Adult Fluvial Bull Trout Passage of Tumwater Dam on the Wenatchee River:

Analysis of WDFW Ladder Counts (1998-2006) with Application to Icicle Creek

Final Report

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Abstract.- Because there is little information available on the timing of the movements of adult fluvial bull trout in Icicle Creek, counts of bull trout moving at Tumwater Dam in the Wenatchee River are used to infer bull trout migration in Icicle Creek. This paper contains an in-depth analysis of the Tumwater Dam bull trout counts and Wenatchee River discharge data. Based on data from 1914 – 1997, the mean peak discharge of the Wenatchee River at Plain is 11,547 ft^3/s and the mean date of peak discharge is May 29. During 1998 – 2006, discharge was below average in 5 years, average in 2 and above average in 2. The date of peak bull trout movement ranged from 28 – 62 days (mean 45 days) after the peak discharge date, and July 7 is the mean date of peak bull trout movement at Tumwater Dam. During the bull trout count period (1998 – 2006) at Tumwater Dam, there was no significant difference in the number of bull trout moving before or after July 7, with an average of 51.8 bull trout moving on or before July 7 and 46.8 after July 7. The yearly percentage of bull trout that moved on or before July 7 ranged from 0 – 76 %, with the highest percentage occurring during years of drought or below average discharge. Ninety percent of all bull trout were counted at Tumwater Dam when daily discharge was less than 5000 ft^3/s, including 50 % when daily discharge was less than 2500 ft^3/s. Wenatchee River daily discharge is the most adaptable parameter of the Tumwater model that could be used to infer migration of bull trout into Icicle Creek, predict their arrival at Leavenworth NFH, and assist in adaptive management of operations. Scenarios illustrating the potential use of the model are provided.

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Introduction

In order to conduct normal operations and maintenance (O&M) of Leavenworth National Fish Hatchery (LNFH), it is important to understand and address the potential impacts of hatchery operations on upstream migration of adult fluvial bull trout. However, there is little information available on the timing of the movements of adult fluvial bull trout in Icicle Creek. It has been suggested that the movement of bull trout at Tumwater Dam in the Wenatchee River provides a reasonable surrogate and can be used to infer Icicle Creek migration (USFWS 2008) and the rationale was developed as follows:

> *Because no information about the timing of bull trout migration in Icicle Creek is available, the likely timing of spawning migration is inferred based on the behavior of bull trout in nearby local populations. Tumwater Dam, located on the Wenatchee River about 5 river miles upstream from Leavenworth provides a reasonable surrogate. Like the dams at LNFH, Tumwater Dam is located in the lower Wenatchee River basin, and is near the mouth of a canyon that provides a bull trout migratory corridor to spawning habitat many miles upstream. LNFH and Tumwater Dam are about 3 air miles apart. The hydrograph patterns for both Icicle Creek near LNFH and the Wenatchee River near Tumwater are similar.*
>
> *There is a strong correlation between stream discharge and fish passage at Tumwater Dam. Bull trout upstream migration consistently peaks about one month after the peak of the hydrograph, which varied between early May and late June during the period of record (1998-2005) (unpublished data available from the USFWS, CWFO). It is a reasonable assumption that bull trout at LNFH and Tumwater would naturally move past these locations at roughly the same time of year. Additional evidence supporting this assertion is found in the bull trout technical literature (Rieman and Mclntyre 1993) and known movement patterns in the lower Wenatchee basin (Bio Analysts 2004, USFWS 2005b). In many systems some migratory bull trout are known to move out of lower basin locations in the spring, well before spawning occurs in late summer and early fall.* [USFWS 2008, pages 46 – 47, italics added}.

The use of timing of bull trout migration at Tumwater Dam as a surrogate for migration in Icicle Creek is a logical and reasonable model. The observation of a correlation between passage and discharge indicates there is potential for further development and refinement of a predictive tool or model to achieve the goal of understanding the timing of fluvial bull trout movements in Icicle Creek. In order to present a potentially useful application of the model, the Tumwater Dam bull trout counts and Wenatchee River discharge data were independently analyzed by the Mid-Columbia River Fishery Resource Office (MCRFRO), and the results are presented here.

Methods

Data on bull trout passage at Tumwater Dam on the Wenatchee River (river kilometer 53) were collected by the Washington Department of Fish Wildlife (WDFW) from ladder counts at the dam during 1998 to 2006 (WDFW 2005, 2006, 2007a). The bull trout were classified as adults, based on the estimated size when observed (WDFW 2007b).

Bull trout movements were categorized into 2 periods: 1) before or on July 7, and 2) after July 7. These periods were chosen to represent the annual default period of May 15 to July 7 for the operation of "Dam 5" at LNFH for collection of spring Chinook salmon brood stock and maintenance of the tribal salmon fishery (USFWS 2008). The 2-tailed paired t-test was used to test for differences in the number of bull trout moving in each period, with a significance level of $p < 0.05$. Bull trout were then categorized by the percentage moving in each of 8 weekly movement periods prior to July 8. The peak date of bull trout movement at Tumwater Dam was designated as the day when 50% of the total number of bull trout counted in each year was reached. Bull trout movements were also categorized by the number and percentage moving during discharge as classified in 500 ft^3/s increments (e.g > 7000, 6500 to 6999, 6000 to 6499, etc).

Discharge data for the Wenatchee River at Plain (station # 12457000 at rkm 74.4) were obtained from the U.S. Geological Survey Water Resources website (USGS 2007). To avoid bias in the analysis, only discharge data from 1914-1997 were used to calculate the mean, standard deviation, median, and mode of the peak discharge and peak discharge date. Because USGS records and disseminates the discharge data in ft^3/s, the data were not reported in metric units for this report.

Results

Wenatchee River Discharge- Based on data from 1914-1997, the mean date of peak discharge in the Wenatchee River at Plain is May 29 with a standard deviation of 16 days, the median date is May 31, and the mode is May 26 (Table 1). The mean peak discharge is 11,547 ft^3/s, the standard deviation from the mean is 3,296 ft^3/s, the median is 11,400 ft^3/s and the mode is 10,400 ft^3/s (Table 1).

During the 9 years that bull trout have been counted at Tumwater Dam, peak discharge was extremely variable. Peak discharge was below average in 5 years, average during 2 years, and above average in 2 years (Table 2). The year 2005 was a drought year, with the peak discharge more than 2 standard deviations lower than the mean (Tables 1 and 2). The date of peak discharge was also extremely variable, with deviations of 31 days earlier to 19 days later than the mean date (Table 2).

Table 1. Mean, median, and mode of date of peak discharge and peak discharge in the Wenatchee River at Plain, from 1914-1997 data set.

	Date peak discharge	Peak discharge ft^3/s
mean (SD):	May 29 (16 days)	11,547 (3,296)
median:	May 31	11,400
mode:	May 26	10,400

Table 2. Date and ft^3/s of peak discharge in the Wenatchee River, 1998-2006.

year	Date peak discharge	Deviation from mean (days)	Peak discharge (ft^3/s)	Deviation from mean (ft^3/s)
1998	May 6, 1998	- 23	11,700	244
1999	Jun. 17, 1999	+19	16,200	4,744
2000	May 23, 2000	-6	8,380	-3,076
2001	May 25, 2001	-4	8,650	-2,806
2002	Jun. 16, 2002	+18	12,400	944
2003	Jun. 09, 2003	+11	9,630	-1,826
2004	May 4, 2004	-25	6,390	-5,066
2005	April 28, 2005	-31	4,750	-6,706
2006	May 19, 2006	-10	15,800	4,344

Bull trout at Tumwater Dam- From 1998 – 2006, a total of 888 adult fluvial bull trout were counted in the ladder at Tumwater Dam. The count each year varied from 33 to 149 individuals (mean 98.6 SD 43.4), with an average of 51.8 (SD 39.4) moving on or before July 7 and 46.8 (SD 20.1) after July 7 (Table 3). There was no significant difference in the number of bull trout moving before or after July 7 (paired t-test: df = 8, p = 0.75). The percentage of bull trout that moved on or before July 7 ranged from 0 – 76 % (mean 46.2, SD 25.1).

Bull trout movement patterns at Tumwater Dam were variable each year, depending on both peak discharge date and flow. Thus in the low water or drought years of 2001, 2004, and 2005, when discharge was well below average and peak discharge date was earlier than average, 65 – 76 % of the bull trout were counted on or before July 7 (Table 3), while in 2000 and 2003, also below average flow years, 51- 53 % were counted on or before July 7 (Tables 2 and 3). In 1998, an average flow year, peak discharge occurred 3 weeks earlier than normal, but only half the bull trout were counted moving on or before July 7, while in 2002, another average flow year, peak discharge was 2 weeks later than normal and only 17 % moved prior to July 8 (Tables 2 and 3). In 1999, the peak discharge was above average and peak date was later than average, and no bull trout were counted at Tumwater Dam before July 16. In 2006, the other high water year, 33 % were counted on or before July 7 (Tables 2 and 3).

Table 3. Summary of numbers of bull trout and movement period at Tumwater Dam on the Wenatchee River 1998-2006.

year	total n	n on or before 7 Jul	n after 7 Jul	% on or before Jul 7	% after Jul 7
1998	33	17	16	51	49
1999	38	0	38	0	100
2000	83	42	41	51	49
2001	123	86	37	70	30
2002	101	17	84	17	83
2003	144	77	67	53	47
2004	149	97	52	65	35
2005	136	104	32	76	24
2006	81	27	54	33	67
mean (SD)	98.6 (43.5)	51.8 (39.4)	46.8 (20.1)	46.2 (25.1)	53.8 (25.1)

During years of low flow or early peak discharge, bull trout arrived earlier than normal at Tumwater Dam and the migration was spread over a longer time period (Table 4). In 2005, when peak discharge was 31 days earlier than average, bull trout were counted in all weekly periods prior to July 8, with 11 – 18 % counted in the 5 weekly periods from early June to July 7 (Table 4). In average or high water years, most bull trout moving prior to July 8 are counted during the week of July 1 – 7, while the majority is counted after July 7 (Table 4). On average, most bull trout that moved before July 7 did so in the 3 weeks prior, with 11 % during June 17 – 23, 11 % during June 24 – 30, and 13 % during July 1 – 7 (Table 4).

Table 4. Percentage of bull trout counted at Tumwater Dam during weekly periods 1998 - 2006.

Week	1998[a,d]	1999[b,e]	2000[c]	2001[c]	2002[a,e]	2003[c,e]	2004[c,d]	2005[c,d]	2006[b,d]	mean
< May 13	0	0	0	1	1	1	3	2	6	2
May 13-19	0	0	0	0	0	1	1	2	0	0
May 20-26	0	0	0	0	0	0	0	1	0	0
May 27- Jun 2	0	0	1	0	0	1	1	5	0	1
Jun 3-9	6	0	0	5	0	1	6	12	1	3
Jun 10-16	0	0	1	17	2	1	3	13	1	4
Jun 17-23	12	0	1	34	1	6	25	18	4	11
Jun 24-30	30	0	8	7	0	26	9	11	4	11
Jul 1-7	3	0	39	6	13	17	16	11	17	13
> Jul 7	48	100	49	30	83	47	35	24	67	54

Notes: a- average flow year b- above average flow year c- below average flow year d- earlier than average peak date e- later than average peak date

Most bull trout were counted in the ladder at Tumwater Dam after peak discharge (Figures 1 – 9). The date of peak bull trout movement ranged from 28 – 62 days (mean 45 days, SD 13) after the peak discharge date (Table 5). Based on the 1998 – 2006 data, July 7 was calculated as the mean, median, and mode date of peak bull trout movement at Tumwater Dam.

Table 5 . Dates of Wenatchee River peak discharge and peak bull trout movement at Tumwater Dam 1998 - 2006.

year	Date peak discharge	Date peak bull trout	Elapsed days
1998	May 6, 1998	July 7, 1998	62
1999	Jun. 17, 1999	August 2, 1999	46
2000	May 23, 2000	July 7, 2000	45
2001	May 25, 2001	June 22, 2001	28
2002	Jun. 16, 2002	July 17, 2002	31
2003	Jun. 09, 2003	July 7, 2003	28
2004	May 4, 2004	July 1, 2004	58
2005	April 28, 2005	June 22, 2005	55
2006	May 19, 2006	July 12, 2006	54

Most bull trout movements in the Wenatchee River at Tumwater dam occurred as discharge declined (Figures 1 – 9). Although the highest discharge when a bull trout was counted was 9410 ft^3/s, very few bull trout moved until daily flows declined considerably further. Ninety percent of all bull trout were counted when daily discharge was less than 5000 ft^3/s, including 50 % when daily discharge was less than 2500 ft^3/s (Table 6).

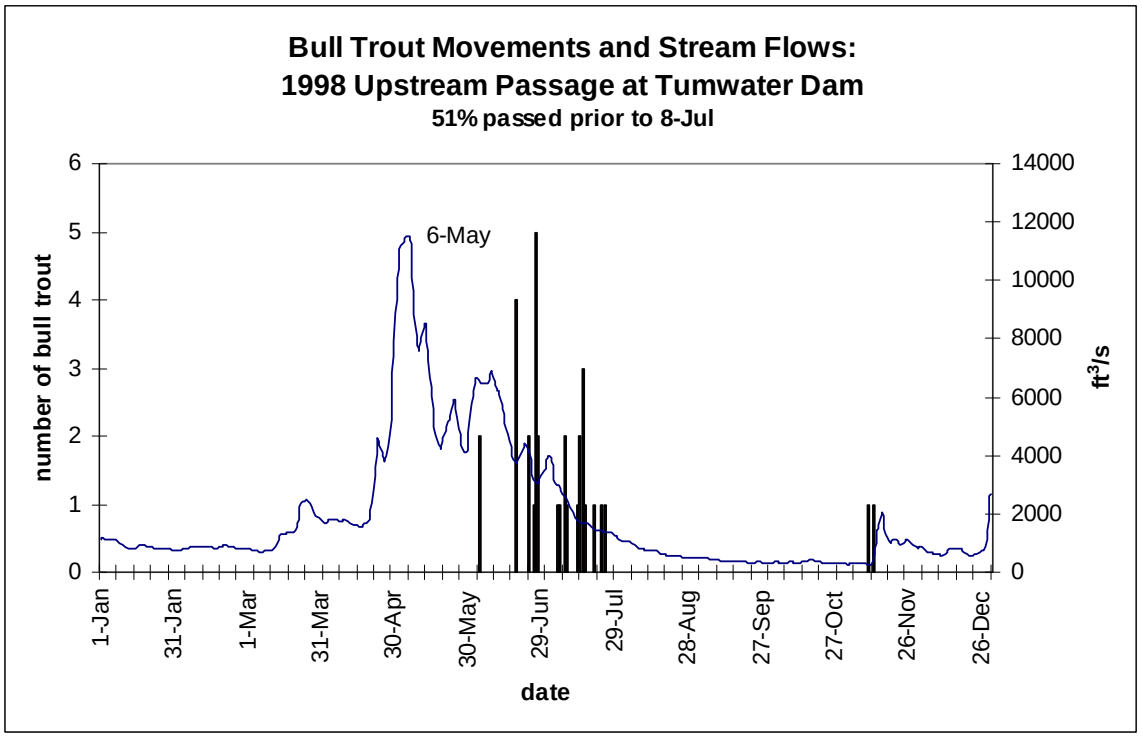

Figure 1. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 1998.

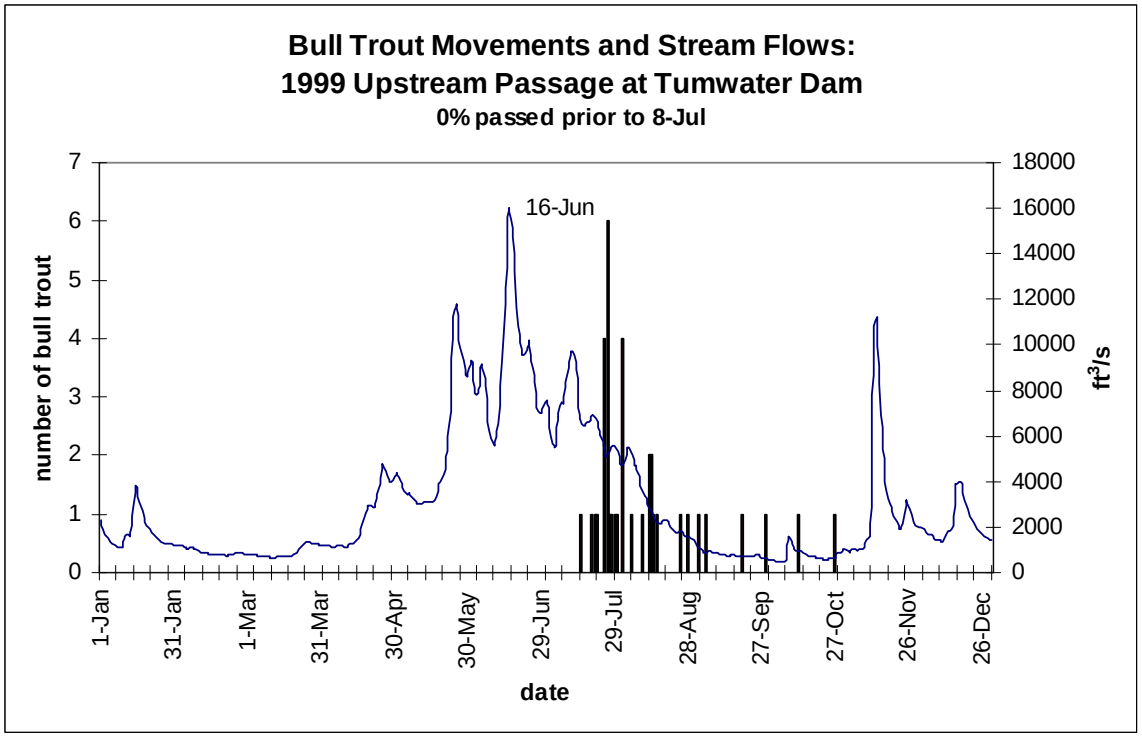

Figure 2. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 1999.

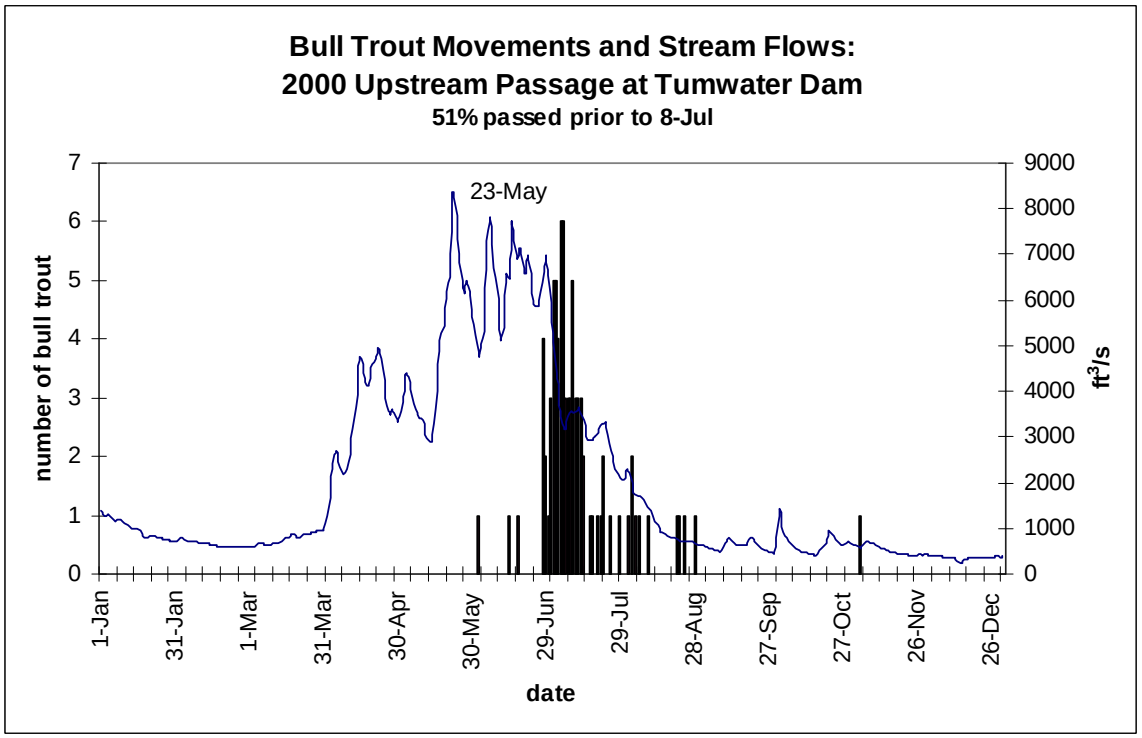

Figure 3. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2000.

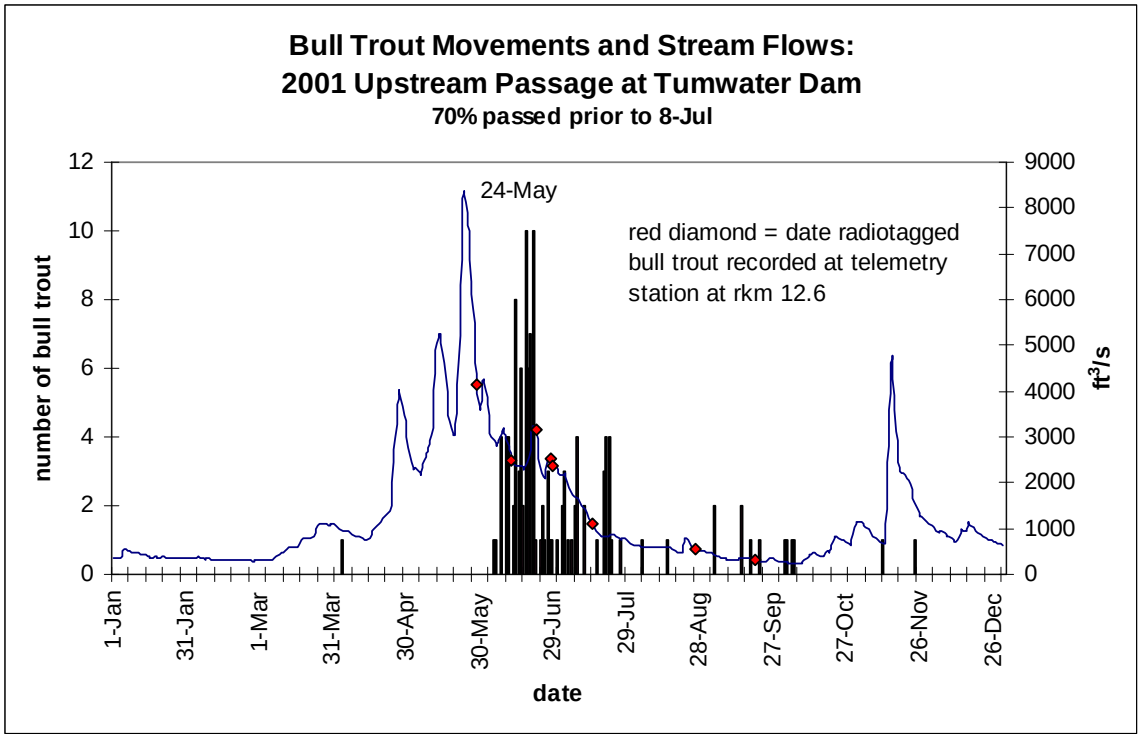

Figure 4. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2001.

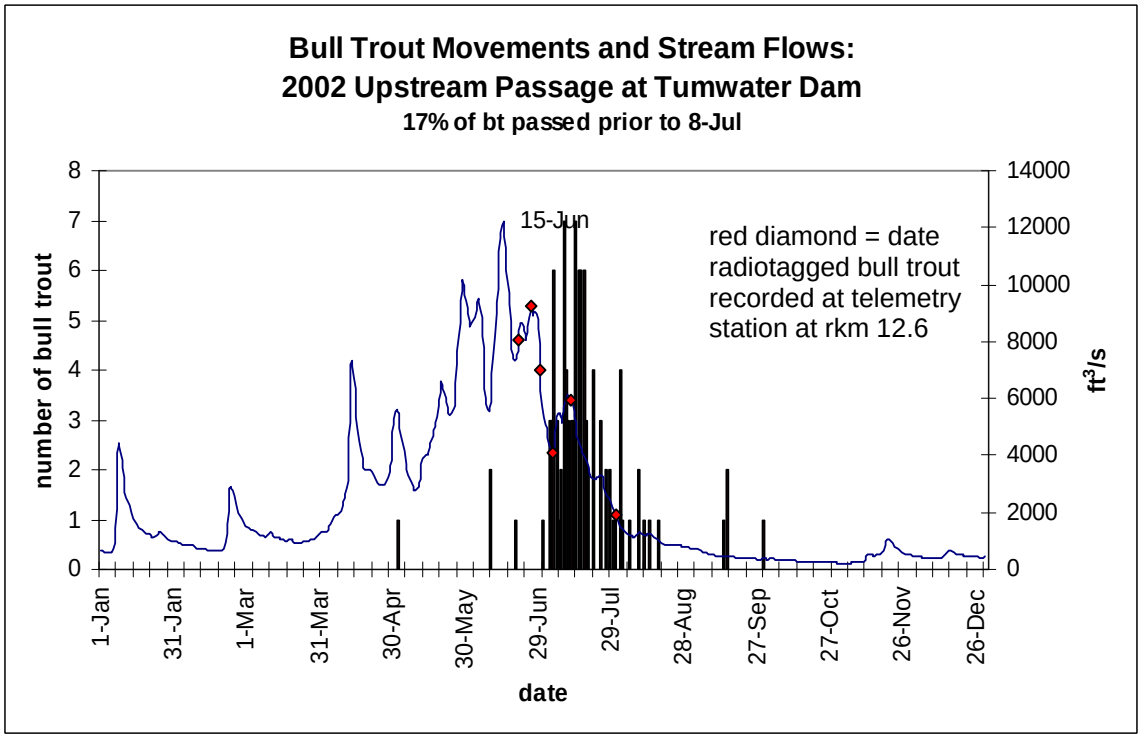

Figure 5. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2002.

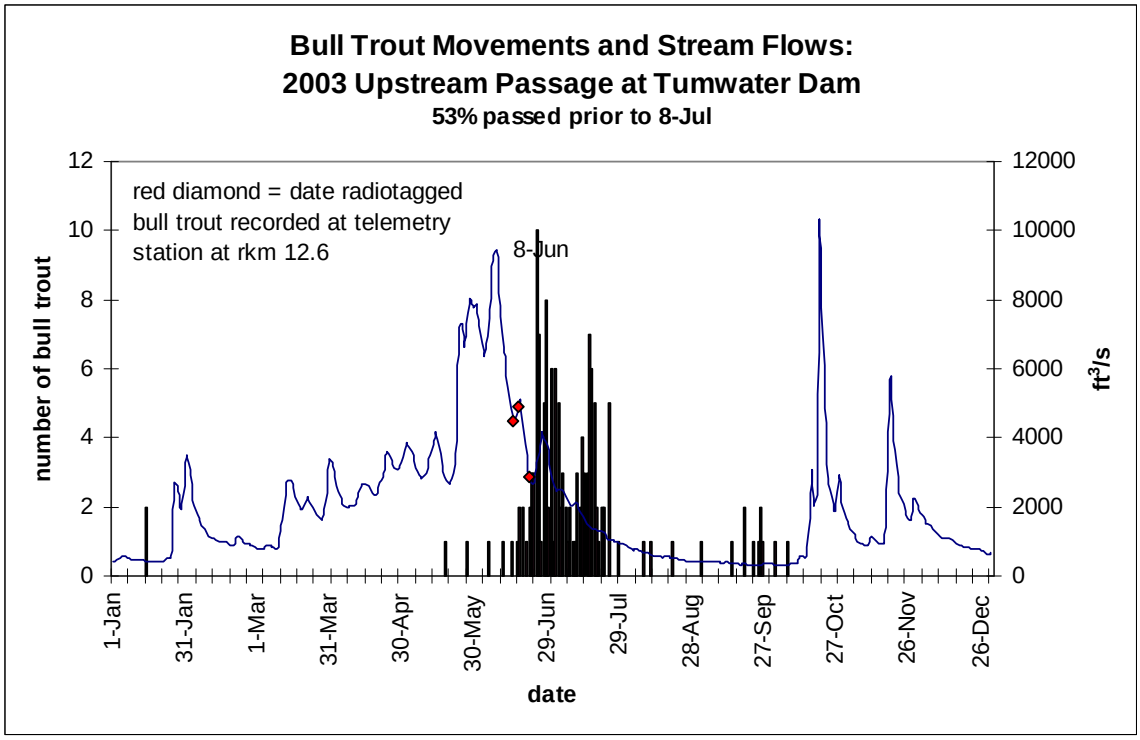

Figure 6. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2003.

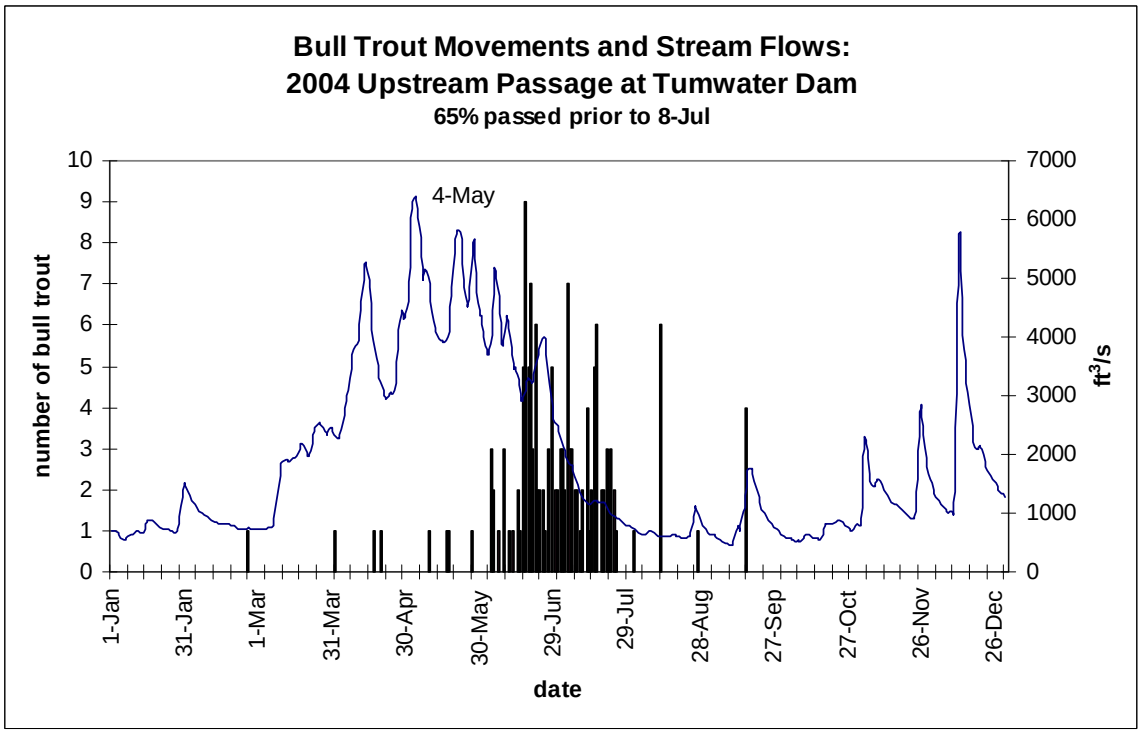

Figure 7. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2004.

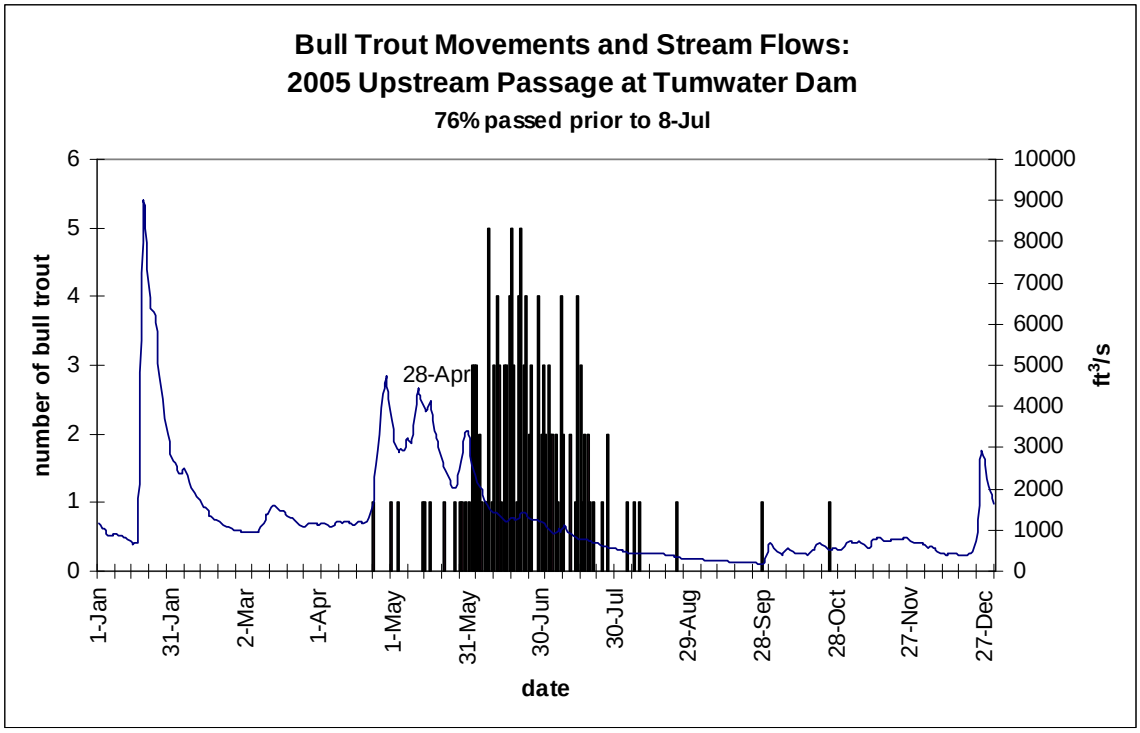

Figure 8. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2005.

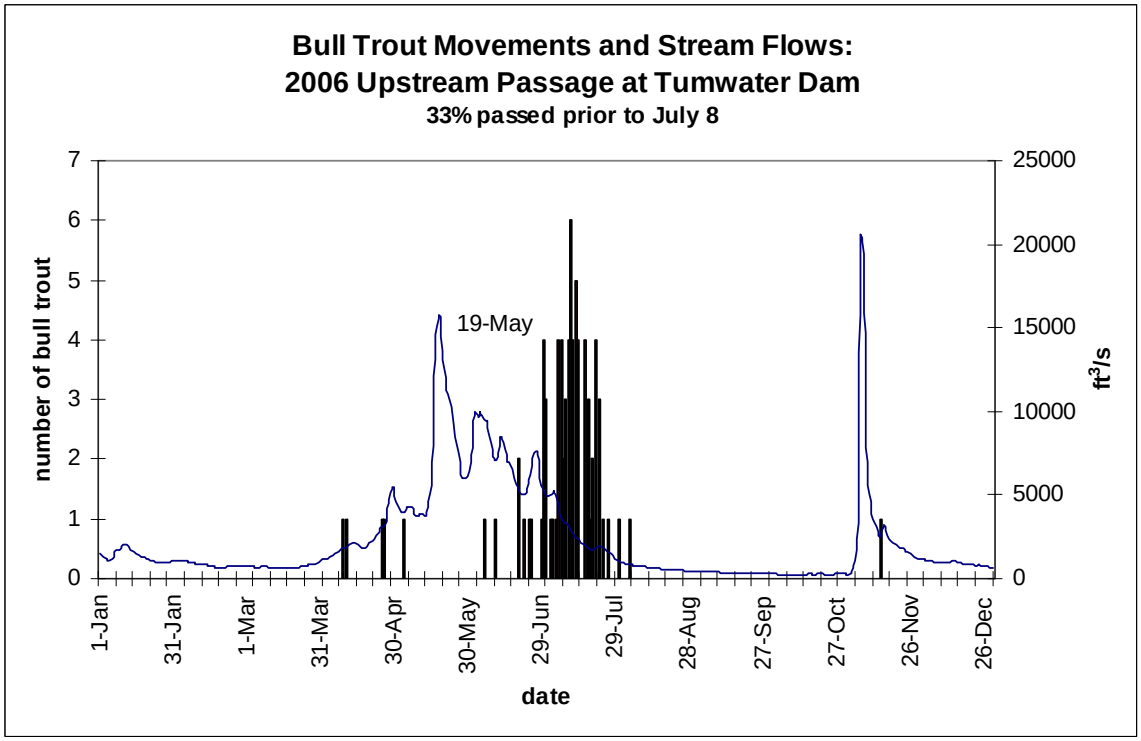

Figure 9. Bull trout counts at Tumwater Dam and Wenatchee R. discharge in 2006.

Table 6. Wenatchee River discharge and number of bull trout counted at Tumwater Dam during 1998 - 2006.

ft^3/s	1998	1999	2000	2001	2002	2003	2004	2005	2006	All Years	%	cum %
>7000			1		1	2			2	6	1	1
>6500		3	7			1			1	12	1	2
>6000	2	1	1		6					10	1	3
>5500		2	3		18		1		2	26	3	6
>5000		13	5		6	2	2		10	38	4	10
>4500		4	1		13	4	2		3	27	3	13
>4000	2		5		24	1	7	1	5	45	5	18
>3500	4	1	21		3	20	16	3	4	72	8	27
>3000	8		24	15	9	13	31	2	11	113	13	39
>2500	4	4	3	27	2	18	13	5	15	91	10	50
>2000	1	2	2	43	3	24	11	11	5	102	11	61
>1500	7	2	4	8	5	12	19	9	21	87	10	71
>1000	3	1	1	2	6	30	33	69	1	146	16	87
>500	1	5	5	18	1	4	14	31	1	80	9	96
<500	1			10	4	13		5		33	4	100
totals	33	38	83	123	101	144	149	136	81	888	100	

Summary of radio-tagged bull trout movements-
In the Wenatchee River- During 2001-2004, the Mid-Columbia Public Utility Districts (Chelan, Douglas, and Grant Counties) conducted a radio telemetry study of adult fluvial bull trout in the Columbia River and tributaries (BioAnalysts 2004). Movements of tagged bull trout were recorded at the Wenatchee River (WR) fixed telemetry station at river kilometer (rkm) 12.6. The dates these tagged bull trout passed the station are recorded as red diamonds on the hydrographs in Figures 4 - 6. Those limited movement patterns indicate the bull trout movements recorded at Tumwater Dam are consistent with the overall migration timing in the Wenatchee River.

In Icicle Creek- The movements of bull trout radio-tagged by MCRFRO and CPUD were monitored in 2004-2006. Using fixed telemetry ground stations maintained by MCRFRO, as well as mobile tracking, 5 tagged bull trout were tracked into Icicle Creek (MCRFRO data from files, Table 7). Three of the bull trout were tracked in the Entiat River, either before or after moving to the Icicle: code 70 was tagged in the Entiat River in 2003, code 43 was tracked on the upper Entiat River spawning grounds in 2005, and code 153 migrated to the Entiat River after exiting Icicle Creek in 2006. Interestingly, of the 3 bull trout tracked in 2006, code 153 arrived earliest at the hatchery, but it spent less than 2 hours in the spillway pool (it never approached Dam 5) before moving downstream and exiting Icicle Creek (MCRFRO data from files). Four of the 5 tagged bull trout entered Icicle Creek after July 7 (after the annual default period of the operation of Dam 5) and thus were not affected by normal brood stock collection or the tribal fishery. The limited telemetry data generally corresponds with the Tumwater Dam counts, and suggests those counts may be applicable to Icicle Creek.

Table 7. Movement dates of radio-tagged bull trout that entered Icicle Creek 2004-2006.

year	code	@ WR rkm 12.6	@ Icicle	@ LNFH	Left LNFH	Left Icicle
2004	70	June 16	July 29	August 4	August 5	< August 6
2005	05	July 10	> July 10	< Sept 30	In Snow Cr	Tag recov.
2006	153	June 13	> June 24	June 26	June 26	< June 28
2006	43		July 21	July 22	July 22	July 22
2006	154	June 29	July 24	July 25	Tag recov.	

Summary of results- The results of this analysis are summarized as follows:

1. Based on data from 1914 – 1997, the mean peak discharge of the Wenatchee River at Plain is 11,547 ft^3/s and the mean date of peak discharge is May 29.
2. During the bull trout count period of 1998 – 2006, discharge was below average in 5 years, average in 2 and above average in 2.
3. There was no significant difference in the number of Tumwater bull trout moving before or after July 7, with an average of 51.7 bull trout moving on or before July 7 and 46.8 after July 7.
4. The percentage of Tumwater bull trout that moved on or before July 7 ranged from 0 – 76 %, with the highest percentage occurring during years of drought or below average discharge.
5. The date of peak Tumwater bull trout movement ranged from 28 – 62 days (mean 45 days) after the peak discharge date.
6. July 7 is the mean date of peak bull trout movement at Tumwater Dam.
7. Very few bull trout migrated before peak flows, and movements began on the declining hydrograph. Ninety percent of all bull trout were counted at Tumwater Dam when daily flows were less than 5000 ft^3/s, including 50 % when daily discharge was less than 2500 ft^3/s.
8. Limited telemetry observations indicate that Tumwater Dam counts are consistent with overall timing of bull trout migration in the Wenatchee River and Icicle Creek.

Conclusions

The historical counts of bull trout at Tumwater Dam are a useful record of Wenatchee River migration windows during past years. Application of the Tumwater data to approximate the timing of migrating bull trout in Icicle Creek provides a measure of the possible impacts that operations of LNFH may have had in those years. However, the extreme yearly variation of peak discharge date and peak bull trout movement dates indicates these parameters are not appropriate for predictive use in the Tumwater model. Wenatchee River daily discharge has the most potential for predicting migration timing in Icicle Creek.

Discussion

Telemetry studies of bull trout indicate that stream discharge strongly influences bull trout migrations in the Upper Columbia Recovery Unit (Nelson et al. 2007, Nelson and Nelle 2008) and other areas (Swanberg 1997). The analysis is this paper indicates that daily discharge is the appropriate and most adaptable parameter of the Tumwater model that could be used to indicate migration of bull trout into Icicle Creek and predict their arrival at Leavenworth NFH. Most bull trout were not counted at Tumwater Dam until after Wenatchee River discharge peaked and daily flows at the Plain gage station declined to less than 5000 ft^3/s, with 50 % counted when flows were less than 2500 ft^3/s. Real time daily discharge data from the USGS gage station at Plain, in conjunction with the passage data in Table 6, could be used as a tool to determine if and when management of broodstock collection and the tribal fishery has the potential to affect bull trout movements in Icicle Creek. Managers could then use this daily discharge model for adaptive management of Dam 5 and assist in the decision-making process to balance the competing needs of brood stock collection, the tribal fishery, and passage of migrating bull trout.

To illustrate the possible use of the daily discharge model, consider the following two imaginary scenarios of the operation of Dam 5. Scenario 1 involves deciding whether to open Dam 5 before the default date of July 7 and Scenario 2 involves deciding whether to extend the date of operation. Of course, in any real situation, managers need to reach a consensus, and if not, then the default period would be used.

> *Scenario 1*- Suppose that on June 28th, the hatchery has collected the necessary number of fish for their broodstock requirements, and the catch in the tribal fishery has tapered off. The default date for the last date of operation of Dam 5 is July 7, but managers are considering opening the dam to provide early passage for bull trout and need more information to make the decision. The hydrograph is on the decline after peak discharge, so managers decide to use the daily discharge model and the real-time discharge data from the Plain station, available online from USGS. The discharge is determined to be 2500 ft^3/s, meaning that in the model, 50 % of the bull trout run has moved in the Wenatchee River and several bull trout could be present downstream of the hatchery. After considering all relevant factors, managers collaboratively decide the benefits of providing early passage outweigh the costs of catching fewer salmon and open the dam. Alternatively, suppose instead that the real-time daily discharge is 6000 ft^3/s, so that on average, only 3 % of the bull trout run is moving. Managers decide not to open the dam early because costs outweigh benefits.
>
> *Scenario 2*- Suppose that the run of salmon returning to the hatchery is very large, but the timing is later than in other years. On July 2, managers have determined that while many salmon are in Icicle Creek, less than half the run has entered the creek or arrived at the hatchery. The tribal and recreational fisheries are still strong and demand is growing for the continued operation of Dam 5. In addition,

hatchery managers are concerned about the risk of disease if too large a number of adult salmon are allowed upstream of the hatchery's water supply. To estimate the potential impacts of extending operation on migrating bull trout, managers use the daily discharge model and consult the gage station at Plain. Real time data indicates the flow in the Wenatchee River is 5000 cfs, indicating that on average, only 10 % of fluvial bull trout have migrated past Tumwater Dam and few bull trout are predicted to be in Icicle Creek. Therefore, managers decide to extend operation of Dam 5, and continue to consult the real time discharge data, allowing daily adaptive management to balance the needs of all stakeholders.

Adoption of the daily discharge model would allow more flexibility to determine the time frame of operation of the bull trout trap at Dam 5, offering potential savings in manpower and budgets. Currently, the trap at Dam 5 must be operated during the broodstock collection period (USFWS 2008). However, the daily discharge model could be used to determine when the trap needs to be operated. For example, very few bull trout migrate before peak discharge is reached, so there is little benefit in operating the trap in this period, but monetary and manpower costs are incurred. The daily discharge model indicates there is also no benefit in operating the trap until flows decline to <10,000 ft^3/s. During temporary high discharge events, the velocity and depth of water in the trap could create safety hazards for the crew, and the daily discharge model could provide a mechanism to temporarily suspend trapping. Adaptive management of the trap during average or high flow years would also provide the flexibility to extend the trapping period and perhaps afford the opportunity to capture and radio-tag more adult bull trout for the MCRFRO telemetry study in Icicle Creek (Nelson and Nelle 2007). The results of that study of bull trout movement patterns in Icicle Creek could then be used to evaluate the validity of the Tumwater model. The model can also be updated with new data each year, increasing the accuracy of its predictive value.

Movement data on radio-tagged bull trout collected by Chelan County PUD revealed that few bull trout tagged at Rock Island or Rocky Reach Dams entered the Wenatchee River (BioAnalysts 2004, Stevenson et al. 2006, 2007). This indicates that most of the bull trout counted at Tumwater Dam come from Rock Island reservoir or the lower Wenatchee River, and are not counted at the Columbia River dams. The ladder counts at Tumwater Dam represent the only accurate continuous data set available on movement patterns and number of bull trout migrating up the Wenatchee River. WDFW should continue to count and monitor bull trout in the ladder at Tumwater Dam and share that information with fishery managers to assist in the recovery of bull trout in the Upper Columbia Recovery Unit.

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