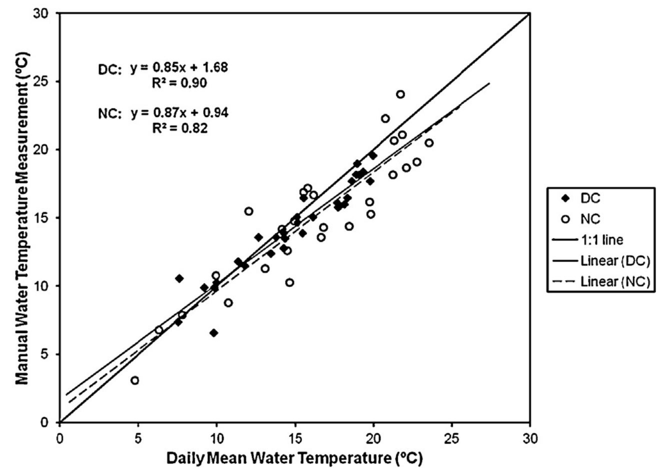

Fig. 2. Correlation between daily mean water temperature calculated from hourly measurements with data logger and manual water temperature measurements made weekly when water samples were collected.

Table 1
Median water temperatures during the irrigation season for 23 irrigation return flow streams and the main irrigation canal.

Site	Subsurface drains	Median water temperature (°C)				
		2005	2006	2007	2008	July[a]
A10	No	17.5	18.5	20.2	16.9	22.9
L10S	No	16.8	16.8	20.8	16.0	21.9
L26	No	17.1	18.6	20.5	17.4	23.3
L3	No	na[b]	18.6	22.4	16.0	23.6
L30	No	15.9	18.5	20.8	14.2	22.2
L43	No	16.7	18.6	22.3	18.2	22.6
L49	No	15.8	18.5	21.9	17.9	22.2
L5A	No	18.0	18.2	21.9	17.1	24.2
NC	No	na	18.1	20.8	15.4	23.9
TF	No	18.2	17.5	22.0	17.7	22.7
CD	Yes	15.3	15.3[*]	18.1[*]	14.2[*]	19.4[*]
DC	Yes	15.6	15.2[*]	18.9[*]	15.1	19.6[*]
EP	Yes	15.3	16.7	18.1	14.8	21.1
IC	Yes	14.2[*]	15.6[*]	18.5[*]	14.6	18.7[*]
L39	Yes	16.2	17.3[*]	21.5	14.7	21.4
MC	Yes	15.4	15.3[*]	18.1[*]	15.2	19.1[*]
PC	Yes	17.8	18.2	19.8	17.2	23.7
Q2	Yes	15.5	17.6	20.2	na	22.5
QC	Yes	na	16.5[*]	17.9	15.4	20.2
RCP	Yes	14.1[*]	14.9[*]	16.2[*]	14.6	17.7[*]
S2	Yes	15.5	15.7[*]	18.2[*]	13.8[*]	19.0[*]
SC	Yes	na	16.9[*]	19.8[*]	14.5	20.1
TN	Yes	15.1	14.8[*]	20.8	15.0	19.5[*]
Main canal		16.5	18.7	21.4	15.9	22.5

[a] Median July water temperature for all four years.
[b] na indicates that the site was not sampled that year.
[*] Indicates that the value is significantly different from the median water temperature in the Main canal.

Table 2
Total volume of flow for each site during the irrigation season.

Site	Subsurfacedrains	Flow volume (ML)			
		2005	2006	2007	2008
A10	No	1370	1740	1380	1900
10S	No	1920	3770	1740	2400
L26	No	1960	3030	2410	2130
L3	No	na[a]	2870	2610	2710
L30	No	1610	1260	2040	1450
L43	No	1370	2060	1600	1670
L49	No	1530	1910	1660	1657
L5A	No	2780	4970	3710	2730
NC	No	na	3360	2230	3430
TF	No	1870	2910	2760	1930
CD	Yes	42000	65900	38200	48600
DC	Yes	39000	43800	52300	52100
EP	Yes	12600	13700	11400	16800
IC	Yes	8480	10700	8650	6490
L39	Yes	na	2720	6440	7350
MC	Yes	40300	40200	35800	44700
PC	Yes	3450	4900	4050	5390
Q2	Yes	1290	2150	2080	na
QC	Yes	na	6320	12000	12500
RCP	Yes	110000	156000	89500	92300
S2	Yes	1950	2260	2430	2640
SC	Yes	na	14190	22000	12900
TN	Yes	2640	1930	2110	1940
Total return flow					
Without drains		14400	27900	22100	22000
With drains		262000	364000	287000	304000
Main Canal		949000	1004000	1009000	1124000

[a] na indicates that the site was not sampled that year.

drains and had flow rates of <0.1 to 0.6 $m^3 s^{-1}$. The manual water temperature measurements correlated well with the daily mean water temperature calculated from hourly measurements for that day (Fig. 2). Based on these two sites, manual temperature measurements were slightly lower than the daily mean temperature as indicated by regression line slopes <1.0 (Fig. 2). This occurred because the minimum water temperature typically occurred in the late morning at these two sites.

4. Conclusions

Results of this study indicate that the temperature of irrigation return flow water was not greater than the temperature of the irrigation water that was originally diverted from the Snake River. The temperature of the water did not increase as it flowed through canals, ditches, furrow irrigated fields, and return flow streams. Furthermore, water temperature in some return flow streams that received flow from subsurface drains was significantly lower than the water in the main irrigation canal.

While this study indicates that return flow water should not increase the temperature of the Snake River, it does not indicate that irrigation diversion has no effect on the river. Diverting water from a river often results in higher water temperature in the river. This study does, however, indicate that mitigation should not be needed for the temperature of water returning to the Snake River if a temperature standard is established for this reach of the river.

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