Fish Entrainment Investigations at the Fort Shaw Diversion 2003-2004, Sun River, Montana

Juddson D. Sechrist, USDI Bureau of Reclamation, PO Box 25007 (86-68290),Denver, CO 80225-0007, 303-445-2198, jsechrist@usbr.gov
Katherine Potak Zehfuss, USDI Bureau of Reclamation, PO Box 25007 (86-68290), Denver, CO 80225-0007, 303-445-2240, kzehfuss@usbr.gov

Abstract

Fish entrainment associated with irrigation has had long-term consequences for many species in the western United States. Investigation of entrainment and attempts at its prevention through physical or behavioral barrier installation are common management practices. However, the factors affecting entrainment are rarely quantified. The purpose of this study was to quantify fish entrained from the Sun River mainstem into the Fort Shaw diversion canal by species using an entrainment monitoring system; and second, to analyze the factors that contributed to this fish entrainment. These factors included: year, photoperiod, Sun River flow, Fort Shaw Canal diverted flow, Fort Shaw lag flow, ratio of diverted flow to Sun River flow, temperature, and moon phase. There were 6536 fish captured in 2003 and 2004 comprising 13 species and unknowns. We found significant differences in entrainment rates associated with Sun River flow, ratio of diverted flow to Sun River flow, and photoperiod. Our data indicated that at this site, fish entrainment is directly related to volume of water diverted, especially when diverted flows exceed mainstem river flows, and that fish entrainment at this site was highest during dark periods. The fish entrainment netting system used at the Fort Shaw Diversion was considered to be both economical and effective for documenting occurrence and determining the composition and number of fish entrained.

Key words: Fish Entrainment, Fish Entrainment Quantification, Fish Entrainment Netting System, Sun River, Fort Shaw Diversion, Factors Affecting Fish Entrainment

Introduction

The practice of irrigation has been practiced in Montana for over 160 yrs. A complete census regarding the number of irrigation diversions in Montana is not currently available; however, historical information regarding increases in irrigated acreage would indicate that the number of irrigation diversions has increased concurrently (Howard 1992). Many of these irrigation diversions lead to unintentional fish entrainment, which can cause long-term detrimental effects on fish populations in Montana (Reiland 1997, Gale et al. 2008) and in the western United States (Prince 1922, Hallock and Van Woert 1959, Cook and Buffaloe 1998, Zydlewski and Johnson 2002, Nobriga et al. 2004, Schrank and Rahel 2004, Moyle and Israel 2005).

Entrainment is defined as the fluvial transport of fish out of their in-stream environment in waters that are passed through a conduit, penstock, or diversion at power generation facilities, dams and / or irrigation canals (Zydlewski and Johnson 2002). Large losses of fish to irrigation canals in Montana have been documented by Thoreson (1952), Clothier (1954), Spindler (1955), Reiland (1997), Mogen and Kaeding (2002), and Sechrist et al. (2005). In addition, Bakes et al. (1998) examined the effects of diversion location on fish movement. Also, quantitative estimates of entrainment at diversions have been determined by Hiebert et al. (2000) and Gale et al (2008).

The effects of irrigation diversions on fish population demographics and connectivity can be cumulative (Helfrich et al. 1999). Several diversions may be located in a specific river basin and, although individual irrigation diversions may not significantly affect fish populations, collectively they may entrain considerable numbers of fish (Hallock and Van Woert 1959).

Most research pertaining to fish entrainment caused by diverted flows has been conducted in accordance with physical fish screen installation and efficiency testing at diversions (Neitzel et al. 1991, McMichael et al. 2001). These research studies therefore have focused on issues such as approach velocities for fish encountering a screened diversion (Pearce and Lee 1991), and physical characteristics at diversion sites that influence entrainment (Spindler 1955).

Many factors contributing to fish entrainment have been assessed in varying degree. These include: placement of irrigation withdrawal structures within a river channel or the channel morphology associated with the structures (Spindler 1955, Hiebert et al. 2000), river discharge as a catalyst for movement (Young 1994, Reiland 1997), temperature effects (Clothier 1954), turbidity effects (Bakes et al. 1998), habitat complementation (for example, spawn to post-spawn movements, e.g. Shrank and Rahel 2004), fish movement based on diel patterns (Nobriga et al. 2004), and ambient light (Gale et al. 2008). It has been assumed qualitatively that the number of fish entrained is positively correlated to the volume of diverted flow and concurrent density of fish in the water being diverted (Hiebert et al. 2000, Hanson 2001, and Post et al. 2006). However, the quantitative relationship between diverted flow and fish entrainment remains poorly understood (Moyle and Israel 2005).

The purpose of our research was to focus on this relationship between entrainment and flow by installing and implementing an entrainment monitoring system. The objectives were to first quantify fish entrained from the Sun River mainstem into the Fort Shaw diversion canal by species; and second, to analyze the factors that contributed to this fish entrainment. Factors included year, photoperiod, Sun River flow, Fort Shaw Canal diverted flow, Fort Shaw lag flow, ratio of diverted flow to Sun River flow, temperature, and moon phase.

Study Area

The Sun River is a tributary to the Missouri River in north-central Montana, with a watershed of ~ 5700-km2 (Fig. 1).

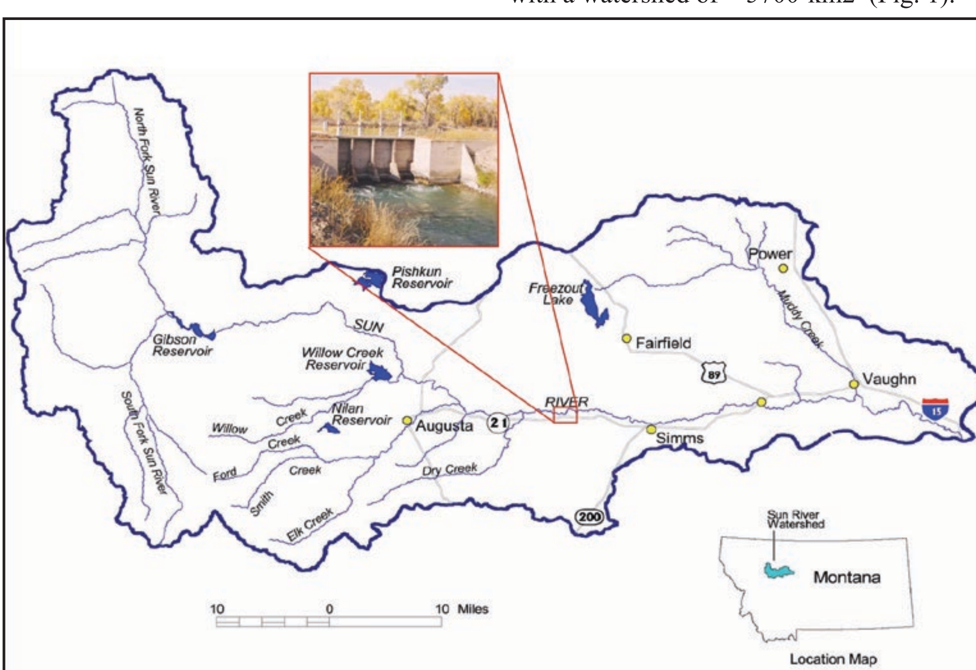

Figure 1. The Sun River watershed with inset of Fort Shaw Diversion Canal.

The Sun River drains from the continental divide via north and south forks to the Missouri River confluence, decreasing in elevation from 2743 m to 914 m along the Rocky Mountain front range for 177 km. Primary water storage on the mainstem Sun River occurs in Gibson Reservoir with a capacity of 122,238,050 m3. Mean annual discharge from Gibson Reservoir in 2003 and 2004 was 15.8 and 14.9 cubic meters/second (m3/s), respectively. The Sun River hydrograph from Gibson Dam to its confluence with the Missouri River is influenced by numerous irrigation diversions. The middle Sun River (from the Sun River Diversion Dam to Fort Shaw, Montana) has three major irrigation diversions and associated districts: Greenfield Irrigation District, Broken 'O' Ranch, and the Fort Shaw Irrigation District.

The Fort Shaw Diversion Dam and Canal is located ~ 8 km upstream from Simms, Montana (Fig. 1). The Fort Shaw Canal inlet is on the main channel of the Sun River immediately upstream from, or south of, the Fort Shaw Diversion Dam. A concrete headworks operates with four gates to regulate the flow into the canal. The canal has an approximate capacity of 6.3 m3/s. The canal is 19.5 km long and supplies water to the Fort Shaw Irrigation District through ~ 85 laterals. Fort Shaw Irrigation District water irrigated ~ 4573 ha during the course of this study (Bill Bohmker, Fort Shaw Irrigation District Irrigation Manager-pers. comm.).

Methods

Fish Sampling Techniques

We designed the entrainment monitoring system implemented at the Fort Shaw Diversion to sample 100 percent of the diverted flow through the diversion's four gates. It consisted of a steel construction frame-work that enabled fyke-type nets to be raised and lowered at the diversion (Figs. 2 and 3). The system utilized eight – 6.4 m steel net frame guides (SAE measurements: 3/16-in non-radiused stock channel, 3.5-in by 2.5-in inside diameter) to guide four 2.3 m2 net frames (2-in by 2-in square tube) into

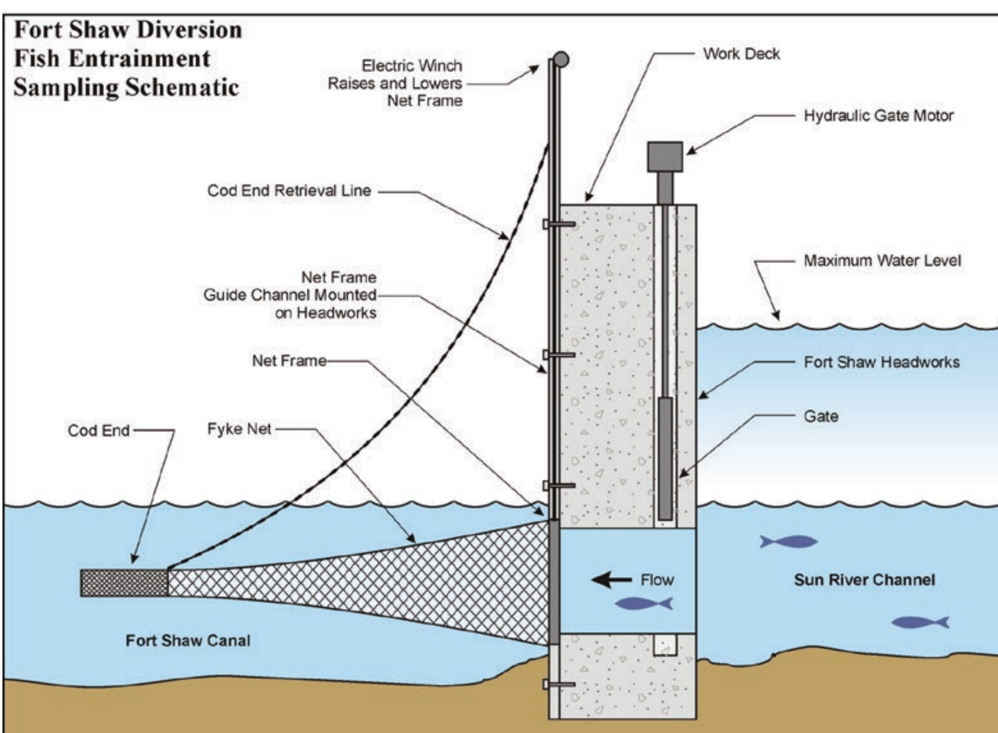

Figure 2. Side-view schematic of the Fort Shaw Diversion entrainment netting system.

Figure 3. Photograph of the deployed Fort Shaw Diversion entrainment netting system. Aspect is from the canal side.

position behind each of the diversion's four gates. Two pieces of 7.6-m channel were welded into place to form a top-bar (2-in radiused bar channel) over the net frame guides. This allowed four 115 V AC electric winches, each with a 454 kg capacity, to be placed above each gate on a mounting bracket to raise and lower the net frames while sampling. Concrete sleeve anchors (1.3 and 1.6 cm or 1/2 and 5/8 in) were used to anchor all un-welded steel to the diversion. Steel installation occurred prior to water-up in the canal in April 2003.

The nets for the entrainment monitoring system consisted of four fyke-type nets from Research Nets (Bothell, WA) used on the net frames. The nets were 6.7 m long and were constructed of 1.3-cm (½-in) knotted mesh running to a 4.8-mm (3/16-in) double-bagged cod-end with a heavy duty zipper to allow contents to be emptied. The nets also had 2.5-cm (1-in) steel rings sewn in to accommodate a 1.6-cm (5/8-in) choker line. The choker line prevented fish and debris from escaping the net during retrieval (Figs. 2 and 3). Ultra-violet resistant industrial zip-ties were used to affix the nets to their respective frames, through grommets near the net mouth. Net installation occurred in May 2003.

In both 2003 and 2004, the four nets were operated for 12-hr "Overall" sampling periods, generally starting at 1500 hrs until 0400 hrs the following day. Nets were pulled every 2 hrs and catch was sorted, measured, and recorded for each sampling period. Sampling periods were further defined as "light" for fish caught before 21:00, and "dark" for fish caught after 21:00. Extended net sets with a 24-hr operational period were also implemented in both years. In 2003, netting occurred on 33 days between 3 June and 25 September. In 2004, netting occurred on 30 days between 25 May and 29 July. Netting coincided with the peak hydrograph for each year. All fish captured in both years were returned to the canal.

Fish Entrainment Rate Calculation

We obtained diverted flow data from the gauge operated by the Fort Shaw Irrigation District (ARC050 V1.4F 09-Dec-1997: Report For Water Year 2003 and Report For Water Year 2004). The gauging station, with Station Identity "FSDM Fort Shaw Diversion Dam near Simms, Montana," is directly downstream of the canal gates (Fig. 1) and generates Daily Mean Canal Discharge (ft3/s). Flows for Sun River were obtained from USGS Real-Time Water Data for Montana using gauging station "USGS 06085800 Sun River at Simms Montana" (http://waterdata.usgs.gov/mt/nwis/uv). Although this gauging station is roughly 15 km downstream of the Fort Shaw diversion dam, it provided an approximation of the magnitude of Sun River flow at the dam. These flow data were converted to cubic meters /second (m3/s), and further converted to cubic meters/sampling period using hours sampled/sampling period.

Because sampling periods generally covered two subsequent dates, an average of these two dates' Daily Mean Discharge were used for volume calculations for overall sampling periods. The first date's Daily Mean Discharge was used for the day sampling period, and the second date's Daily Mean Discharge was used for the night sampling period. This generated a volume for diverted flow per each sampling period. Two types of fish entrainment rates were calculated during this study. For the purposes of comparisons of variables related to flow (Q), the first entrainment rate was calculated and presented as fish per hr. Comparisons of other variables not related to flow are reported are fish per m3.

We divided the number of fish captured per sample period by the diverted flow per sampling period. This yielded an entrainment rate for each overall, day, and night sampling period. Composition metrics and entrainment rates were calculated for all fish species combined, and for individual species in both years.

To obtain an estimate of total fish entrainment occurring at the Fort Shaw diversion during periods outside of the standardized collection period, and to estimate fish entrainment occurring at this diversion during the course of the June-September irrigation season, 24-hr continuous sampling periods were implemented. These data were collected in conjunction with the standardized 12-hr sample periods. The two 24-hr entrainment rates were derived from one 60-hr (14-17 Jul 2003) and one 72-hr (26-29 Jul 2004) continuous sampling effort.

Statistical Analyses

The 2003, 2004, and combined 2003/2004 number of fish entrained and entrainment rates at Fort Shaw were statistically analyzed to determine if they were independent of certain factors. These factors were: year, photoperiod, Sun River flow, Fort Shaw Canal diverted flow, Fort Shaw lag flow, ratio of diverted flow to Sun River flow, temperature, and moon phase. Nonparametric statistical procedures were used, which did not require assuming normality or equal variance. For all significance testing, the alpha level was 0.05 using two-tailed tests.

Flow and Temperature Parameters.— Diverted canal flows were the same data as used for the entrainment rate calculations. The flow being diverted into the Fort Shaw canal in comparison to the concurrent flow in Sun River, or Ratio Flow, was calculated as:

FS/SR Ratio Flow = Fort Shaw canal flow/ Sun River flow

The change in flow being diverted into the canal before each overall sampling period and the preceding day was calculated as:

$$\text{Fort Shaw Lag Flow} = (\text{Fort Shaw canal flow})_{\text{time 2}} - (\text{Fort Shaw canal flow})_{\text{time 1}}$$

Where: Time 2 is current study day and Time 1 is prior calendar day

Temperature data were obtained from Montana Fish Wildlife and Parks (MFWP) thermograph array at Lowry Bridge, which is approximately 5.5 km downstream of the Fort Shaw Diversion (Fig 1).

The Spearman Rank Order Correlation was used to measure the strength of association, or correlation, between pairs of variables (Sokal and Rohlf 1995). The Spearman Rank Order Correlation coefficient is computed by ranking all values of each variable, then computing the Pearson Product Moment Correlation coefficient of the ranks. This Pearson Product Moment Correlation Coefficient, R, was then used to test study hypotheses regarding a correlation between numbers of fish entrained per hour and flow and temperature factors. It is a dimensionless index that ranges from -1.0 to 1.0 inclusive, and reflected the extent of correlation between entrainment (overall sampling period fish entrainment results) and a factor, e.g., Sun River flow, Fort Shaw flow, Fort Shaw lag flow, ratio flow, and temperature.

Year, Photoperiod, and Moon Phase Parameters.— The Mann-Whitney Rank Sum Test was used to test for differences between sample groups that were greater than what could be attributed to random sampling variation (Sokal and Rohlf 1995). The null hypothesis was that the two samples, such as light and dark period entrainment rates, were not drawn from populations with different medians.

Entrainment rates from 2003 and 2004 were compared to assess a difference between years. Within each year, light sampling period entrainment rates were compared to dark sampling period entrainment rates to assess differences in entrainment rates due to photoperiod. We preferred within year day and night entrainment comparisons to pooled comparisons (by year) because of the uncertainty associated with annual run-off timing, etc. Also, for each dark sampling period, moon phase was recorded and verified using a lunar calendar. Entrainment rates for sampling periods with either full moon or new moon phases using both years' data were compared to assess lunar effects.

Results

2003 Entrainment Results

Sampling occurred for 33 days during 3 June 2003 to 25 September 2003 for a total of 395 hours of sampling. There were a total of 2585 fish entrained during this period, comprised of 10 species (Table 1, Fig. 4) with 247 fish of unknown species. Unknown species were attributed to field situations where netting system maintenance required immediate attention so fish identification was hampered or in cases of incomplete specimens. Additionally, 2799 crawfish (Orconectes virilis) were entrained during the netting operations. Mean overall entrainment rates and lengths are given in Table 2.

Twenty-Four Hour Entrainment Rates.— On 14 - 17 July 2003, a 60-hr continuous netting effort was performed to obtain the 24-hr entrainment rates. These 24 hr entrainment rates for all pooled species were 0.000134 fish / m3 14 July-15 July, and 0.000124 fish / m3 on 15 July-16 July. These were lower than the average overall entrainment rates given in Table 2. Although diverted flows into the canal peaked on 16 July and 17 July at approximately 7 m3/s, entrainment rates (qualitatively) appeared to not be affected by the peak (Fig. 4).

By summing seasonal flow data, there were approximately 25,573,828 m3 (ARC050 V1.4F 09-Dec-1997 Report For Water Year 2003) of water diverted from the Sun River into the Fort Shaw Diversion June 2003 – September 2003. We estimated total fish entrainment occurring at this diversion during the course of the June-September irrigation season using the 24-hr entrainment rate and this total diverted flow. Using the 14 July-16 July 24 hour entrainment rate of 0.000134 and 0.000124 fish/m3, multiplied by total flow, we estimate between 3171-3427 fish were entrained June through September 2003.

Table 1. Summary of number of fish captured during the three sampling periods in 2003 and 2004 in Fort Shaw Diversion Canal, Sun River, Montana.

Year	2003			2004			
Sampling Period Species	Light	Dark	Overall	Light	Dark	Overall	Total
Brown Trout *Salmo trutta*	28	76	104	24	51	75	**179**
Fathead Minnow *Pimephales promelas*	0	0	0	0	49	49	**49**
Lake Chub *Couesius plumbeus*	1	9	10	0	27	27	**37**
Longnose Dace *Rhinichthys cataractae*	58	1310	1368	63	2565	2628	**3996**
Longnose Sucker *Catostomus catostomus*	14	198	212	65	218	283	**495**
Mottled Sculpin *Cottus bairdi*	7	109	116	8	207	215	**331**
Mountain Sucker *Catostomus platyrhynchus*	6	17	23	0	23	23	**46**
Mountain Whitefish *Prosopium williamsoni*	95	171	266	181	136	317	**583**
North. Redbelly Dace *Phoxinus eos*	0	9	9	0	2	2	**11**
Rainbow Trout *Oncorhynchus mykiss*	22	165	187	6	146	152	**339**
Silvery or Brassy Minnow *Hybognathus sp.*	0	0	0	0	25	25	**25**
White Sucker *Catostomus commersoni*	5	38	43	30	113	143	**186**
Yellow Perch *Perca flavescens*	0	0	0	0	1	1	**1**
Unk/Unmeas.	8	239	247	0	11	11	**258**
Total	**244**	**2341**	**2585**	**377**	**3574**	**3951**	**6536**

2004 Entrainment Results

Sampling occurred for 30 days during 25 May 2004 to 29 July 2004 for a total of 358 hours of sampling. There were a total of 3951 fish entrained during our sampling effort, comprised of 13 species (Table 1, Fig. 5) with 11 fish of unknown species. Additionally, 2630 crawfish were entrained during the netting operations. Again, longnose dace were the most common species captured (see 2003 vs. 2004, Table 1). Mean overall entrainment rates and lengths are given in Table 2.

Entrainment rates in 2004 appeared to increase as the amount of water being diverted at Fort Shaw approached or became greater than the downstream river flow below the diversion in the summer (Fig. 5).

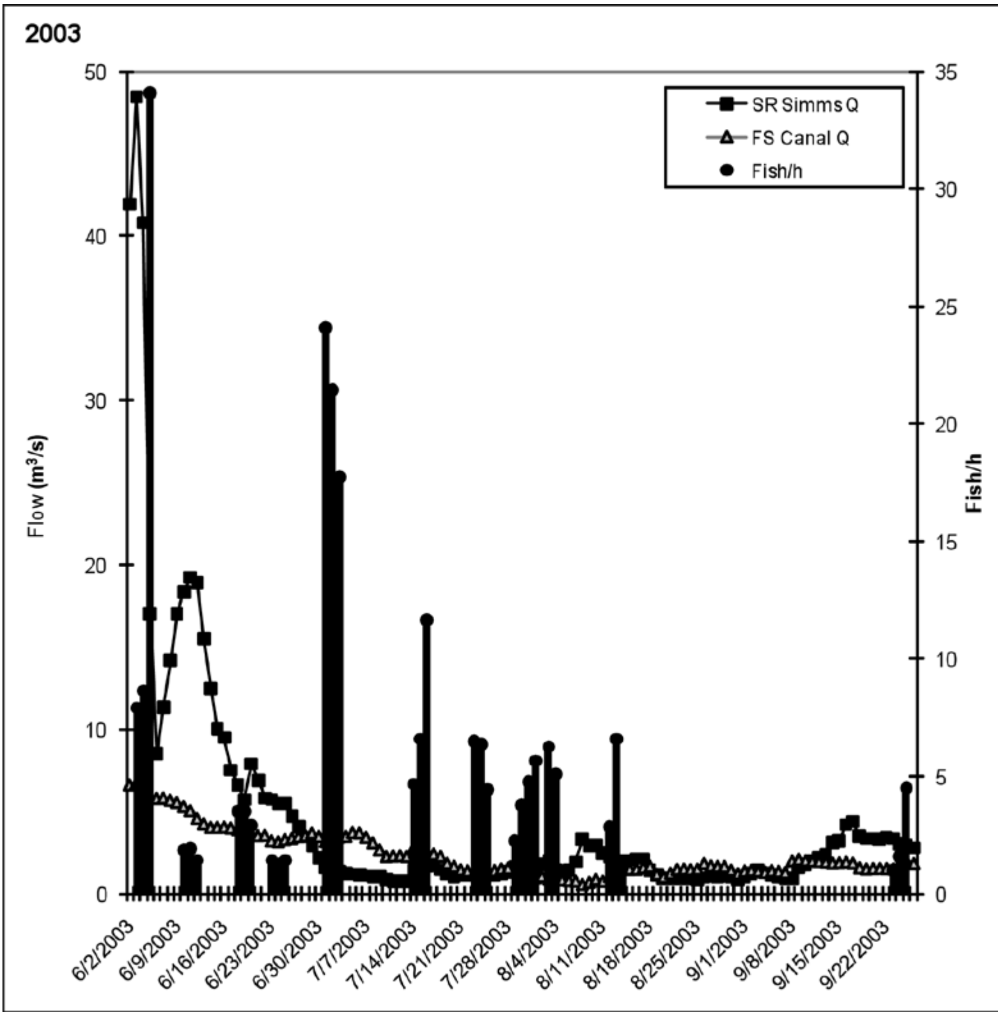

Figure 4. Fish entrained per study hour in 2003 overall sampling period in Fort Shaw Canal with Fort Shaw Canal diverted flow and Sun River flow at Simms, MT.

These inflection points in June and July represented the highest entrainment rates for the sample period.

Twenty-Four Hour Entrainment Rates.— On 26 - 29 July 2004, a 72-hr continuous netting effort was performed to obtain the 24-hr entrainment rates. These 24-hr entrainment rates, 0.000088 (27 Jul) and 0.00012 fish / m3 (28 Jul), were lower than the average overall entrainment rates as shown in Table 2. There were ~ 46,169,269 m3 (ARC050 V1.4F 09-Dec-1997 Report For Water Year 2004) of water diverted from the Sun River into the Fort Shaw Diversion June 2004-September 2004. May flow estimates were not included so that flow during irrigation seasons could be compared between years. Using the 27-28 July 24-hr entrainment rates, multiplied by total flow, we estimate between 4063-5540 fish were entrained June-September 2004.

Flow and Temperature Effects on Entrainment Results

During the 2003 study period, diverted flow into the Fort Shaw Canal was highest during June, ranging 3.1-6.7 m3/s, and was lower during July-September staying 0.6 - 3.7 m3/s (Fig. 4, also Table 1 in Appendix A). During the 2004 study period, diverted

Table 2. Summary of lengths of fish entrained during all sampling periods and mean entrainment rates for Overall sampling period during 2003 and 2004 in Fort Shaw Diversion Canal, Sun River, Montana. ER is the entrainment rate of fish per 1000 m3 of flow.

Species	Mean Study Year	Min. Length (mm)	Max. Mean Length (mm)	Length (mm)	Overall ER
Brown Trout	2003	157	39	565	0.0252
	2004	148	42	385	0.0145
Fathead Minnow	2003	.	.	.	0
	2004	43	25	77	0.0084
Lake Chub	2003	77	57	108	0.0031
	2004	44	26	75	0.0035
Longnose Dace	2003	71	25	225	0.4670
	2004	61	22	109	0.4762
Longnose Sucker	2003	145	33	457	0.0821
	2004	120	23	372	0.0493
Mottled Sculpin	2003	79	32	111	0.0510
	2004	63	26	90	0.0381
Mountain Sucker	2003	125	52	184	0.0069
	2004	68	40	173	0.0042
Mountain Whitefish	2003	142	27	372	0.0727
	2004	142	36	370	0.0626
North. Redbelly Dace	2003	53	32	67	0.0013
	2004	49	45	52	0.0003
Rainbow Trout	2003	129	41	456	0.0400
	2004	92	30	300	0.0246
Silvery or Brassy Minnow	2003	.	.	.	0
	2004	38	30	60	0.0040
White Sucker	2003	197	48	449	0.0116
	2004	110	46	280	0.0302
Yellow Perch	2003	.	.	.	0
	2004	66	.	.	0.0002
All Species	2003				0.7959
	2004				0.7181

flow was highest in late July with flows reaching 7.4 m3/s with slightly lower flows earlier in the season (Fig. 5, also Table 2 in Appendix A). In both years, Sun River flows peaked above 39 m3/s early in the season, and then quickly dropped to ~ 1.5 m3/s the remainder of the season.

In assessing effects of flow variables on fish entrained/hour, only the effects of Sun River flow and the FS:SR Ratio Flow appeared significant (Table 3, Fig. 6). Fish entrained/hour was negatively correlated with Sun River flow, with more fish entrained as less flow was discharged in the river. Fish entrainment was positively correlated with the ratio of Fort Shaw Canal flow to Sun River flow, indicating that more fish were entrained as Fort Shaw Canal flow exceeded that of the Sun River. The Sun River temperature was not significantly

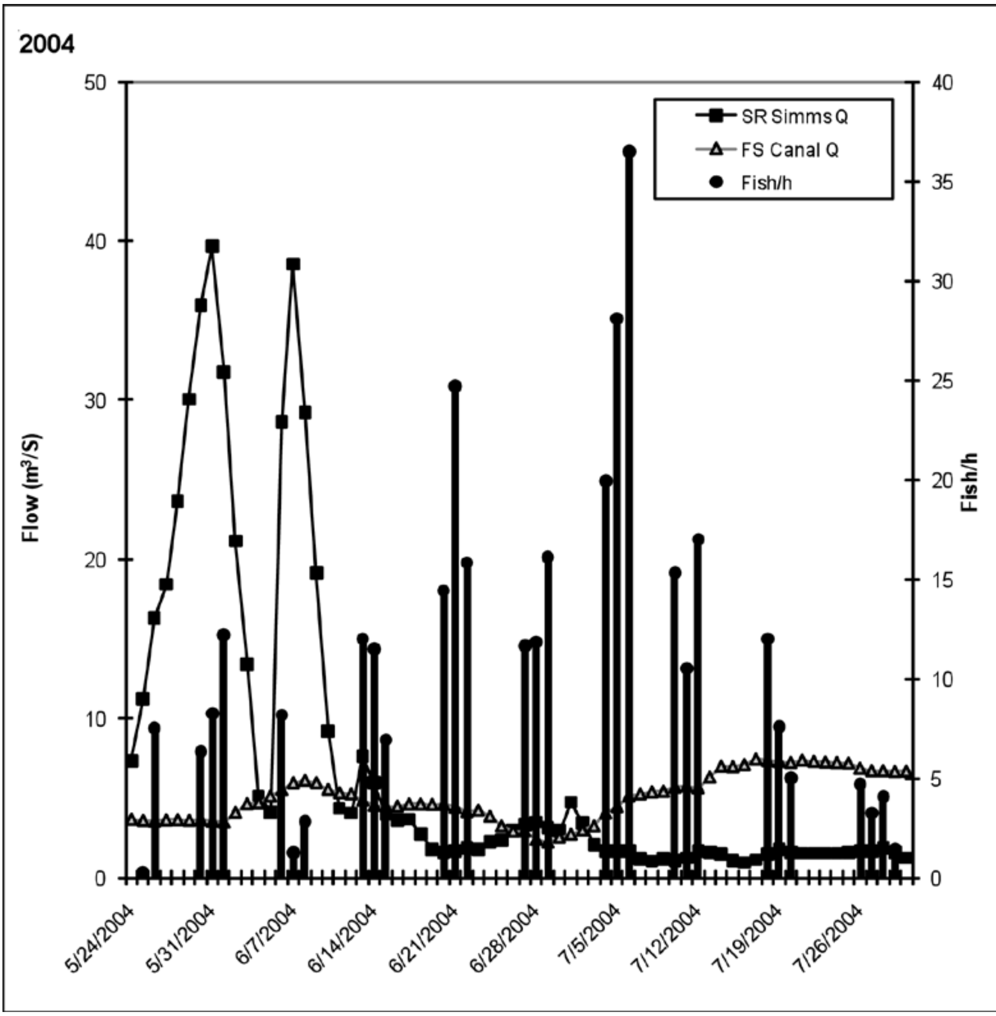

Figure 5. Fish entrained per study hour in 2004 overall sampling period in Fort Shaw Canal with Fort Shaw Canal diverted flow and Sun River flow at Simms, MT.

Table 3. Statistical results for variables correlated with Number of Fish Entrained per Hour in both years for Overall Sampling Period using Spearman Rank Order Correlation. Asterisk indicates significance.

Correlation to Fish Entrained per Hour			
Variable	**N**	**Correlation Coefficient**	**P Value**
Sun River Q	63	-0.254	0.0444*
Fort Shaw Canal Q	63	0.180	1.1570
Ratio FSQ:SRQ	63	0.370	0.0029*
Lag Sun River Q	63	-0.121	0.3430
Lag Fort Shaw Canal	63	0.101	0.4290
Temperature	57	0.071	0.5990

correlated with fish entrainment (Table 3, also Tables 1 and 2 in Appendix B).

Year, Photoperiod, and Moon Phase Effects on Entrainment Results

A graphical comparison of median entrainment rates is given in Figure 7. There was not a significant difference (Mann -Whitney U Statistic = 517.0 P = 0.767) in median overall entrainment rates for all species between 2003 and 2004.

We detected a significant difference both years (2003: Mann-Whitney U Statistic = 997.0 P ≤ 0.001, 2004: Mann-Whitney U Statistic= 835.0 P ≤ 0.001) when comparing

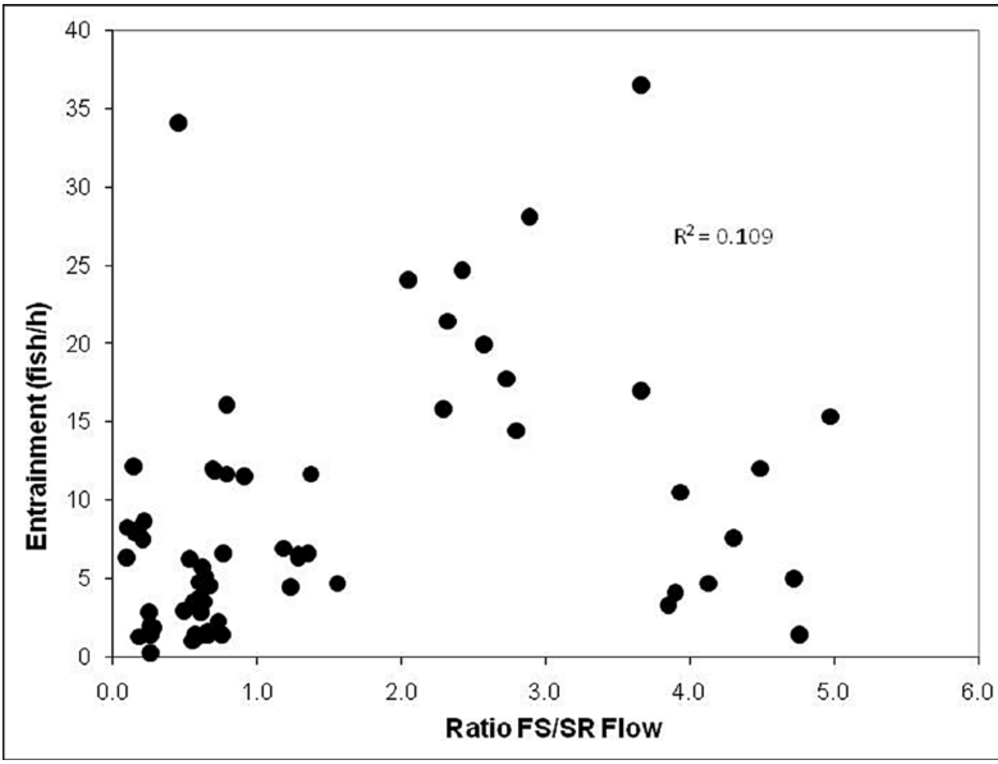

Figure 6. Scatter Plot depicting correlation between fish entrained per study hour in Fort Shaw Canal during overall sampling periods and ratio of Fort Shaw Canal diverted flow to Sun River flow at Simms, MT.

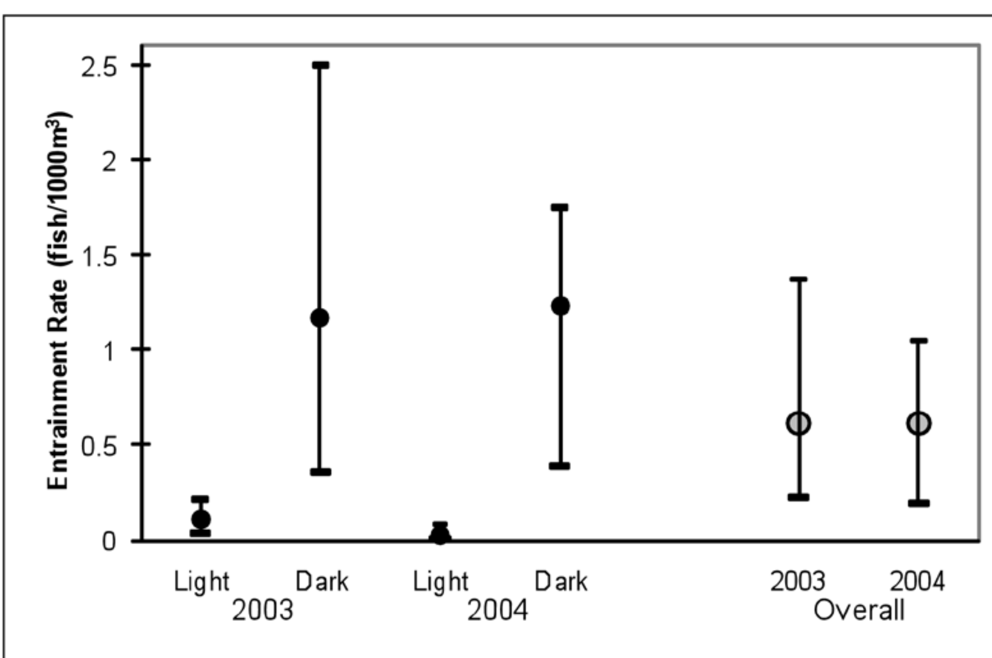

Figure 7. Comparison of Entrainment Rates between years and sampling periods, depicting median Entrainment Rate with 25% and 75% quartiles.

median values for light and dark sampling period entrainment rates.

There was not a significant difference (Mann-Whitney U Statistic = 272.0 P = 0.420, Tables 1 and 2 in Appendix B) when comparing the difference in median dark entrainment rates for all species between new moon and full moon periods for both years.

Discussion

The Fort Shaw nets captured 10 species previously identified to occur within the Sun River, but 3 species [northern redbelly dace (*Phoxinus eos*), fathead minnow (*Pimephales promelas*), and yellow perch (*Perca flavescens*)] were captured but were previously unrecorded within the Sun River Mainstem (based on Horton et al. 2006). Brook trout (*Salvelinus fontinalis*), burbot (*Lota lota*), carp (*Cyprinus carpio*), and northern pike (*Esox lucius*) have all been sampled in low numbers in the Sun River, and of these, burbot were the only species sampled in the vicinity of the Fort Shaw Diversion by Horton et al. (2006) that was not captured. Entrainment rates and percentage of larger trout as defined by Horton et al. (2006) > 200 mm total length were similar in both years, i.e., 14.4 of brown trout and 4.3 percent of rainbow trout in 2003, and 16.0 percent of brown trout and 2.6 percent of rainbow trout in 2004). Trout population density estimates obtained from MFWP indicated Sun River densities near the Fort Shaw Diversion were low in comparison to other trout population densities in North-Central Montana. Mean trout densities of fish > 200 mm near the Fort Shaw Diversion were the lowest of all reaches sampled by Horton et al. (2006). This could be a result of irrigation withdrawals since our net capture data supports that trout are being entrained. We do not, however, know whether trout of all sizes were entrained disproportionately to their abundance since we did not simultaneously obtain an abundance estimate. Also, the relationship between abundance in Sun River and entrainment rate for all species remains unclear. For example, our estimates for longnose dace entrainment at the Fort Shaw Diversion indicated a potential for very high losses of this species. However, electrofishing-based population estimates for small, non-game species such as longnose dace are not particularly effective (Horton et al. 2006). Thus, application of the hypothesis that entrainment rates are related to main stem population density is one of probability, supported only by evidence that some small-bodied fishes have been found to have swimming performances inversely proportionate to water velocity (Warren and Pardew 1998), and have preferences for shallower shoreline habitat (Gryska et al. 1998), likely making them susceptible to entrainment due to diversion canal structure and velocities.

Although the 2003 sampling period encompassed a longer period of the irrigation season than 2004, the total number of fish entrained during 2004 was higher than 2003 by 1366 fish, which consisted mostly of the species longnose dace. There was a lower volume of water diverted in 2003 than in 2004 (20,595,441 fewer m3/s in 2003). This qualitatively seems to support common assumptions that fish entrainment is directly related to volume of water diverted (Hiebert et al. 2000, Hanson 2001, Post et al. 2006).

In both years there was a significant relationship between diverted flow and entrainment. The significance of the ratio of mainstem flow to diverted flow on fish entrained per hour indicates that fish may follow the cue of the larger flow. The numbers of fish entrained increased as the ratio (FS/SR) became > 1, indicating that the fish were following the larger diverted flow cue.

The 2004 Sun River hydrograph experienced a double peak in early June, yet this did not seem to affect entrainment. We would have expected to see higher entrainments in response to this second peak if Sun River flow was positively instead of negatively affecting entrainment. With one exception (4 June 2003), entrainment in both years appears to be the highest directly after an event where the diverted flow into the canal exceeded the Sun River flow (Figs. 4 and 5). In addition, there was a statistically significant effect of this ratio between the two flows and entrainment. This would indicate that entrainment is probably affected by the change in flow with fish following the magnitude of the flow, whether it is down river or into the diversion. Our data indicate that when diverted flows exceed mainstem Sun River flows, fish are at greater risk for entrainment.

Many species such as salmon (Salmonidae), sturgeon (Ascipensceridae), paddlefish (*Polydon spathula*), and blue suckers (*Cycleptus elongates*) have been shown to initiate large scale spawning movements within rivers experiencing discharge peaks (Russell 1986, Young 1994, Holton and Johnson 1996). Movement into the canal could be falsely cued by diversion discharges, which could increase entrainment probabilities for fish species in the Sun River.

In both years, entrainments rates were significantly higher during dark than during light sampling periods. Fish were more prone to entrainment during dark periods because they were likely more active during the dark periods, (e.g., Beers and Culp 1990, Schmetterling and Adams 2004). The 12-hr sample period used in our study appeared to be effective at capturing fish entrained into the canal because it likely incorporates this period of highest activity, which yielded higher capture efficiencies. For example, two 24-hour sampling periods from 2003 are compared in Figure 8. The hours of 2130-0330 appeared to be periods of highest entrainment. Future research studies at this site could consider doing only dark net sets if resources are limited.

There are examples in the literature that both support and refute a corollary for the effect of lunar periodicity. For example, Rooker and Dennis (1991) found that

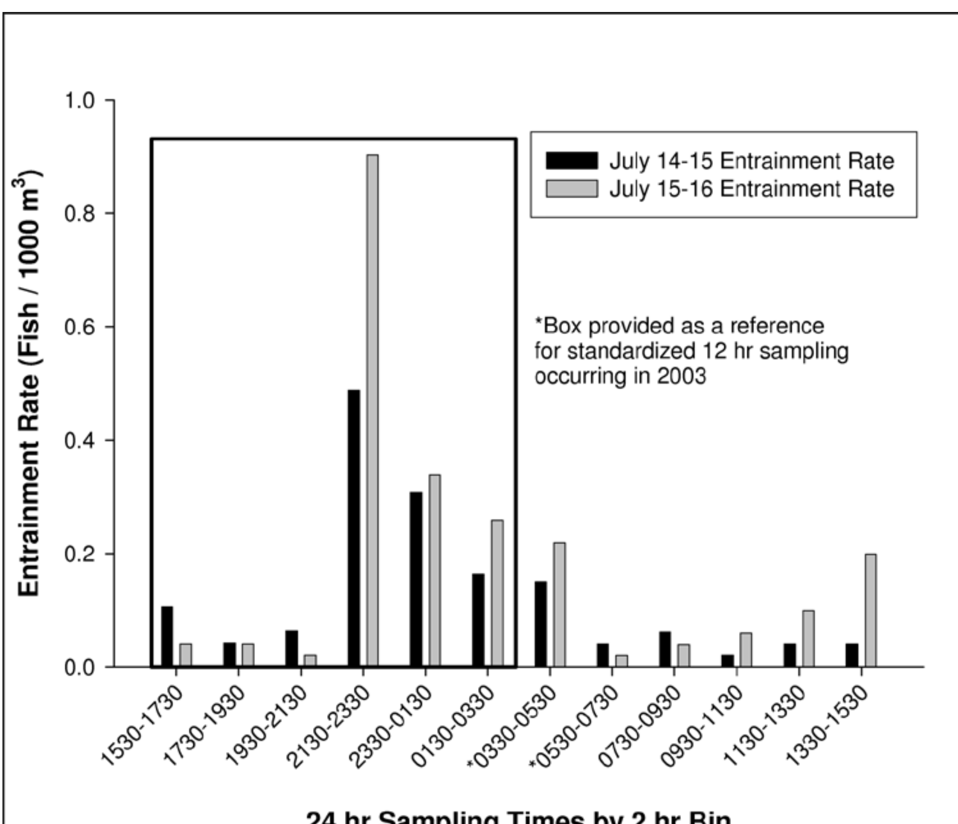

Figure 8. Twenty-four hour entrainment rates (14-16 July, 2003), Fort Shaw Diversion, Sun River, MT.

lunar periodicity had no obvious effect on abundance of migratory fish assemblages in a tidal system, whereas Gale (2005) found lunar cycles may have influenced downstream movement young cutthroat trout; however, it did not appear to have an effect on fish entrainment at this diversion. We did not find that in-stream temperature had an effect on entrainment at the Fort Shaw Diversion although increasing stream temperatures likely initiate movement of cool or cold-water fishes (Lessard and Hayes 2003); and this movement presumably would increasing the chance of entrainment as fish encounter diversions while seeking thermal refugia.

We considered the fish entrainment netting system used at the Fort Shaw Diversion to be both economical and effective. This general design has been used on several Bureau of Reclamation entrainment studies in Montana but has not been formally published. For example, the Huntley (Best et al. 2004) and Intake Diversions (Hiebert et al. 2000) on the Yellowstone River, the St. Mary Diversion on the St. Mary River (Mogen and Kaeding 2002), the Frenchtown Diversion on the Clark Fork River (Sechrist et al. 2005), and in other river systems in the Western United States. Larger netting systems of this type have also been used to monitor entrainment from large reservoir turbine outfalls at Shasta and Blue Mesa Reservoirs (California and Colorado respectively, USDI Bureau of Reclamation, Unpub. data). These systems allow for quantification of entrainment timing (diurnal, seasonal) and species composition, yielding daily, seasonal, and species-specific entrainment rates. However, fyke-type netting systems of this design are monitoring intensive because they require frequent checks to clear debris and to prevent fish impingement at the back of the cod-end. The system is not robust to high water volume or velocity because the working ratio of frame opening to net length is assumed to be roughly 1:3/m2 of frame opening (the net must be 3 times longer) to dissipate flow energy through our chosen mesh size. Thus in some diversion locations, net lengths could become unmanageable. Also, capture efficiency for larval or large, strong swimming fish have not been measured at any of the locations where these systems have been installed.

Conclusions and Management Implications

Losses of Sun River fishes to irrigation diversions have been documented since 1952 (Thoreson 1952). Our study further revealed that many of these fish are entrained when the majority of the instream flow is diverted into irrigation canals. It is apparent that effective screening techniques would decrease entrainment at the Fort Shaw Diversion, and by extension, other large diversions within the Sun River.

In addition to potential screening, other proactive management techniques merit consideration. For example, in 2004, a limited salvage operation at the Fort Shaw canal did return some fish to the Sun River after irrigation deliveries had ceased. Further, in some years, an informal downstream flow agreement has existed to maintain limited flow below the Sun River Diversion Dam. To be effective, and because there are many diversions on the Sun River, any proactive water management that is likely to succeed will rely on consensus and cooperation between suppliers (government) and water users (stakeholders).

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Appendix A.

Table 1. USGS and Hydromet stream flow gage data for Sun River at Simms and Fort Shaw Canal during 2003. Lag proportional flow is percentage change in flow from previous day. Entrainment (Fish/h) is based on 12 h sample periods.

Date	SR Simms Q (m3/s)	FS Canal Q (m3/s)	Ratio FS/SR Q	Lag Prop. SR Flow	Lag Prop. FS Flow	Overall Study Fish/h
6/2/2003	41.9136	6.6000	0.1575	.	.	
6/3/2003	48.4272	6.7124	0.1386	0.155	0.017	7.91
6/4/2003	40.7808	6.5586	0.1608	-0.158	-0.023	8.64
6/5/2003	16.9920	5.8336	0.3433	-0.583	-0.111	34.09
6/6/2003	8.4960	5.7937	0.6819	-0.500	-0.007	
6/7/2003	11.3280	5.8149	0.5133	0.333	0.004	
6/8/2003	14.1600	5.6773	0.4009	0.250	-0.024	
6/9/2003	16.9920	5.5485	0.3265	0.200	-0.023	
6/10/2003	18.3514	5.3083	0.2893	0.080	-0.043	1.83
6/11/2003	19.2293	5.0500	0.2626	0.048	-0.049	1.92
6/12/2003	18.9178	4.5742	0.2418	-0.016	-0.094	1.42
6/13/2003	15.5194	4.2534	0.2741	-0.180	-0.070	
6/14/2003	12.4608	4.0387	0.3241	-0.197	-0.050	
6/15/2003	9.9970	4.0381	0.4039	-0.198	0.000	
6/16/2003	9.4872	4.0577	0.4277	-0.051	0.005	
6/17/2003	7.5048	4.0047	0.5336	-0.209	-0.013	
6/18/2003	6.6269	3.9031	0.5890	-0.117	-0.025	3.50
6/19/2003	5.7206	3.8793	0.6781	-0.137	-0.006	3.50
6/20/2003	7.9013	3.7238	0.4713	0.381	-0.040	2.92
6/21/2003	6.9101	3.5341	0.5114	-0.125	-0.051	
6/22/2003	5.8056	3.5522	0.6119	-0.160	0.005	
6/23/2003	5.7206	3.2262	0.5640	-0.015	-0.092	1.42
6/24/2003	5.4941	3.1684	0.5767	-0.040	-0.018	1.25
6/25/2003	5.4658	3.2967	0.6032	-0.005	0.040	1.42
6/26/2003	4.7294	3.3783	0.7143	-0.135	0.025	
6/27/2003	4.0498	3.4808	0.8595	-0.144	0.030	
6/28/2003	3.4550	3.5434	1.0256	-0.147	0.018	
6/29/2003	2.9170	3.7026	1.2693	-0.156	0.045	
6/30/2003	2.1806	3.4910	1.6009	-0.252	-0.057	
7/1/2003	1.5859	3.1902	2.0116	-0.273	-0.086	24.08
7/2/2003	1.5576	3.2429	2.0820	-0.018	0.017	21.42
7/3/2003	1.3310	3.4590	2.5987	-0.145	0.067	17.75
7/4/2003	1.2178	3.4938	2.8691	-0.085	0.010	
7/5/2003	1.1894	3.7300	3.1360	-0.023	0.068	
7/6/2003	1.1611	3.7068	3.1924	-0.024	-0.006	
7/7/2003	1.0762	3.4420	3.1984	-0.073	-0.071	
7/8/2003	1.0478	3.1036	2.9619	-0.026	-0.098	
7/9/2003	1.0478	2.6765	2.5543	0.000	-0.138	
7/10/2003	0.8213	2.2783	2.7741	-0.216	-0.149	
7/11/2003	0.7646	2.3103	3.0215	-0.069	0.014	
7/12/2003	0.7363	2.3302	3.1646	-0.037	0.009	
7/13/2003	0.7646	2.2775	2.9785	0.038	-0.023	

Appendix A, Table 1 (cont).

Date	SR Simms Q (m3/s)	FS Canal Q (m3/s)	Ratio FS/SR Q	Lag Prop. SR Flow	Lag Prop. FS Flow	Overall Study Fish/h
7/14/2003	1.4443	2.7725	1.9196	0.889	0.217	4.67
7/15/2003	1.9258	2.4687	1.2819	0.333	-0.110	6.58
7/16/2003	1.6426	2.3503	1.4309	-0.147	-0.048	11.67
7/17/2003	1.8408	2.4282	1.3191	0.121	0.033	
7/18/2003	1.4726	2.2914	1.5560	-0.200	-0.056	
7/19/2003	1.2461	1.8708	1.5014	-0.154	-0.184	
7/20/2003	1.0478	1.6825	1.6057	-0.159	-0.101	
7/21/2003	1.0762	1.4721	1.3679	0.027	-0.125	
7/22/2003	1.1611	1.4021	1.2076	0.079	-0.048	
7/23/2003	1.0762	1.2954	1.2037	-0.073	-0.076	6.50
7/24/2003	1.0478	1.4282	1.3630	-0.026	0.103	6.33
7/25/2003	1.1328	1.3684	1.2080	0.081	-0.042	4.43
7/26/2003	1.1328	1.4225	1.2558	0.000	0.040	
7/27/2003	1.1894	1.5313	1.2874	0.050	0.076	
7/28/2003	1.3310	1.5703	1.1798	0.119	0.026	
7/29/2003	1.5859	1.3285	0.8377	0.191	-0.154	2.25
7/30/2003	1.6426	1.0311	0.6278	0.036	-0.224	3.75
7/31/2003	1.5576	0.8873	0.5696	-0.052	-0.140	4.75
8/1/2003	1.5576	0.9858	0.6329	0.000	0.111	5.67
8/2/2003	1.7842	1.0815	0.6062	0.145	0.097	
8/3/2003	1.9541	0.9314	0.4767	0.095	-0.139	6.25
8/4/2003	1.4726	0.8952	0.6079	-0.246	-0.039	5.08
8/5/2003	1.2744	0.8592	0.6742	-0.135	-0.040	
8/6/2003	1.4160	0.8252	0.5828	0.111	-0.040	
8/7/2003	1.9258	0.7952	0.4129	0.360	-0.036	
8/8/2003	3.3134	0.5797	0.1750	0.721	-0.271	
8/9/2003	2.9170	0.7241	0.2483	-0.120	0.249	
8/10/2003	2.9170	0.8932	0.3062	0.000	0.233	
8/11/2003	2.4638	0.7881	0.3199	-0.155	-0.118	
8/12/2003	2.2656	1.0725	0.4734	-0.080	0.361	2.83
8/13/2003	1.9541	1.4922	0.7636	-0.138	0.391	6.58
8/14/2003	1.9824	1.5140	0.7637	0.014	0.015	1.42
8/15/2003	2.0390	1.5089	0.7400	0.029	-0.003	
8/16/2003	2.1240	1.5171	0.7143	0.042	0.005	
8/17/2003	2.1240	1.6165	0.7611	0.000	0.066	
8/18/2003	1.4443	1.6848	1.1665	-0.320	0.042	
8/19/2003	1.1045	1.1960	1.0828	-0.235	-0.290	
8/20/2003	0.9629	1.0529	1.0935	-0.128	-0.120	
8/21/2003	0.9346	1.2625	1.3509	-0.029	0.199	
8/22/2003	0.9346	1.4973	1.6021	0.000	0.186	
8/23/2003	0.9629	1.5211	1.5797	0.030	0.016	
8/24/2003	0.9346	1.4817	1.5855	-0.029	-0.026	
8/25/2003	0.8496	1.5086	1.7757	-0.091	0.018	
8/26/2003	0.9912	1.8618	1.8783	0.167	0.234	
8/27/2003	1.1045	1.7083	1.5467	0.114	-0.082	

Appendix A, Table 1 (cont).

Date	SR Simms Q (m3/s)	FS Canal Q (m3/s)	Ratio FS/SR Q	Lag Prop. SR Flow	Lag Prop. FS Flow	Overall Study Fish/h
8/28/2003	1.0478	1.6822	1.6054	-0.051	-0.015	
8/29/2003	1.0762	1.6729	1.5545	0.027	-0.006	
8/30/2003	1.0195	1.4508	1.4231	-0.053	-0.133	
8/31/2003	0.8496	1.2305	1.4483	-0.167	-0.152	
9/1/2003	0.9912	1.4007	1.4131	0.167	0.138	
9/2/2003	1.2178	1.4330	1.1767	0.229	0.023	
9/3/2003	1.4443	1.4021	0.9708	0.186	-0.022	
9/4/2003	1.2744	1.3214	1.0369	-0.118	-0.058	
9/5/2003	1.1045	1.4149	1.2810	-0.133	0.071	
9/6/2003	0.9912	1.3704	1.3826	-0.103	-0.031	
9/7/2003	0.9346	1.3087	1.4003	-0.057	-0.045	
9/8/2003	0.9629	2.0073	2.0847	0.030	0.534	
9/9/2003	1.5859	2.1070	1.3286	0.647	0.050	
9/10/2003	1.7842	2.0218	1.1332	0.125	-0.040	
9/11/2003	1.9541	1.9920	1.0194	0.095	-0.015	
9/12/2003	2.1523	1.9600	0.9107	0.101	-0.016	
9/13/2003	2.3506	1.9317	0.8218	0.092	-0.014	
9/14/2003	3.1152	1.8841	0.6048	0.325	-0.025	
9/15/2003	3.2002	1.9059	0.5956	0.027	0.012	
9/16/2003	4.1914	1.9314	0.4608	0.310	0.013	
9/17/2003	4.3896	1.8872	0.4299	0.047	-0.023	
9/18/2003	3.5117	1.5941	0.4540	-0.200	-0.155	
9/19/2003	3.3418	1.5364	0.4597	-0.048	-0.036	
9/20/2003	3.3418	1.5556	0.4655	0.000	0.013	
9/21/2003	3.3134	1.5616	0.4713	-0.008	0.004	
9/22/2003	3.4550	1.5502	0.4487	0.043	-0.007	
9/23/2003	3.3418	1.5310	0.4581	-0.033	-0.012	1.00
9/24/2003	3.0019	1.9422	0.6470	-0.102	0.269	1.58
9/25/2003	2.9170	1.9442	0.6665	-0.028	0.001	4.50
9/26/2003	2.8037	1.8589	0.6630	-0.039	-0.044	

Appendix A.

Table 2. USGS and Hydromet stream flow gage data for Sun River at Simms and Fort Shaw Canal during 2004. Lag proportional flow is percentage change in flow from previous day. Entrainment (Fish/h) is based on 12 h sample periods.

Date	SR Simms Q (m3/s)	FS Canal Q (m3/s)	Ratio FS/SR Q	Lag Prop. SR Flow	Lag Prop. FS Flow	Overall Study Fish/h
5/24/2004	7.3349	3.6655	0.4997	.		
5/25/2004	11.2430	3.5975	0.3200	0.533	-0.019	0.25
5/26/2004	16.2840	3.5397	0.2174	0.448	-0.016	7.50
5/27/2004	18.4080	3.6241	0.1969	0.130	0.024	
5/28/2004	23.6472	3.6388	0.1539	0.285	0.004	
5/29/2004	30.0192	3.6017	0.1200	0.269	-0.010	
5/30/2004	35.9664	3.6383	0.1012	0.198	0.010	6.33
5/31/2004	39.6480	3.5309	0.0891	0.102	-0.030	8.25
6/1/2004	31.7184	3.4848	0.1099	-0.200	-0.013	12.17
6/2/2004	21.1550	4.0905	0.1934	-0.333	0.174	
6/3/2004	13.3670	4.6300	0.3464	-0.368	0.132	
6/4/2004	5.1259	4.6867	0.9143	-0.617	0.012	
6/5/2004	4.1064	5.1067	1.2436	-0.199	0.090	
6/6/2004	28.6032	5.5269	0.1932	5.966	0.082	8.17
6/7/2004	38.5152	5.9469	0.1544	0.347	0.076	1.25
6/8/2004	29.1696	6.1069	0.2094	-0.243	0.027	2.83
6/9/2004	19.1160	5.9523	0.3114	-0.345	-0.025	
6/10/2004	9.2040	5.5334	0.6012	-0.519	-0.070	
6/11/2004	4.3330	5.3182	1.2274	-0.529	-0.039	
6/12/2004	4.0498	5.2485	1.2960	-0.065	-0.013	
6/13/2004	7.6181	4.8572	0.6376	0.881	-0.075	12.00
6/14/2004	5.9472	4.5326	0.7621	-0.219	-0.067	11.50
6/15/2004	3.9648	4.4782	1.1295	-0.333	-0.012	6.92
6/16/2004	3.6250	4.4828	1.2366	-0.086	0.001	¬
6/17/2004	3.6533	4.6125	1.2626	0.008	0.029	
6/18/2004	2.7470	4.6139	1.6796	-0.248	0.000	
6/19/2004	1.7558	4.5870	2.6124	-0.361	-0.006	
6/20/2004	1.5576	4.5969	2.9513	-0.113	0.002	14.42
6/21/2004	1.6709	4.4174	2.6437	0.073	-0.039	24.67
6/22/2004	1.8691	4.1460	2.2182	0.119	-0.061	15.83
6/23/2004	1.7842	4.2293	2.3705	-0.045	0.020	
6/24/2004	2.2656	3.8498	1.6993	0.270	-0.090	
6/25/2004	2.3506	3.2432	1.3798	0.038	-0.158	
6/26/2004	2.9736	2.9175	0.9811	0.265	-0.100	
6/27/2004	3.3134	2.9257	0.8830	0.114	0.003	11.67
6/28/2004	3.4550	2.4027	0.6954	0.043	-0.179	11.83
6/29/2004	3.1435	2.2384	0.7121	-0.090	-0.068	16.08
6/30/2004	2.9170	2.5380	0.8701	-0.072	0.134	
7/1/2004	4.7294	2.7292	0.5771	0.621	0.075	
7/2/2004	3.4267	2.9872	0.8717	-0.275	0.095	
7/3/2004	2.0674	3.2327	1.5637	-0.397	0.082	
7/4/2004	1.6709	4.0560	2.4275	-0.192	0.255	19.92

APPENDIX A, TABLE 2 (CONT).

Date	SR Simms Q (m3/s)	FS Canal Q (m3/s)	Ratio FS/SR Q	Lag Prop. SR Flow	Lag Prop. FS Flow	Overall Study Fish/h
7/5/2004	1.6426	4.4562	2.7129	-0.017	0.099	28.08
7/6/2004	1.6709	5.1146	3.0610	0.017	0.148	36.50
7/7/2004	1.1611	5.2437	4.5161	-0.305	0.025	
7/8/2004	1.0195	5.3740	5.2711	-0.122	0.025	
7/9/2004	1.1611	5.4145	4.6632	0.139	0.008	
7/10/2004	1.0762	5.6657	5.2647	-0.073	0.046	15.33
7/11/2004	1.2178	5.7368	4.7109	0.132	0.013	10.50
7/12/2004	1.6709	5.6221	3.3647	0.372	-0.020	17.00
7/13/2004	1.5859	6.2972	3.9707	-0.051	0.120	
7/14/2004	1.4726	6.9888	4.7458	-0.071	0.110	
7/15/2004	1.0762	6.9554	6.4632	-0.269	-0.005	
7/16/2004	0.9346	7.0803	7.5761	-0.132	0.018	
7/17/2004	1.1328	7.4247	6.5543	0.212	0.049	
7/18/2004	1.4726	7.3315	4.9785	0.300	-0.013	12.00
7/19/2004	1.7842	7.2799	4.0803	0.212	-0.007	7.58
7/20/2004	1.5859	7.2083	4.5452	-0.111	-0.010	5.00
7/21/2004	1.5010	7.3652	4.9070	-0.054	0.022	
7/22/2004	1.5293	7.2913	4.7678	0.019	-0.010	
7/23/2004	1.5010	7.2434	4.8258	-0.019	-0.007	
7/24/2004	1.5010	7.2029	4.7989	0.000	-0.006	
7/25/2004	1.5576	7.1686	4.6024	0.038	-0.005	
7/26/2004	1.6426	6.8520	4.1716	0.055	-0.044	4.67
7/27/2004	1.6426	6.7042	4.0816	0.000	-0.022	3.25
7/28/2004	1.8408	6.7056	3.6428	0.121	0.000	4.08
7/29/2004	1.5859	6.6527	4.1948	-0.138	-0.008	1.39
7/30/2004	1.2178	6.6790	5.4847	-0.232	0.004	
7/31/2004	1.0762	6.6849	6.2118	-0.116	0.001	
8/1/2004	1.2744	6.7960	5.3327	0.184	0.017	

Appendix B.

Table 1. Temperature gage and moon phase data for Fort Shaw Canal at diversion during 2003.

Date	Moon phase	Mean Temp. at Canal °C	Hours netted	Sum Fish Entrained
6/3/2003	New		11	87
6/4/2003	New	.	11	95
6/5/2003	New	.	11	375
6/10/2003	Full	.	12	22
6/11/2003	Full	.	12	23
6/12/2003	Full	.	12	17
6/18/2003	Last Quarter	21.15	12	42
6/19/2003	Last Quarter	18.65	12	42
6/20/2003	Last Quarter	16.87	12	35
6/23/2003	New	14.10	12	17
6/24/2003	New	13.65	12	15
6/25/2003	New	13.60	12	17
7/1/2003	New	21.20	12	289
7/2/2003	New	20.42	12	257
7/3/2003	New	18.20	12	213
7/14/2003	Full	19.37	12	56
7/15/2003	Full	20.48	12	79
7/16/2003	Full	21.87	12	140
7/23/2003	Last Quarter	22.64	12	78
7/24/2003	Last Quarter	20.20	12	76
7/25/2003	Last Quarter	19.26	14	62
7/29/2003	New	21.98	12	27
7/30/2003	New	22.14	12	45
7/31/2003	New	21.42	12	57
8/1/2003	New	21.37	12	68
8/3/2003	First Quarter	22.03	12	75
8/4/2003	First Quarter	20.70	12	61
8/12/2003	Full	19.81	12	34
8/13/2003	Full	21.15	12	79
8/14/2003	Full	21.48	12	17
9/23/2003	New	10.99	12	12
9/24/2003	New	11.66	12	19
9/25/2003	New	13.76	12	54

Appendix B.

Table 2: Temperature gage and moon phase data for Fort Shaw Canal at diversion during 2004.

Date	Moon phase	Mean Temp. at Canal °C	Hours netted	Sum Fish Entrained
5/25/2004	First Quarter	11.27	12	3
5/26/2004	First Quarter	11.93	12	90
5/30/2004	Full	10.77	12	76
5/31/2004	Full	11.60	12	99
6/1/2004	Full	12.71	12	146
6/6/2004	Last Quarter	13.54	12	98
6/7/2004	Last Quarter	9.38	12	15
6/8/2004	Last Quarter	8.88	12	34
6/13/2004	New	14.65	12	144
6/14/2004	New	15.10	12	138
6/15/2004	New	13.99	12	83
6/20/2004	New	12.54	12	173
6/21/2004	New	15.60	12	296
6/22/2004	New	17.15	12	190
6/27/2004	First Quarter	17.15	12	140
6/28/2004	First Quarter	19.04	12	142
6/29/2004	Full	20.54	12	193
7/4/2004	Full	16.59	12	239
7/5/2004	Full	17.37	12	337
7/6/2004	Full	18.65	10	365
7/10/2004	Last Quarter	18.81	12	184
7/11/2004	Last Quarter	18.76	12	126
7/12/2004	Last Quarter	18.70	12	204
7/18/2004	New	21.09	12	144
7/19/2004	New	21.20	12	91
7/20/2004	New	20.81	12	60
7/26/2004	First Quarter	21.53	6	28
7/27/2004	Full	19.48	12	39
7/28/2004	Full	19.65	12	49
7/29/2004	Full	19.98	18	25