ASHMON-1 Assessment of Adult Fish Passage during Pulse Flow Releases

Program Synthesis Report

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Prepared for

BC Hydro

Water Use Planning

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Executive Summary

Results of a multi-year study to assess adult fish passage during pulse flow releases in the Ash River (ASHMON-1) were reviewed, including two additional years of monitoring. Two key management questions identified in the terms of reference were:

1. Do the pulse flow releases during August and September improve Steelhead passage at Dickson Falls, and thus increase the number of Steelhead present upstream of the falls; and
2. What is the appropriate magnitude and hourly flow release to maximize Steelhead passage?

Snorkel survey data provided a contrast of migration rates for 10 cms and 20 cms releases. 10 cms pulse flows were found to have a significant positive effect on migration rate while no effect was detected for the 20 cms pulse when compared to non-pulse periods. The magnitude and hourly release schedule which maximized passage were investigated with radio telemetry but few tags ascended the falls during pulse flow periods which limited the analysis. However, Steelhead were found to ascend the falls at range of 3.7-11.2 cms which supports snorkel survey data. Leap monitoring data indicated the frequency of attempts increased for the 10 cms pulse only but the number of successful leaps was highest at 20 cms. The confidence in accurately determining migration success was low so the frequency of attempts was highlighted. Results of the study indicate that moderate pulse flow releases (<11 cms) significantly improved the rate of passage at Dickson Falls but the majority of passage likely occurred during non-pulse periods. Base flow conditions of 3.5 cms did not prevent migration.

The operational implications of this work are that moderate pulse flow releases of 10 cms from Elsie Dam do improve Steelhead fish passage and that base flow conditions of 3.5 cms do not impede migration, effectively answering Management Question 1. If additional work is contemplated to further optimize pulse flow releases for fish passage (Management Question 2), the current study design is unlikely to be strong enough to detect an effect. Alternative tracking technologies and more comprehensive snorkel survey program would be required to define the flow at which passage is maximized. A complete season of non-treatment (no pulse) monitoring may be useful for contrasting past and future results. The collection of additional "leap attempt" monitoring and environmental data outside of flow and temperature may not be required. Incremental biological gains from further adjustments to the pulse flow schedule should be considered prior to proceeding with additional work.

Introduction

The Ash River is one of two main tributaries to the Stamp River, which enters Alberni Inlet on the west coast of Vancouver Island at the City of Port Alberni. The Ash River watershed originates on the west side of the Beaufort Mountain Range, flows southeast for approximately 25 km, and meets the Stamp River 18 km upstream of tidewater. The Stamp meets the Sproat River 14 km downstream of the Ash River confluence. At this point it becomes the Somass River which flows for 3.7 km before it terminates in the Alberni Canal at the City of Port Alberni.

The Elsie Lake impoundment structure consists of one main rock and earth filled dam 185 m long and 30 m high, as well as four separate saddle dams ranging in length from 50 m to 450 m and 3 m to 18 m in height. The purpose of the structures is to divert water down to a powerhouse located 6.5 km away on the north side of Great Central Lake. The facility, constructed in 1958, has an operating capacity of 25.2 MW. The water licence allows for a maximum of 76.5 million m^3 of storage and 339 million m^3 to be diverted into Great Central Lake per annum.

Stream flow releases from Elsie Dam are now regulated according to the Ash River Project Water Use Plan (2004). The WUP was expected to achieve a number of cultural, biological and social benefits which were monitored during ASHMON -1 (assessment of adult fish passage during pulse flow releases) and AHSMON-2 (Elsie Lake Reservoir archaeological investigations). The monitors were implemented for 6 and 5 years, respectively. This review will determine if monitors have provided answers to key management questions for considerations during the Ash Water Use Plan Order Review. This review focusses on the review of the ASHMON-1 studies; a separate synthesis report has been prepared for ASHMON-2 (Jones 2016).

Background

Issue

Through the Ash River Water Use Planning (WUP) process, concerns regarding fish passage were raised by the Consultative Committee. Primary concerns involved summer Steelhead passage at Dickson Falls in August and September although Coho and Chinook migration in the lower river was also identified. In addition, Steelhead passage downstream of Dickson Falls at Lanterman Falls was also of concern. A considerable amount of uncertainty regarding migration success at regulated base flows of 3.5 m^3/s, and the newly proposed 10 cms pulse flows throughout the summer migration period, existed amongst the committee. It was believed that periodic rain events were not expressed as an increase in the hydrograph due to the impoundment of water at Elsie Lake. As a result, the newly drafted WUP included a provision for pulse flows to facilitate the upstream migration of adult Steelhead past Dickson Falls.

In order to determine the appropriate schedule, magnitude, and duration of pulse flows a comprehensive monitoring study was developed (ASHMON-1). This study design focused on Steelhead migration which was also used as a proxy for Coho and Chinook. Expert opinion and knowledge of Steelhead migration in other coastal watersheds was used to develop two pulse flow options to be tested. Peak magnitudes of 10 m^3/s and 20 m^3/s were selected with varying durations in order to stay within the allocated water budget and were approved for the study period. The first pulse flows occurred in the summer of 2005 in conjunction with the first year of the ASHMON-1 monitoring project. Specific details regarding the study design are summarized below. For the complete document please refer to the terms of reference (BCH 2005).

Objectives

The ASHMON-1 study focused on resolving two key uncertainties with respect to fish passage at Dickson Falls. The primary objective was to assess the benefits of pulse flow releases to Steelhead in terms of migration rate. It was theorized that the response of Steelhead to pulse flows would be positive but it was uncertain if it would be significant.

The second key objective was to collect appropriate data in order to determine the characteristics of the pulse flow that would be most beneficial while staying within the water budget of 26 cms days[1]. Testing two different release strategies was intended to improve understanding of the appropriate flow magnitude and duration required to optimize migration success during pulses.

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[1] This volume was allocated to pulse flows in addition to the 3.5 cms base flow. The original provision was for two pulses measured at 10 cms near Moran Creek lasting two days each (BCH 2004).

Management Questions

The objectives of the study were directly linked to two key questions involving the management of water and fish in the Ash River watershed. As described in the ASHMON-1 Terms of Reference (BCH 2005) these questions were:

1) Do the pulse flow releases during August and September improve Steelhead passage at Dickson Falls, and thus increase the number of Steelhead present upstream of the falls?
2) What is the appropriate magnitude and hourly flow release to maximize Steelhead passage?

Expected Biological Response - Hypotheses

In addition to key management questions, three hypotheses were identified to further direct the study design. The hypotheses as per the Terms of Reference (BCH 2005) were:

H_1: Flow conditions at Dickson Falls during August and September hinder adult Steelhead migration.

H_2: The pulse flow release improves the rate of adult Steelhead migration past Dickson Falls.

H_3: The magnitude and duration of the pulse flow release affects Steelhead passage at Dickson Falls.

It was expected that study results would determine if the hypotheses were true or false and provide additional details regarding the effects of other environmental variables. Essentially these factors could be combined into a fourth hypothesis, presented below.

H_4: A combination of environmental factors such as water temperature, light intensity, turbidity and changes in barometric pressure produce optimal conditions to elicit a migratory response.

Methods

Snorkel survey counts in index sections of the Ash River were used to infer the relative abundance and distribution of Steelhead before and after pulse flows. The relative change in abundance in each section (upstream/downstream) was expressed as fish per day to correct for varying durations between surveys. Periods between pulse flows were designated as controls in order to compare migration rates during pulse periods while correcting for yearly differences in fish abundance.

Leap attempt observations were implemented to monitor the migration behavior of Steelhead prior to, during, and following pulse flow releases. Attempts were classified as successful or unsuccessful based on which part of the falls fish were last observed. The duration of observations was originally set for one hour intervals at morning and afternoon periods. Recommendations from the first two study years to increase the observation period to two-one hour intervals during each morning and afternoon period were implemented in years three through five. Although data from both the upper and lower falls were collected, only the upper section was included in the analyses due to inconsistencies in data collection.

The radio telemetry component was included to collect more detailed migration information from a subset of the Steelhead population. This information was considered to be highly valuable as it would identify the specific times of passage at Dickson Falls, and the related flow conditions which were found to produce the highest rate of passage success. In addition, the distance migrated during pulse and base flows was expected to be calculated. A total of 50 tags were to be applied including 10 in year two, 20 in year three and 20 in year five. A summary of monitoring activities and objectives for the study is presented below in Table 1.

TABLE 1. SUMMARY OF MONITORING ACTIVITIES AND OBJECTIVES OUTLINED IN THE ASHMON 1 TERMS OF REFERENCE (BCH 2005).

Task	Key Measurement Variable
1. Snorkel count	1: Relative distribution of Steelhead upstream and downstream of Dickson Falls.
2. Telemetry	2a: Distance migrated during control and pulse Periods; and 2b: Timing of and discharge during falls passage.
3. Direct observation	3a: Leap attempts per unit time; 3b: Successful leap attempts per unit time; and 3c: Migration route.

Detailed Review of ASHMON-1

The previous report section outlined a brief background and methods of the ASHMON-1 study to investigate fish passage in response to pulse flows on the Ash River. The primary purpose of this document is to provide a review of the methods and results to see if study objectives were met. A further objective includes providing recommendations for future studies to fill data gaps, if required. The ultimate decision to accept whether pulse flows were effective in achieving management objectives lies with the Monitoring Advisory Committee, and this document is intended to assist with their interpretation of results.

Snorkel Surveys

A total of eight survey sections were swum over seven years of monitoring. The anadromous length of the Ash River from Elsie Lake to the confluence of the Stamp River was measured at 22.2 km (excluding Dickson Lake). The total length of sections regularly surveyed was 10.0 km which included 4.0 km upstream of Dickson Falls and 6.0 km downstream (Table 2). Overall, 45% of the anadromous section was consistently surveyed, including 35% of the habitat upstream and 56% of the area downstream of Dickson Falls. In 2010, additional sections upstream (+2.1 km) and downstream (+4.8 km) of Dickson Falls were swum on the last survey which increased coverage to 76% of the anadromous length. The remaining 5.3 km of habitat that was not surveyed included a 1.8 km section downstream of the Ash Mainline Bridge and a 3.5 km section in the middle of the upper Ash River.

Although seven years of snorkel data were collected between 2005 and 2011 only the last five years were able to be used in the analysis due to inconsistencies in collection. This restricted the analysis of the early 20 cms pulse flow to just one year.

The primary metric used in the analysis of fish migration rate in response to pulse flows was the change in fish per day between swims in the upstream survey reaches (Δ fish/day). This approach was used to standardize the data due to the varying time between surveys resulting from relatively short pulse periods and longer control periods.

After processing snorkel survey data in this manner a statistically significant increase in migration rate ($\alpha = 0.06$) was associated with the 10 cms pulse flows. Similarly, no significant differences in migration rates were observed between the 20 cms pulse flow and control period.

TABLE 2. SUMMARY OF SNORKEL SURVEY SECTIONS IN THE ANADROMOUS SECTION OF THE ASH RIVER.

km	Section
4.0	Elsie Dam to top of Dickson Falls - Regular Survey Sections (1, 2, 3.1)
6.1	Elsie Dam to top of Dickson Falls - All Survey Sections (1, 1.1, 2, 2.1, 3.1)
5.3	Sections not surveyed
11.4	Total Upstream
6.0	Dickson Falls to Stamp River - Regular Survey Sections (3.2, 4)
10.8	Dickson Falls to Stamp River - All Survey Sections (3.2, 3.3, 4)
0.0	Sections Not Surveyed
10.8	Total Downstream
10.0	Regular Survey Sections (1, 2, 3.1, 3.2, 4)
16.9	All Survey Sections (1, 1.1, 2, 2.1, 3.1, 3.2, 3.3, 4)
5.3	Sections not surveyed
22.2	Total Length
45.1%	Habitat Surveyed - Regular sections
76.1%	Habitat Surveyed - All sections
23.9%	Habitat not Surveyed

Historic data from survey section 4 were plotted with data collected during pulse flow monitoring (Figure 1). The abundance of Steelhead in this section at the end of September was found to exceed 135 adults in three consecutive years prior to pulse flows (1999-2001). Abundance of many summer-run Steelhead populations was high during this time (MoE and BCCF files) and similarly declined in 2003 and 2004. Pulse flows were first implemented in the summer of 2005 and continued through 2011. During this time, Steelhead abundance was believed to be stable with the exception of 2010 which showed a strong return (year 6 report). Despite the large return in 2010 and six other years of monitoring, no more than 72 fish were observed below Lanterman Falls suggesting pulse flows may have a positive impact on Steelhead migration at this location.

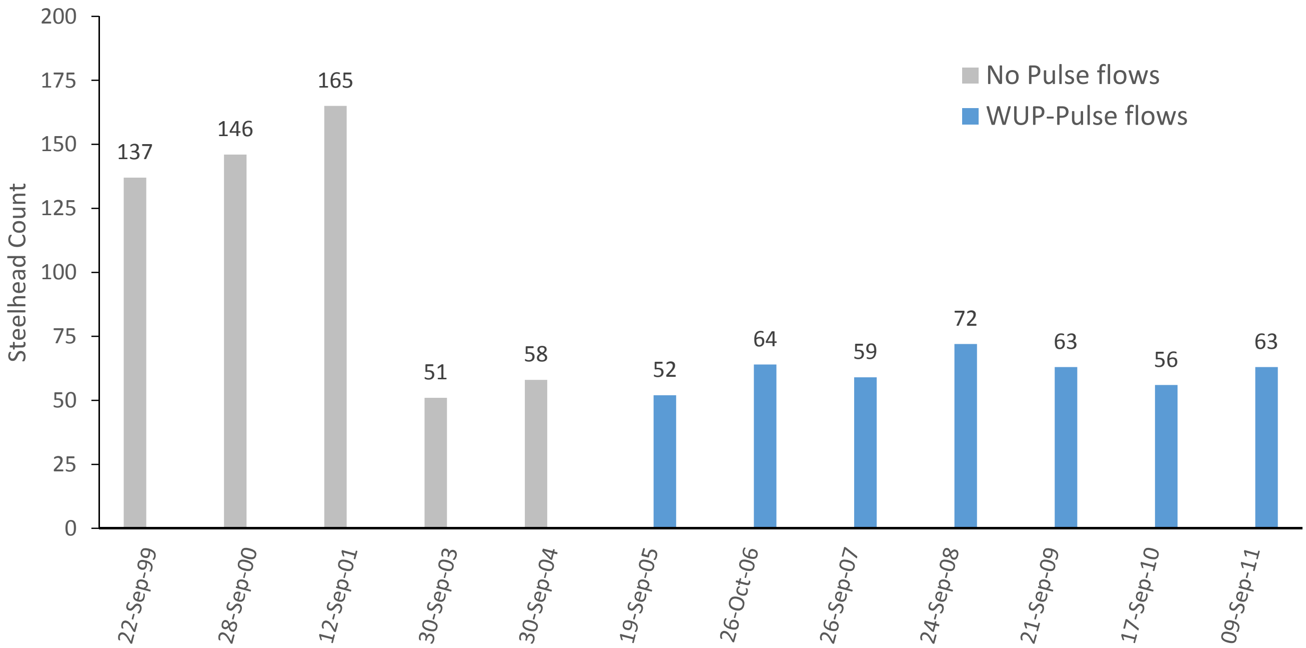

FIGURE 1. SNORKEL SURVEY COUNTS OF SUMMER-RUN STEELHEAD IN SECTION 4, 1999-2011. NOTE: IMPLEMENTATION OF WUP PULSE FLOWS BEGAN IN 2005.

Timing of snorkel surveys and pulse flow releases were also investigated. The number of Steelhead present upstream of the falls prior to the first pulse flow was compared to the peak count following pulse flows for 2007-2011. On average, 38% of the peak count was achieved prior to the beginning of pulse flows (range 26%-56%). This suggests that flows were accurately timed with peak abundance near Dickson Falls.

A closer examination of Figure 7 in Lewis et al. (2010) indicates that the rate of Steelhead migration under all flow conditions is strongly correlated with the time of year. It appears that migration rate (Δ fish/day) was the highest at the first survey interval which occurred no earlier than August. This suggests that timing of peak migration likely occurs before peak abundance and prior to the typical timing of the pulse flows. It may be more appropriate for pulse flows to be timed when migration rate is expected to be highest rather than when fish density is highest. Large numbers of fish below obstructions typically indicate a passage limitation has already persisted for some time. Furthermore, it may be possible that the earlier component of the population is more likely to migrate up river compared to a later component that may inhabit reaches downstream of Dickson Falls. Defining the time at which the peak migration rate occurs could be achieved by conducting surveys earlier in the season and as early as July 1. Summer Steelhead in nearby west coast Vancouver Island systems (e.g. Nahmint River, BCCF Files) are known to migrate from late May through September further suggesting surveys could commence earlier than August.

Although Coho migration was of secondary importance, snorkel data showed a clear response to pulse flows. The 20 cms pulse was found to double the number of Coho at the base of Dickson Falls while the effect of the 10 cms pulse was negligible (Lewis et al. 2010). If Coho were used as a proxy for Steelhead then it is possible that Steelhead migration rate also improves at Lanterman Falls as flows approach 20 cms. Limited observations of Steelhead passage at Lanterman Falls hindered the understanding of passage rates in relation to pulse and base flow conditions. Lewis et al. 2010 reported that the supply of Steelhead to the base of Dickson Falls increased the most following the 20 cms pulse flow. This suggests that the 20 cms pulse may have increased passage at Lanterman Falls and/or stimulated migration for fish holding in reaches not surveyed. Increasing migration rates at Lanterman Falls should increase the supply of fish to Dickson Falls and may have direct consequences to migration rate and overall migration success.

Radio Telemetry

Radio telemetry was included in the study design to identify the specific migration timing for a subset of the adult Steelhead population. A total of 50 fish were tagged immediately below Dickson and Lanterman falls over three study years. The sample size of 20 in each of the study years was based on a power analysis where it was determined that 17 tagged fish would be required to test for statistical differences in migration rates for each pulse flow (BCH 2005).

In all years combined, 16 tagged fish were confirmed to ascend Dickson Falls of which the timing was known for 12. Of the 12 migration events, only three were associated with pulse flows (Lewis et al. 2010). It appears that for fish that did migrate above Dickson Falls, flows up to 7 cms facilitated a similar level of migration. Flows between 7 and 11 cms appeared to increase migration with the highest rate observed in the 7-9 cms range (Figure 2).

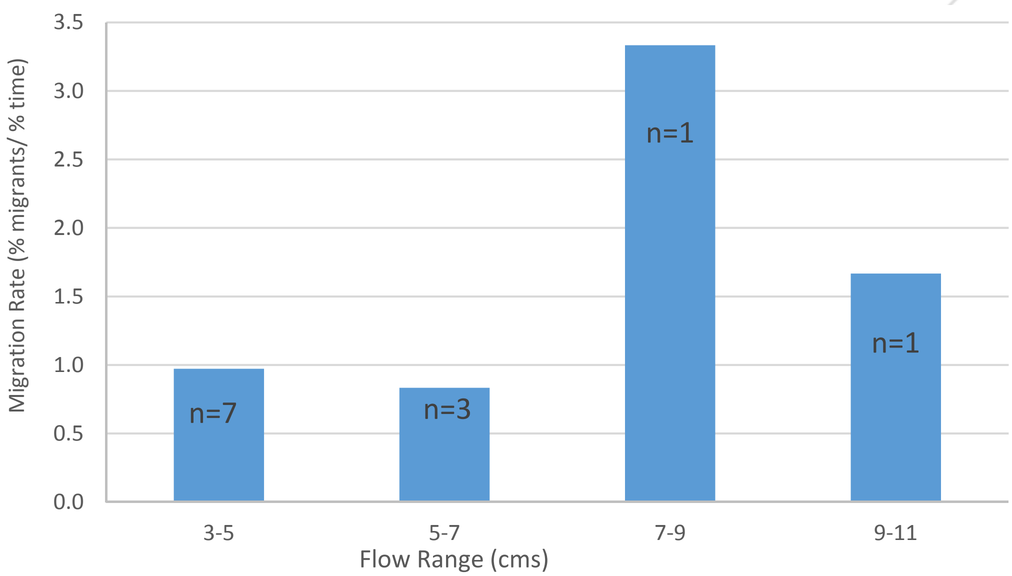

FIGURE 2 COMPARING FLOW FREQUENCY TO PASSAGE SUCCESS OF 12 TAGGED STEELHEAD AT DICKSON FALLS, 2006, 2007 AND 2009. NOTE: FLOWS INTERPRETED FROM FIGURE 18 IN LEWIS ET AL. (2010)

The migration success of fish tagged at Dickson and Lanterman falls was also investigated. Over the three year period 16 of 50 fish were known to ascend Dickson falls (32.0%) of which 9 were tagged at Dickson Falls and 7 were tagged at Lanterman Falls. Taking the number tagged at each location into account (28 and 22, respectively) the migration success rate for fish tagged at Dickson Falls (32.1%) was identical to those tagged at Lanterman Falls (31.8%). This provides evidence that the probability of fish ascending Dickson Falls is not linked to the capture location. However, the probability they will migrate above the falls in response to a pulse flow may still be linked to where they are located within the river at the start of the flow release.

If we assume that approximately half of the population is destined for the reaches above Dickson Falls based on the quantity of available habitat (11.4 km vs. 10.8 km) then the expected passage rate for all tagged fish would be 51%. Earlier it was suggested that 38% of the migration above the falls occurred prior to pulse flows on average based on snorkel counts. If fish were tagged close to the beginning of the first pulse flows then the expected number of tagged fish to ascend Dickson Falls would drop by 38% or from 51 in 100 to 32 in 100 (32%). This value is close to the 16 of 50 fish which ascended the falls over the study period (32%). This suggests that tagging fish earlier in the season would increase the probability of each fish ascending the falls resulting in a greater understanding of flow requirements for passage.

Migration distance during control and pulse periods was a key measurement variable identified in the TOR. It was anticipated that radio telemetry would provide data on the migration of each tagged fish such that the rate (e.g. km/day) could be calculated for each period to test for significant differences. The collection of data during the study was limited by the number of mobile tracking days and ability to track each fish on every event (Lewis et al. 2010). As a result, limited data were available for assessing migration rates and no analyses were conducted.

Leap Monitoring

The primary objectives of Steelhead leap monitoring were to measure the total number of leaps per unit time as well as the number of successful leaps during control and treatment periods. Also of importance was to identify the migration route which fish used to ascend the falls successfully. The study was able to determine that the number of leap attempts per hour associated with the 10 cms pulse flow were significantly higher than the control period at the 94% confidence level. The number of attempts per hour associated with the 20 cms pulse were found to be less compared to the control but the difference was not statistically significant.

The route of passage at Dickson Falls was first mapped by Griffith (1993) and presented as Figure 2 in Lewis et al. (2010) following several modifications (Burt 2001, Hryhorczuk and Silvestri 2002). The majority of leap monitoring analysis focused on the upper half of the falls after data consistency issues and a low number of leap attempts were documented. The conclusion from monitoring the lower falls was that fish migrated earlier in the day to holding pools within the middle falls (#3-5) and then leaping activity increased in the afternoon primarily from holding pool #5. The route of successful passage was not discussed in detail but the one fish confirmed to have ascended the falls at 7.2 cms did so using pool 6 b which is the path with the greatest number of steps and lowest maximum cascade height.

Limitations of the leap monitoring component were identified in the TOR and included a low likelihood of observing a successful leap as well as considerable uncertainty in determining if a leap was successful or not. Analysis focused on the frequency of leap attempts during control and pulse periods at the upper portion of the falls in years 3-5 only. No analysis on migration route or attempted migration route was conducted. It is unclear how this information would have been used to evaluate the effectiveness of pulse flows. It can be hypothesized that if migration success is dramatically improved by fish leaping to pool 6b instead of 7 then the flow that produces the largest relative increase in the number of attempts at 6b would be the most beneficial. Essentially the hydraulics of the 6-7 route distract fish from finding the easier 6-6b route but altering flow may make the latter more attractive.

Although documenting the frequency of leap attempts provided valuable insight into behaviour at a population level it can’t be used to evaluate individual behavior. For example, the number of attempts per fish or the number of days between the first attempt and success are unknown. If success were high then the number of leaps would be low. In this case, a high number of leaps has been used as a positive indication that a specific flow is suitable for migration, which may be misleading.

Environmental Data

A significant amount of environmental data was collected over the study including solar radiation, turbidity, air temperature, water temperature, and barometric pressure. Linear regression analysis revealed a weak association between increased leap attempts and solar radiation as well as air temperature. A principal component analysis suggested that both timing and hydrometric conditions were important considerations for scheduling pulse flows.

When taking into consideration the time of day that fish passed Dickson Falls and the frequency of leap attempts it appears that both are highest in the afternoon period. This is an important finding in that passage success may be dramatically increased as the daily maximum water temperature is realized. Looking at only the correlation between water temperature and frequency of leaps may not reveal this trend as water temperature is correlated to day of year and not an independent variable. Monitoring of winter Steelhead migration on the Salmon River at a hydraulically challenging fishway revealed a very strong correlation between the timing of peak daily water temperature and fish migration behavior (Figure 4). This suggests the direction of daily temperature change may be an important cue for migration while the magnitude of the daily peak may be less important (i.e. leap attempts/hr may peak at 14:00 for two sample intervals weeks apart yet max water temp may be 16°C one day and 18°C the other).

Of note with respect to water temperature is the maximum reported value of 27.41°C on July 27, 2009. Temperatures over 20°C are believed to negatively impact fish migration and increase stress while sustained temperatures (1000 min) over 23.9°C can be lethal to Steelhead (Bjornn and Reiser 1991). In 2009, temperatures that radio tagged fish passed Dickson Falls averaged 19.05°C with a range of 15.0-21.6°C. It is unclear how far outside this range passage occurs and at which temperature threshold leap attempts and passage are dramatically reduced.

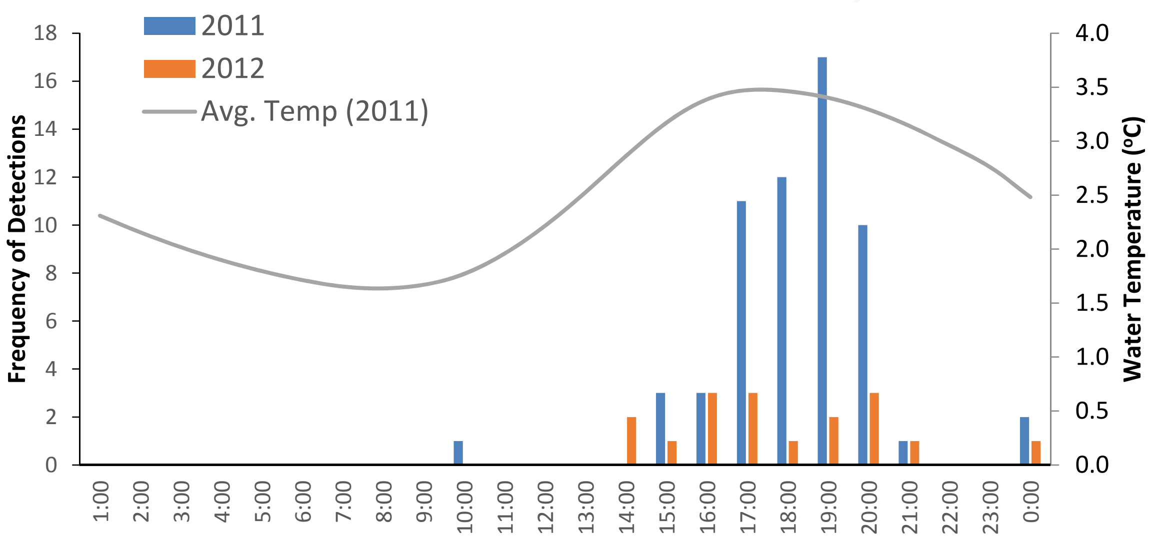

FIGURE 3. FREQUENCY OF FISHWAY DETECTIONS FOR ADULT STEELHEAD TAGGED WITH PASSIVE INTEGRATED TRANSPONDERS AT THE SALMON RIVER DIVERSION DAM IN RELATION TO DAILY WATER TEMPERATURE, SPRING 2011 AND 2012.

Water temperatures in the Ash River peak in late July and early August while the majority of migration monitoring in ASHMON-1 studies occurred from mid-August through September. Temperature data collected in 2009 (Ecofish Research Ltd. 2010) revealed that temperatures above 22°C occur in about a 20 day period between July 20 and August 10.

Summary

Considerable knowledge regarding the migration of summer-run Steelhead in the Ash River was gained through ASHMON-1. Data were sufficient to answer key management questions with varying levels of confidence. In response to the first management question, snorkel survey results indicated pulse flows improve the rate of

Steelhead passage at Dickson Falls. Of the two flows which were implemented from 2005-2009, the 10 cms pulse appeared to be more effective. Alternate flow regimes tested in 2010 and 2011 of a lower magnitude were also found to increase passage, although it could not be determined if the effect was significantly different from the 10 cms pulse.

The ASHMON 1 study was found to follow the terms of reference closely with few deviations. Data were collected in a consistent manner with a few exceptions in the first two years regarding leap monitoring and snorkel surveys. As a result, data from 2005 and 2006 were unable to be fully utilized in later analyses. The TOR suggested that a second fixed telemetry station would be located at Lanterman Falls but it appears that the station upstream of Dickson Falls was the only one implemented in the study. This limited the investigation of Steelhead passage at Lanterman Falls and may also have provided migration data in control and pulse periods. As no reference for this deviation was made it is unclear if the TOR was amended or if this component was omitted.

There is enough evidence to support the implementation of pulse flows prior to mid-September, with each pulse persisting for at least 48 hours. Evidence suggests that the afternoon period may be critical to passage which should be taken into account when scheduling pulses. A more defined magnitude of pulse which maximizes passage at either Dickson or Lanterman Falls remains unclear. This is due to an inadequate number of data points which failed to identify the exact flow at which most passage occurs. In order to meet this objective, additional monitoring using alternative fish tracking techniques could be considered if the Water Use Plan Order Review deems further refinement is necessary. Snorkel surveys should be continued in order to adequately assess future pulse flows but additional survey sections could be added to improve resolution of data.

Conclusions

The two key management questions identified in the terms of reference were addressed by the study results. Pulse flow releases during August and September were found to improve the rate of Steelhead passage at Dickson Falls.

The answer to the first management question relating to improved fish passage at Dickson Falls was expressed as a change in the number of fish per day observed above the falls. The increase in passage rate was found to be significant for the 10 cms pulse at approximately two fold compared to non-pulse periods. The duration of the pulse was limited by constraints in the water budget which resulted in a 42 hour flow improvement. Although the rate of passage improved during the pulse, the benefit to the population as a whole is likely less significant. If August and September are considered the key migration months, then each 10 cms pulse represents a two fold increase in passage over approximately two of sixty days. Base flow migration rates were lower than pulse flow migration rates, but the majority of migration occurred during base flows given the longer duration of those flows.

The second management question relating to the magnitude and hourly flow release required to maximize Steelhead passage proved more difficult to answer. The lack of successful passage times documented during the radio telemetry project decreased the resolution for assessing the optimal magnitude. It was clear that the 10 cms pulse improved the rate of passage significantly while the 20 cms pulse was found to have no effect (positive or negative) relative to base flow. It is, however, not known if passage could be further improved at other flows. Limited data suggest the optimal flow to maximize passage may be in the 7-9 cms range. The afternoon/evening period proved to be the most significant passage window each day which is important for timing future flow releases. Given the improvements observed with the 10cms pulse flows and the difficulties in assessing further refinements to this regime, the Water Use Planning Order Review will need to determine if future study is required.

Recommendations for future WUP studies

The Management Questions associated with ASHMON-1 were largely addressed in this study, but uncertainties with the specific timing and optimal pulse flow magnitude were not fully addressed. If the WUP Order Review finds that further pulse flow assessment is required, the following steps are recommended.

A full review of the available information referenced in this review should be undertaken before additional work is contemplated to address these uncertainties. Based on the existing information, there is potentially limited ability to detect changes in passage success between pulse flows in the moderate (7-11cms) range. There may be value in exploring the timing of pulse flow releases as the current strategy is to focus on peak abundance rather than peak migration. Focusing the timing of releases earlier to coincide with peak migration could better support summer run Steelhead habitat use in upper Ash River. If this uncertainty is to be explored, we recommend the following changes to the existing study:

- Identify a suitable metric: A variety of measures for passage success exist but the end of season distribution may also be an appropriate metric to consider.

- Include all sections in the distribution analysis: it is highly recommended that section 3.3 be included as part of regular snorkel surveys in order to understand passage at Lanterman Falls and the subsequent distribution of fish relative to Dickson Falls. A comprehensive survey of all index sections (16.9 km) conducted around September 20 would be beneficial to understanding end of season Steelhead distribution. It is not known if section 3.3 is safely navigable at slightly higher flows as it was only surveyed once in 2010.

- Start snorkel monitoring earlier: it is recommended that monitoring begin earlier such that the seasonal timing of the peak migration rate can be better defined.

- Further radio telemetry may have limited effectiveness: . It is recommended that alternative fish tracking technologies be investigated and fish capture techniques reviewed. Additional tagging studies should only be implemented if a more cost effective method can be identified such that the number of tagged fish can be increased to ~50-100 per year. It would also be beneficial if the technology could track fish behavior (i.e. # of attempts) such that leap monitoring could be replaced. Finally, the method should also have the ability to document information regarding migration distance in response to pulse flows as well as passage at Lanterman Falls.

- Snorkel surveys should include determination of observer efficiency particularly where mark-recapture techniques are employed.

- "No Pulse Flow" control: if further changes are contemplated to the existing pulse flow regime, it is recommended that at least one year of full monitoring be conducted in which no pulse flows are released in order to better assess the benefits of pulse flows. Results to date indicate that passage is not restricted under base flow conditions so the risk of migration failure as a result of eliminating pulse flows is low. This appears necessary in order to better understand the effect of pulse flows relative to base conditions by eliminating confounding variables.

- Consideration of other pulse flows: The hypothesis that base flows impede migration was found to be false although migration rate increased with moderate pulse flows. However, it is possible that migration may be improved at somewhat lower flows as every barrier has its own suite of hydraulic characteristics. Understanding how passage is affected by a wider range in flows may be beneficial to the process.

Next Steps

Considerable migration monitoring and flow manipulations have occurred on the Ash River since 2005. This has been conducted in response to concerns that base flow conditions hinder the ability of summer Steelhead to migrate past Dickson Falls in August and September. This underlying hypothesis has been proven false although migration rate is improved with moderate pulse flows of 10 cms. This improvement is considered biologically significant as per the terms of reference for this study (BC Hydro 2005). However, there is room to further refine the results if deemed necessary during the Water Use Plan Order Review. If there is interest in further refining the existing 10cms pulse flow regime, additional monitoring in one or more non-pulse years would greatly assist in defining the scale of the apparent problem such that a baseline for Steelhead migration could be established. However, this study has provided sufficient data to guide current pulse flows and incremental gains from further adjustments should be considered before proceeding with additional work.

APPENDIX A

Summary of ASHMON 1 objectives, activities, results and implications

Component	Objectives	Performance Measures	Study Results (ASHMON-1)	Operational Implications	Remaining Uncertainties
1. Snorkel Surveys	Pre and post pulse swims to enumerate adult Steelhead in key index reaches upstream and downstream of Dickson Falls	1 a. Rate of Steelhead migration above Dickson Falls increases after pulse flow relative to control period	The rate of migration past Dickson Falls was increased by approximately 2.2 fish/day in reponse to 10 cms pulse, equivalent to 11 fish over 5 days between surveys. No detectable response to 20 cms pulse.	20 cms pulse flow not requred to improve Steelhead passage. Water budget is best used for 10 cms pulse flows. Flows released in early August may be more effective when seasonal migration rate is highest.	Conducting surveys in section 3.3 (between Dickson and Lanterman falls) would provide valuable data regarding passage at Lanterman and the supply of fish to Dickson.
2. Radio Telemetry	Radio tag 50 fish over 3 years and monitor specific timing of migration past Dickson Falls relative to environmental conditions	2a: Timing of and discharge during falls passage periods 2b: Distance migrated during control and pulse flows	16 of 50 tagged fish passed Dickson Falls. Of the 12 where flow and timing were known, only 3 were associated with a pulse flow event and passed between 7-11 cms. Migration distance was not able to be analyzed due to few Steelhead recoveries and successful passage events.	Data also support 10 cms pulse in favour of 20 cms with some evidence suggesting 7-9 cms could be the preffered range. Migration events typically occurred in afternoon/evening so potential to focus pulse flows at a fine scale	Specific flows which maximized migration rate were not determined with confidence due to an insufficient number of tagged fish ascending Dickson Falls. Secondary objectives including migration distance and passage at Lanterman not investigated.
3. Leap Monitoring	Pre, mid and post pulse monitoring of leap attempts at Dickson Falls	3a: Leap attempts per unit time 3b: Successful leap attempts per unit time 3c: Migration route	Leap attempts for 10 cms pulse increased by 3.68/hr and decreased by 1.1/hr at 20 cms. Only the 10 cms pulse was found to be significant at 94%; potentially higher rate of success at 20 cms but low confidence in this result	Frequency of leap attempts highest at 10 cms which supports conclusions from 1. and 2. Additional support for focusing efforts on 10 cms pulse flows.	Leaping activity at the lower half of the falls was unable to be analyzed. Passage success was believed to be higher during the 20 cms pulse which contradicts other migration data from activities 1 and 2 although confidence in the data is low. Migration route was not investigated.

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