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MEMORANDUM

TO: Steve Williams (PSMFC)
Lance Keller (Chelan PUD)
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FROM: Michele DeHart

DATE: October 3, 2017

SUBJECT: Recommendations on Gas Bubble Trauma Monitoring Protocol at Rock Island Dam.

In an attempt to address concerns over holding times for fish examined for Gas Bubble Trauma (GBT) monitoring at Rock Island Dam (RIS), the Fish Passage Center (FPC) staff and Chelan PUD Smolt Monitoring Program (SMP) personnel at Rock Island Dam (RIS) implemented a pilot GBT sampling protocol in 2016 and 2017 to reduce the amount of time that fish collected for GBT exams were held prior to being examined. Under the pilot protocol, SMP personnel at RIS attempted to collect fish for the GBT sample directly from the dewatering screens, as they entered the trap. This direct sampling occurred from the time the staff arrived at the project until approximately 9:00 am (approximately one to two hours). These "freshly sampled" fish were then prioritized for GBT exams. If the total number of "freshly sampled" fish fell short of the target sample size of 100 fish, SMP personnel would then examine fish from the daily collection (i.e., "traditional" method), until the target sample size for GBT was met. Each "fresh" fish from the GBT sample was flagged with a code for later identification.

There were four primary questions that the pilot protocol was conducted to address: 1) can "fresh" fish be captured and examined in a safe and efficient manner at RIS, 2) for how much of the season can "fresh" fish be captured at RIS, 3) can sample size requirements be met by exclusively using "fresh" fish, and 4) is there a difference in GBT incidence rates between "fresh" and "traditional" fish. The purpose of this memorandum is to address the four objectives of the pilot protocol, discuss the results from the two sampling schemes, and to provide some recommendations on how GBT monitoring may be improved at RIS, in an attempt to make the

GBT data from this site more representative of what is occurring to the run-at-large and less susceptible to potential effects introduced by the sampling protocol. Below is a brief synopsis of our findings, followed by a more detailed discussion of each.

- Based on the two years of the pilot study, it appears that "fresh" fish can be captured and examined in a safe and efficient manner at RIS.
- In 2016, only four samples of "fresh" fish were conducted. In 2017, 31 of the 35 total GBT samples conducted had at least some "fresh" fish in the sample. Based on the 2017 results, it appears that "fresh" fish can be sampled to some extent over the majority of the season, particularly when there is a commitment to do so.
- To date, the target sample size of 100 fish has not been met with exclusively "fresh" fish.
- Based on results from 2016 and 2017, "traditional" fish had significantly higher GBT incidence rates than "fresh" fish.
- Given that "traditional" fish had higher GBT incidence, it appears that past GBT incident rates at RIS are likely biased high and should be considered in the context of the sampling protocol in those years.
- It appears that using "fresh" fish in the GBT sample may reduce this bias and make results from RIS sampling more representative of what is occurring to the run-at-large. The degree to which "fresh" fish are used in the GBT sample will influence the degree to which the bias is reduced.
- Based on our review of the results from the pilot protocol, we would recommend that every effort should be made to increase the use of "fresh" fish in future GBT samples at RIS.

Background of Gas Bubble Trauma Monitoring Program and Sampling at Rock Island Dam

The objective of the Gas Bubble Trauma (GBT) monitoring program is to provide a measure of the exposure to harmful levels of total dissolved gas (TDG) experienced by migrating juvenile salmonids. The monitoring assesses both the incidence and severity of exposure, and provides an "early warning" of potentially harmful levels of TDG. The data are reported to the fisheries management entities and the water quality agencies of Washington and Oregon, and are available to other interested parties through FPC weekly reports and daily postings to the FPC website (http://www.fpc.org/smolt/gasbubbletrauma.html) during the season. The fisheries management entities review these data in-season to determine if modifications to spill are necessary based on the GBT monitoring.

Fish that are held at shallow depths for long periods of time may exhibit signs of GBT even at low TDG levels and, therefore, would not be representative of the migrating population (Weitkamp, 2000). The GBT monitoring program is designed to minimize the holding time prior to examining fish. Fish to be examined for GBT are netted at the separator at Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), and McNary (MCN) dams, which greatly reduces the holding time at these sites. However, sampling at the separator is not possible at Bonneville (BON) and Rock Island (RIS) dams. Instead, fish at these sites are removed from the sample tank (BON) or sample trap (RIS). Over the years, SMP personnel at

BON have reduced the amount of time that GBT sample fish are held in the sample tank to 2-3 hours by taking multiple draws from the sample tank on GBT exam days.

Rock Island Dam does not have a traditional bypass system. There are no screens that guide fish entering the powerhouse into a bypass system. Instead, a portion of the fish that enter the second powerhouse will swim through a series of submerged orifices into a bypass channel. While these submerged orifices are lighted to attract fish into the bypass channel, the process of swimming through the orifices is completely voluntary. Because of the voluntary nature of this collection system, it is unknown how much time fish may spend in the powerhouse prior to entering the bypass channel or how long fish are in the channel before being routed into the sample trap. In addition to the orifices and bypass channel that run parallel to the second powerhouse, some juvenile salmonids are also "opportunistically" collected from a screening system associated with an adult attraction pump that draws water from the forebay, just above the second powerhouse. Fish collected from this screening system are diverted to the bypass channel.

From the bypass channel, juveniles are routed to a sample trap that is located in the tailrace of the project where they are held for up to 24-hours before being processed for the SMP. The sample trap is relatively shallow (~2-3 ft). Just before 9:00 am, fish in the trap are crowded into a hopper and transported to a large sample tank in the sample room. Once fish are in the sample tank, they are enumerated for the SMP and returned to a recovery tank before ultimate release into the tailrace. On GBT sample days, a subset of 100 Chinook and steelhead (combined) are also examined for GBT prior to being returned to the recovery tank. This is what we refer to as the "traditional" method of GBT monitoring. Therefore, fish sampled under the "traditional" method, may have been held in the shallow sample trap for up to 24-hours prior to the exam, which increases the potential that incidences of GBT may be inflated.

Scheduling and budget constraints at RIS have made implementation of a protocol similar to the one used at BON more difficult. Since fish examined at RIS have been held in shallow depths for a longer period of time, the FPC staff has cautioned the fisheries managers that GBT data from RIS should be evaluated within the context of the sampling procedure. Since the values are likely biased high, the results are evaluated independently of the other monitoring locations.

Methods: Comparing GBT Incidence Rates of "Traditional" and "Fresh" Fish

As mentioned above, FPC staff and SMP personnel at RIS implemented a pilot sampling protocol in 2016 and 2017 to explore the use of "fresh" fish in the GBT sample. Under the pilot protocol, SMP personnel at RIS collected fish for the GBT sample directly from the dewatering screens, as they entered the trap. If the total number of "freshly sampled" fish fell short of the target sample size of 100, SMP personnel would then examine fish in the "traditional" method until the target sample size for GBT was met. Each "fresh" fish from the GBT sample was flagged with a code for later identification.

In 2016, only four of the 24 GBT samples had "fresh" fish in them. River flows in 2016 were near average. Total Dissolved Gas levels above Rock Island were mostly within waiver limits, with a few exceptions. These exceptions included: 1) 11 total days where TDG in the Rocky Reach Dam (RRH) tailrace exceeded 120%, 2) three days where TDG in the RRH forebay exceeded 115%, and 3) four days where the TDG in the RIS forebay exceeded 115%. As a result of the 2016 river conditions, GBT incidences at RIS were relatively infrequent (8 out of a possible 24 samples) and low, with a maximum GBT incidence rate of 4%. In 2017, 31 of the 35 GBT samples had "fresh" fish in them. River flows in 2017 were above average throughout the Columbia River Basin and, as a result, TDG levels exceeded the 115%/120% waiver limits for most of the spring and early summer periods. Due to the high TDG in the Upper Columbia, GBT incidences at RIS were frequent (all 35 samples had at least some signs of GBT) and high, with a maximum GBT incidence rate of 53%.

In all, 35 total GBT samples from 2016 and 2017 contained "fresh" fish but at no point in these two years were SMP personnel at RIS able to meet the sample size criterion of 100 fish with exclusively "fresh" fish. Therefore, all 35 days contained a mix of "fresh" and "traditional" fish. A breakdown of all 35 of these exam days can be found in Appendix A, along with the daily GBT incidence rates for the entire sample, the "traditional" sample only, and the "fresh" sample only. We conducted an analysis to compare GBT incidence rates between the two methods with two basic questions in mind: 1) Do "fresh" and "traditional" fish have different GBT incidence rates and 2) if yes, are they consistently higher or lower? To minimize seasonal and year-to-year variations, only days with both "traditional" and "fresh" sampling schemes were included in the analyses. For each day, GBT rates of the two sampling schemes were first calculated, and the "fresh" GBT rate was subtracted from the "traditional" GBT rate to find the difference. After the paired-differences of all sampling days were obtained, the mean was calculated to estimate the overall difference in GBT rates between the two sampling types. Finally, a bootstrap procedure with 5,000 iterations was used to estimate the standard errors (SE) and 95% confidence intervals (CI) around these means.

In addition, a permutation test was conducted to test for a difference in the GBT rates between "traditional" and "fresh" fish. GBT rates were randomly assigned to each fish regardless of sampling type, and the difference between the new GBT rates was calculated for each day. The mean difference was calculated and the process was repeated to yield a permutation distribution of 5,000 simulated mean differences in GBT rates. The null hypothesis was that no difference in GBT rates existed between "traditional" and "fresh" fish. Therefore, the assumption was that the GBT rates were exchangeable between the two sampling types within each day. That is, one can randomly shuffle GBT rates among sampling types and simulate a scenario under the null hypothesis. By repeating the permutation process, we created an approximate distribution to the null hypothesis. With this model, we can then evaluate whether the observed difference was outside the likely outcome assuming no difference existed. We estimated a p-value to quantify how extreme the observed result was by calculating the portion of the simulated results that were as far or farther from zero than the observed value.

Results: Comparing GBT Incidence Rates of "Traditional" and "Fresh" Fish

The results from our analysis indicate that, on average, "traditional" fish had a higher GBT incidence rate than "fresh" fish. The estimated mean GBT rate for "traditional: fish was 15.9% (95% CI: 10.6%-21.9%), whereas that for "fresh" fish was 5.1% (95% CI: 2.8%-7.8%).

Therefore, the estimated mean difference was 10.8% (95% CI: 6.0%-16.0%). Under the null hypothesis, the simulated distribution of differences in GBT incidences ranged approximately from -0.08 to 0.07 (Figure 1). No value in the simulated distribution was greater than the observed value of 0.108. Therefore, the observed difference of 10.8% in GBT incidence was extremely unlikely under the null hypothesis ($p < 0.00001$; Figure 1). This indicates that "traditional" fish had higher GBT incidence rates than "fresh" fish.

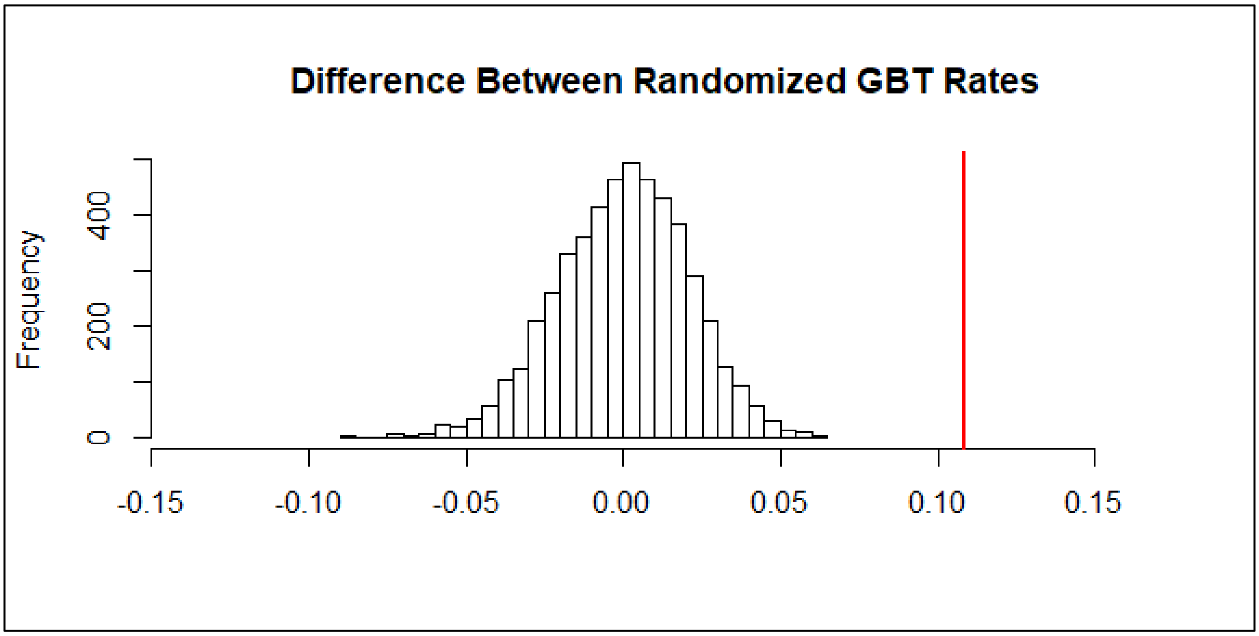

Figure 1. Histogram of permutation distribution for a paired-comparison of GBT rates between "traditional" and "fresh" fish. Red line indicates the observed difference from 2016 and 2017 samples.

Discussion

Given that "traditional" fish had higher GBT incidence rates than "fresh" fish, it appears that historic GBT rates at RIS are likely biased high, as these were collected using only "traditional" fish. Therefore, these GBT rates should be considered in the context of the sampling protocol in those years. From our 2016 and 2017 pilot protocol, it appears that using "fresh" fish in the GBT sample may reduce this bias and potentially make results from RIS GBT sampling more representative of what is occurring to the run-at-large. However, the degree to which "fresh" fish are used in the GBT sample will influence the degree to which the bias is reduced. For example, during the implementation of the pilot protocol, SMP personnel at RIS were unable to obtain the target sample size of 100 fish by targeting "fresh" fish only. Therefore, the estimates of GBT incidence rates may still be slightly biased on the high side due to the influence of "traditional" fish. Minimizing the influence of "traditional" fish would be the most desired outcome. It is worth noting that increasing the number of "fresh" fish to meet the sample size target of 100 fish may not completely eliminate the bias because it is still unknown how long fish spend in the powerhouse and bypass channel before being routed to the sample tank.

Based on our review of the results from the pilot protocol, we would recommend that every effort should be made to increase the use of “fresh” fish in GBT samples at RIS. Based on our understanding of how sampling works at RIS, we offer the following suggestions on how to accomplish this. First, SMP personnel at RIS could increase the amount of time that sampling of “fresh” fish is conducted. As mentioned above, the pilot protocol was limited to the 1-2 hours before the sample was to be processed. Starting earlier would be one way to increase the amount of time that “fresh” fish are sampled. In addition, SMP personnel could begin sampling “fresh” fish the afternoon before the GBT sample and then again that morning. This may improve the likelihood of reaching the target sample size of 100 “fresh” fish. Another way to increase the amount of time that “fresh” fish are sampled (and processed) would be to establish an examination station closer to the sample trap, similar to what is done at LGR, LGS, and LMN. Assuming this is feasible from a safety perspective, this would allow personnel to spend more time netting and examining “fresh” fish as they enter the trap and less time transporting those fish to the sample room for examination.

Finally, if personnel constraints do not allow for increased sampling of “fresh” fish, perhaps Chelan PUD/PSMFC should consider subcontracting the GBT portion of the SMP contract to someone who is not as limited by these personnel constraints. For example, this subcontractor could begin collecting “fresh” fish at the sample trap for GBT exams at 9:00 am, while the full sample from the previous day is being worked up by Chelan PUD personnel, and continue doing this until the target sample size is reached or some established time is up. Species compensation data from this GBT sample can then be compiled by the subcontractor and handed over the Chelan PUD personnel for inclusion in the next day’s data entry for the SMP. This would be similar to what currently occurs at LGR, LGS, LMN, and MCN and the GBT.net data entry program is set up to provide summaries of these data for entry into FPC32.net.

We hope you find these analyses and suggestions useful to inform future GBT monitoring at RIS. The FPC staff looks forward to continuing discussions on how to improve the representativeness of GBT samples at RIS and are available to discuss these analyses and other potential solutions.

Literature Cited:

Weitkamp, D.E. 2000. Total Dissolved Gas Supersaturation in the Natural River Environment. Report by Parametrix to Chelan County Public Utility District, No.1. Wenatchee, WA. 21 p.

Appendix A
GBT Exam Data for Days of Where "Fresh" and "Traditional" GBT Samples were Conducted at Rock Island Dam (2016 & 2017)

Table A.1. Number examined and GBT incidence rates (%) of total, "traditional" only, and "fresh" only GBT samples at RIS during 2016 and 2017 pilot sampling protocol.

Date	Total Examined	Total GBT Incidence (%)	"Traditional" Examined	"Traditional" GBT Incidence (%)	"Fresh" Examined	"Fresh" GBT Incidence (%)
4/29/16	100	4.0%	23	4.3%	77	3.9%
5/3/16	100	1.0%	38	0.0%	62	1.6%
5/5/16	100	1.0%	59	0.0%	41	2.4%
5/10/16	100	0.0%	84	0.0%	16	0.0%
4/20/17	100	45.0%	96	46.9%	4	0.0%
4/25/17	100	53.0%	94	54.3%	6	33.3%
4/27/17	100	41.0%	49	65.3%	51	17.6%
5/2/17	100	20.0%	53	32.1%	47	6.4%
5/4/17	100	17.0%	37	43.2%	63	1.6%
5/9/17	100	20.0%	64	25.0%	36	11.1%
5/11/17	100	20.0%	45	22.2%	55	18.2%
5/16/17	100	21.0%	92	22.8%	8	0.0%
5/18/17	100	30.0%	91	33.0%	9	0.0%
5/23/17	100	24.0%	93	25.8%	7	0.0%
5/25/17	100	19.0%	93	20.4%	7	0.0%
6/1/17	100	19.0%	93	19.4%	7	14.3%
6/6/17	100	22.0%	93	23.7%	7	0.0%
6/8/17	100	31.0%	92	33.7%	8	0.0%
6/15/17	100	11.0%	50	10.0%	50	12.0%
6/22/17	100	2.0%	65	1.5%	35	2.9%
6/27/17	100	6.0%	74	8.1%	26	0.0%
6/29/17	100	4.0%	6	0.0%	94	4.3%
7/5/17	75	6.7%	73	6.8%	2	0.0%
7/6/17	75	2.7%	63	3.2%	12	0.0%
7/11/17	100	8.0%	77	7.8%	23	8.7%
7/13/17	100	14.0%	83	15.7%	17	5.9%
7/17/17	100	6.0%	83	4.8%	17	11.8%
7/20/17	100	2.0%	85	2.4%	15	0.0%
7/25/17	100	3.0%	73	1.4%	27	7.4%
7/27/17	100	3.0%	62	4.8%	38	0.0%
8/1/17	100	5.0%	84	6.0%	16	0.0%
8/3/17	100	2.0%	98	2.0%	2	0.0%
8/8/17	100	3.0%	95	3.2%	5	0.0%
8/10/17	100	6.0%	93	5.4%	7	14.3%
8/27/17	100	2.0%	97	2.1%	3	0.0%