Appendix I

2019 Fish Passage Summary

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FISH PASSAGE CENTER

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November 5, 2019

Mr. Daniel Turner
U.S. Army Corps of Engineers
Northwestern Division
PO Box 2870
Portland, OR 97208-2870

Dear Mr. Turner:

As per our agreement, we are providing a copy of our *Gas Bubble Trauma Monitoring and Data Reporting for 2019* to you and Mr. Paul Wagner and Ms. Claire McGrath of National Marine Fisheries Service. This report summarizes data collected during the 2019 juvenile salmonid migration.

Please feel free to contact us if you require any additional information.

Sincerely,

Michele DeHart
Fish Passage Center Manager

CC: Paul Wagner, NOAA Fisheries
Claire McGrath, NOAA Fisheries
Laura Hamilton, USACE
Julie Ammann, USACE

Gas Bubble Trauma Monitoring and Data Reporting for 2019

Overview

The objective of the juvenile salmonid 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 Fish Passage Center weekly reports and daily postings to the FPC website during the season (http://www.fpc.org/smolt/gasbubbletrauma.html). The fisheries management entities review the data in-season to determine if modifications to spill are necessary based on the GBT monitoring.

The monitoring of juvenile salmonids in 2019 for GBT was conducted at Upper Columbia, Middle Columbia and Snake River sites. Fish were collected and examined for signs of GBT at Rock Island Dam (RIS) on the Upper Columbia River, and at Bonneville Dam (BON) and McNary Dam (MCN) on the Middle Columbia River. The Snake River monitoring sites were Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams. The goal of the GBT monitoring program was to sample 100 salmonids each day of sampling at each site. The proportion of each species sampled (limited to Chinook and steelhead) was dependent upon their prevalence at the time of sampling. Yearling Chinook and steelhead dominated the samples in the spring, with samples gradually shifting to subyearling Chinook predominance in the summer through the end of August, unless an adequate sample could not be collected. Sampling at some sites was terminated prior to the end of August as a result of high temperatures and/or lack of ability to reach target sample sizes (more detail on these instances is provided below). A daily sample size of 100 fish is necessary to assure that the sample observation accurately represents the population incidence of signs of gas bubble trauma.

Since fish held at shallow depths for long periods of time may exhibit bubbles even at low TDG levels and 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 were netted off the bypass separator bars (at LGR, LGS, LMN, and MCN) or removed from the sample tank or other sampling apparatus (at RIS and BON). Due to the configuration if the collection systems at BON and RIS, sampling at the separator is not possible. Therefore, fish for the GBT sample can be held for prolonged periods at these sites, particularly at RIS where fish may be held for up to 24-hours. Over the years, SMP personnel at BON have minimized the amount of time that GBT sample fish are held in the sample tank prior to examination. However, due to continued limitations at RIS, data from this site should be evaluated within the context of the sampling procedure(s) used. Since the values can be biased high, the results are evaluated independently of the other monitoring locations. In an attempt at minimizing the impact of prolonged holding periods, the FPC and RIS staff continued to implement a modified sampling protocol in 2019. Details of this protocol and an evaluation of the data are provided below in a separate discussion.

Once collected, fish are anesthetized and examined using a modified examination tray. The tray is equipped with a siphon tube that delivers anesthetic water over the fish's gills allowing fish to be continually anesthetized during the GBT examination. Sampling occurred two days per week at the Columbia River sites and one day a week at each of the Snake River sites throughout the spring and summer spill programs. Examinations of fish were conducted using variable magnification (6x to 40x) dissecting scopes. The eyes and unpaired fins (e.g., dorsal, caudal, and anal fins), were examined for the presence of bubbles. The bubbles present were quantified using a ranking system based on the percent area of the fins or eyes covered with bubbles (USGS 1997) (Table J-1). Additional information was recorded for each fish during the examination, including species, age, fork length, fin clips, and tags present.

Table J-1
Ranking criteria used in monitoring for signs of gas bubble trauma.

Rank	Sign
0	no bubbles present
1	up to 5% of a fin area or eye covered with bubbles
2	6% to 25% of a fin area or eye covered with bubbles
3	26% to 50% of a fin area or eye covered with bubbles
4	> than 50% of a fin area or eye covered with bubbles

In an effort to standardize handling and reporting practices among sites and to provide accounting for Endangered Species Act permitting purposes, the FPC modified the handling protocol for the GBT program in 2015. Monitoring in 2019 followed the same protocol that was issued in 2015. For more detailed information on the examination procedure, the 2019 GBT Monitoring Protocol is available on the FPC website (ftp://ftp.fpc.org/GBT/GBTManual_Datasheet/GBTMonitoringProtocol_2019.pdf).

2019 Water Conditions and Spill Operations

The runoff volume (January–July) for the 2019 water year was below average in the Middle Columbia River and above average in the Snake River. Runoff (January–July) was 89% of average (1981–2010) at The Dalles Dam and 106% of average at Lower Granite Dam. To put the runoff volumes into perspective, the 2019 January–July runoff volumes at The Dalles and Lower Granite were ranked 65th and 38th, respectively, over the last 91 years (1929–2019).

Runoff in the Snake River was atypical in 2019, with overall above average flows in April through June and four distinct flow spikes in early April, late April, mid-May, and early June (Figure J-1). These flow spikes included daily flow values in the 153.5-194.7 Kcfs range. Flows during these peak events were sufficiently high that at least some level of uncontrolled spill was warranted at Snake River sites. Soon after the fourth peaking event on June 1st, flows at LGR began to drop rapidly. In fact, by June 9th, flows

at LGR were below the current ten-year average, where they remained for the rest of June and most of July. August flows at LGR were close to the current ten-year average (Figure J-1).

Although generally lower than the current 10-year average, runoff in the Middle Columbia was a bit more typical in shape, with generally higher flows in April, May, and early June (Figure J-2). Similar to flows at LGR, there were also four pronounced flow spikes at MCN, one in mid-April, one in late April, one in mid-May, and one in early June. Flows during these four spikes ranged from 304.8 Kcfs to 347.3 Kcfs. However, soon after the fourth spike event, flows at MCN began to drop rapidly. In fact, by June 3rd, flows at MCN had fallen below the current ten-year average, where they remained until early August. Flows in August fluctuated between being at or below the current ten-year average (Figure J-2). In general, flows in the Middle Columbia River never peaked to levels that required uncontrolled spill, except at BON. There were a couple of brief periods in April where high flows necessitated uncontrolled spill at BON.

Figure J-1.
Average daily flows at Lower Granite Dam
2019, 2018, and the 10-year average

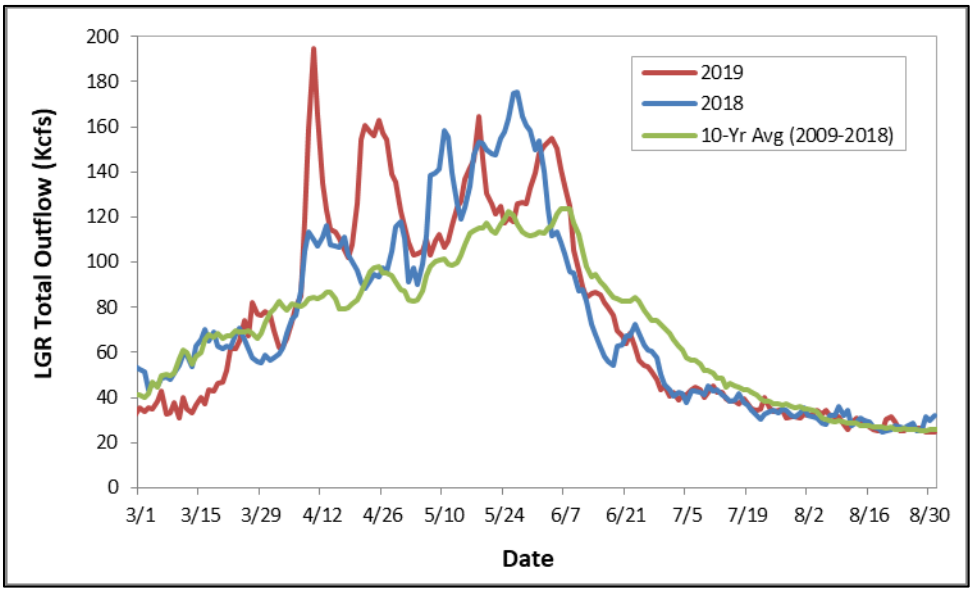
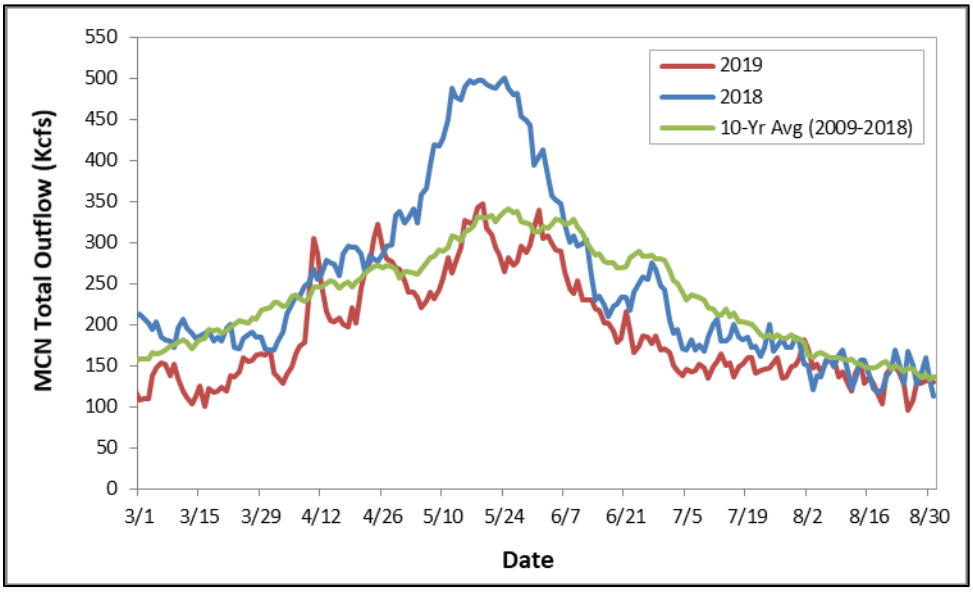


Figure J-2
Average daily flows at McNary Dam
2019, 2018 and the 10-year average



In December of 2018, the Action Agencies (Bonneville Power Administration, the U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation) signed an agreement with the states of Oregon and Washington and the Nez Perce Tribe for 2019-2021 Spill Operations. The spill operations under this agreement are referred to as "Flex Spill". In accordance with the 2019-2021 Spill Operations Agreement, the 2019 Fish Operations Plan (FOP) specified that spring spill operations on the FCRPS projects in the Snake and Mid-Columbia rivers will be to spill to the 120% spill caps for sixteen hours per day and "performance standard" spill for eight hours per day. The eight hours of "performance standard" spill will occur in up to two blocks per calendar day, an am block and a pm block. The timing and duration of each "performance standard" block is flexible and may change between days. Summer spill operations were also specified in the Spill Operations Agreement and the 2019 FOP. However, "Flex Spill" did not occur in the summer, as all summer spill operations were provided on a 24-hour basis. The spring and summer spill operations specified by the 2019-2021 Spill Operations Agreement and the 2019 FOP are summarized in Table J-2.

For the spring spill season, the COE estimated the 120% TDG spill caps (tailrace only) for each FCRPS project on a daily basis and projects were operated to these estimated spill caps for the 16-hours of gas cap spill. The daily 120% TDG spill caps were published on the TMT website (http://pweb.crohms.org/tmt/documents/ops/spill/caps/201904-120.html).

Table J-2
2019 spring and summer spill operations at Snake and Mid-Columbia FCRPS projects under the 2019 Flex Spill Agreement and Fish Operations Plan.

Project	Spring "Flex" Spill			Summer Spill	
	Dates	Gas Cap Spill (16 hrs/day)	Perf. Standard Spill (8 hrs/day)	Dates	Spill Operation (24 hrs/day)
LGR	4/3-6/20	120% Gas Cap	20 Kcfs	6/21-8/31	18 Kcfs
LGS	4/3-6/20	120% Gas Cap	30%	6/21-8/31	30%
LMN	4/3-6/20	120% Gas Cap	30 Kcfs (bulk pattern)	6/21-8/31	17 Kcfs
IHR	4/3-6/20	120% Gas Cap	30%	6/21-8/31	30%
MCN	4/10-6/15	120% Gas Cap	48%	6/16-8/31	57%
JDA	4/10-6/15	120% Gas Cap	32%	6/16-8/31	35%
TDA	4/10-6/15	120% Gas Cap	40%	6/16-8/31	40%
BON	4/10-6/15	120% Gas Cap	100 Kcfs	6/16-8/31	95 Kcfs

For the Flex Spill Agreement, the State of Washington made two modifications to their TDG waiver for FCRPS projects in the Snake and Mid-Columbia rivers. These modifications only applied to the spring season. First, the requirement to not exceed 115% TDG in the downstream forebay was been eliminated. Therefore, TDG was only be managed to 120% in the tailrace during the spring season. Second, the methodology of calculating the 12-hour average TDG was changed to align with the State of Oregon's methodology. This meant that, during the spring season, the 12-hour average TDG was based on the 12 highest hourly TDG measurements in a single calendar day (not necessarily consecutive). When summer spill began in June, the State of Washington's 115% forebay TDG requirement was reinstated and the Washington methodology of calculating the 12-hour average based on rolling average was re-implemented. Therefore, in the summer, the more restrictive of the two methodologies for calculating the 12-hour average TDG (OR vs. WA) was reported for the tailrace monitors in the Mid-Columbia River (MCN, JDA, TDA, and BON).

Results

In all, 11,328 juvenile salmonids were examined for GBT between April and August of 2019 (Table J-3). The fish were collected and examined as part of the Smolt Monitoring Program.

Table J-3
Number of juvenile salmonids examined for signs of GBT at dams on the Lower Snake River and on the Columbia River from April to August 2019 as part of the Smolt Monitoring Program.

Species	BON	MCN	LMN	LGS	LGR	RIS	Total
Chinook Subyearlings	1,092	1,267	501	488	0	1,010	4,358
Chinook Yearlings	1,277	1,051	319	396	505	864	4,412
Steelhead	271	525	495	354	396	517	2,558
Total	2,640	2,843	1,315	1,238	901	2,391	11,328

Fin signs were found in 224 or 1.98% of the total fish sampled at all sites (Table J-4), with 156 of those detections occurring at Rock Island Dam. Of the 224 fish that had signs of fin GBT in 2019, 209 (93.3%) had a maximum fin ranking of 1, where less than 5% of a fin area was covered with bubbles. The remaining 15 (6.7%) had maximum fin rankings of 2, where 6-25% of a fin area was covered with bubbles. No severe (i.e., ≥26% of a fin area was covered with bubbles) signs of GBT were observed in 2019. A more detailed breakdown of GBT exams and signs for 2019 can be found in Tables J-6 through J-11.

Table J-4

Number of juvenile salmonids found with fin GBT at dams on the Lower Snake River and on the Columbia River from April to August 2019 as part of the Smolt Monitoring Program.

Species	Fin GBT by Site						Grand Total
	BON	MCN	LMN	LGS	LGR	RIS	
Chinook Subyearlings	2	3	7	7	0	68	87
Chinook Yearlings	7	0	4	15	0	80	106
Steelhead	2	4	12	5	0	8	31
Total	11	7	23	27	0	156	224

The action criteria for GBT is established as 15% of fish showing any signs of fin GBT, or 5% of the fish showing severe signs of fin GBT. Signs of fin GBT are deemed severe when ≥26% of an unpaired fin is covered with bubbles (i.e., rank 3 or 4). Spill may be curtailed, if possible, when one or both of these criteria are met. These action criteria were developed based on lab studies that indicated that significant mortality did not occur until 60% of the exposed population exhibited signs of GBT or 30% exhibited severe signs in their unpaired fins. The action levels were set at 15% with any signs and 5% with severe signs to provide a large margin of safety, primarily because the results from the lab studies indicated some level of uncertainty between fin bubble percentage and the onset of mortality (FPC 2007b).

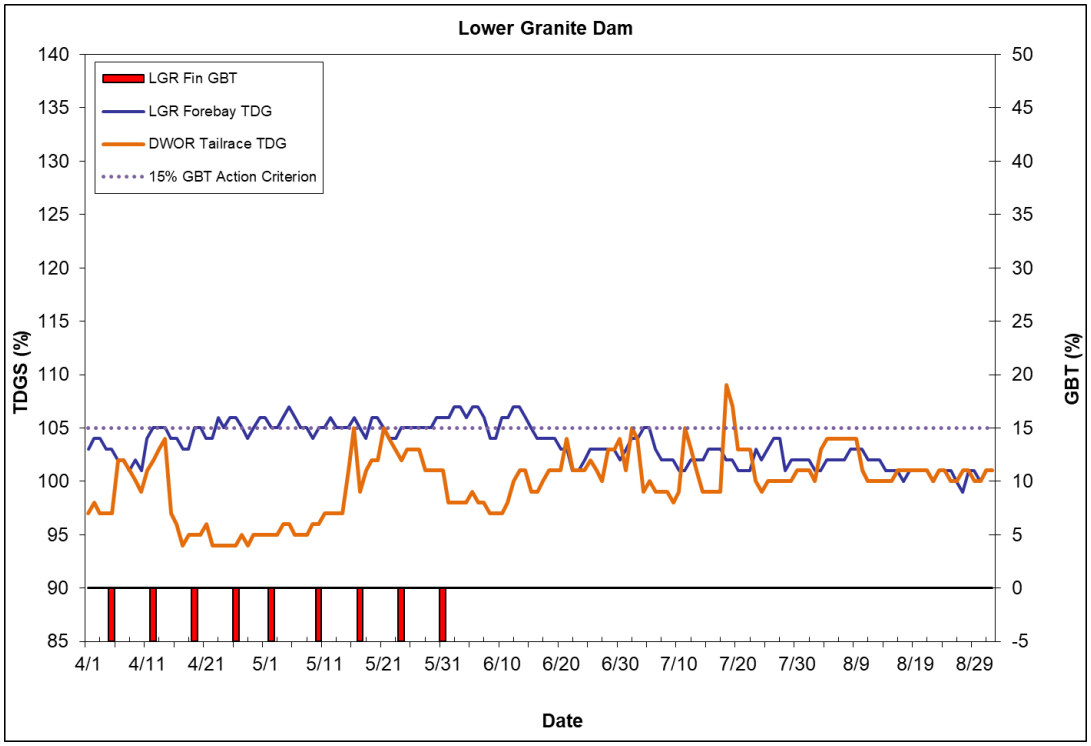
The 15% criterion was never met in 2019 at the Snake or Mid-Columbia River sites but was met once at the Upper Columbia River site (RIS). This single instance at Rock Island Dam occurred on June 13th. During this occurrence, flows in the Upper Columbia River were below the hydraulic capacities at upstream projects and TDG in the Rocky Reach tailrace had been at or below 116% for several days prior. For more discussion on this instance, see the RIS results section below. The criterion of 5% severe GBT was never met in 2019.

Lower Granite Dam (LGR)

Rehabilitation work to Unit #3 at Dworshak Dam (DWR) was completed in the summer of 2018. Therefore, powerhouse capacity at DWR was not limited in 2019, as it had been in the previous two years, and TDG in the DWR tailrace never exceeded the 110% Environmental Protection Agency (EPA) standard (Figure J-3). In addition, TDG in the LGR forebay never exceeded 110% in 2019. In fact, the maximum 12-hour average TDG in the LGR forebay in 2019 was 107%, which occurred on several occasions in May and June. Sampling at LGR is usually used to provide a background level of GBT for migrating juvenile salmonids that are first entering the hydrosystem. Sampling in 2019 began on April 5th and ran through May 31st. As is typical at this site, GBT sampling at LGR was terminated when subyearling Chinook began to pre-dominate the collection and meeting sample size requirements with yearling Chinook and/or steelhead was no longer possible.

In all, 9 total GBT samples were conducted at LGR in 2019, from April 5th to May 31st. Sampling was terminated after the sample on May 31st because of low fish numbers and inability to reach target sample sizes with yearling Chinook and steelhead. None of the 9 total GBT samples had fish with signs of fin GBT (Figure J-3, Table J-6).

Figure J-3
Percent GBT observed in the sample at Lower Granite Dam in 2019



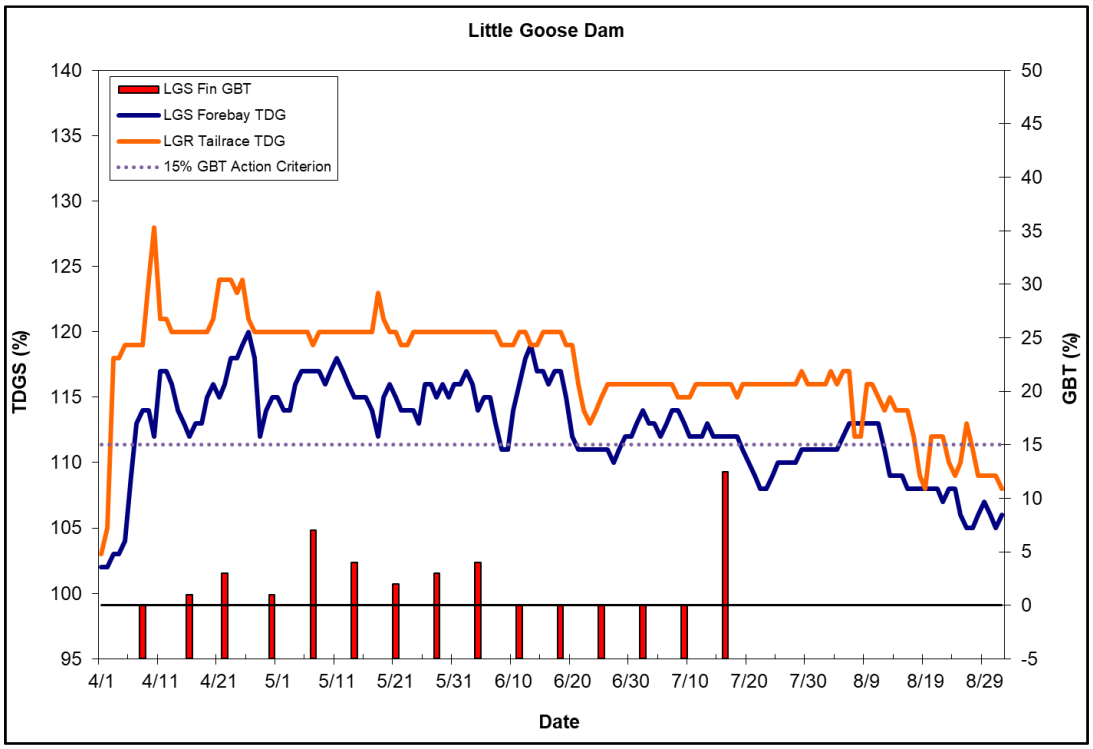
Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line).

Little Goose Dam (LGS)

GBT sampling at LGS occurred from April 8th to July 16th. Sampling at LGS was terminated after the sample on July 16th due to decreasing numbers of fish in the sample that precluded the examination of an adequate sample size. During the spring spill season (Apr. 3-June 20), TDG levels in the LGR tailrace exceeded the 120% criteria a total of 13 times in 2019. These exceedances included a four day period in mid-April (April 9-12), a seven day period in late April (April 20-26), and a two day period in mid-May (May 18-19) (Figure J-4). These TDG exceedances were largely due to periods of high flows that necessitated over-generation spill at LGR. During the summer spill period (June 21-August 31), TDG levels in the LGR tailrace and LGS forebay were below the 115%/120% standard that was applied during that period.

Fifteen total GBT samples were conducted at LGS in 2019. Of these 15 GBT samples, nine had at least one fish with signs of GBT (Figure J-4, Table J-7). The highest GBT incidence rate at LGS in 2019 was 12.5% of the sample showing signs of fin GBT. This incidence rate was observed on the sample conducted on July 16th. However, it should be noted that the sample size criteria was not met on this date, as only 16 fish were examined for GBT, with 2 showing signs of fin GBT. On July 16th, TDG in the LGS forebay was 112% and TDG levels in the LGR tailrace had been 116% in the five days leading up to this occasion. The second highest GBT incidence rate at LGS was 7% of the sample showing signs of fin GBT. This incidence rate was observed on the sample conducted on May 7th. Total dissolved gas in the LGS forebay was 117% on this date and TDG in the LGR tailrace was 120% over the five days leading up to this occasion. Of the 27 total fish that exhibited signs of fin GBT at LGS in all of 2019, all but one exhibited Rank 1 signs. The single exception exhibited Rank 2 signs of fin GBT.

Figure J-4
Percent GBT observed in the sample at Little Goose Dam in 2019



Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line).

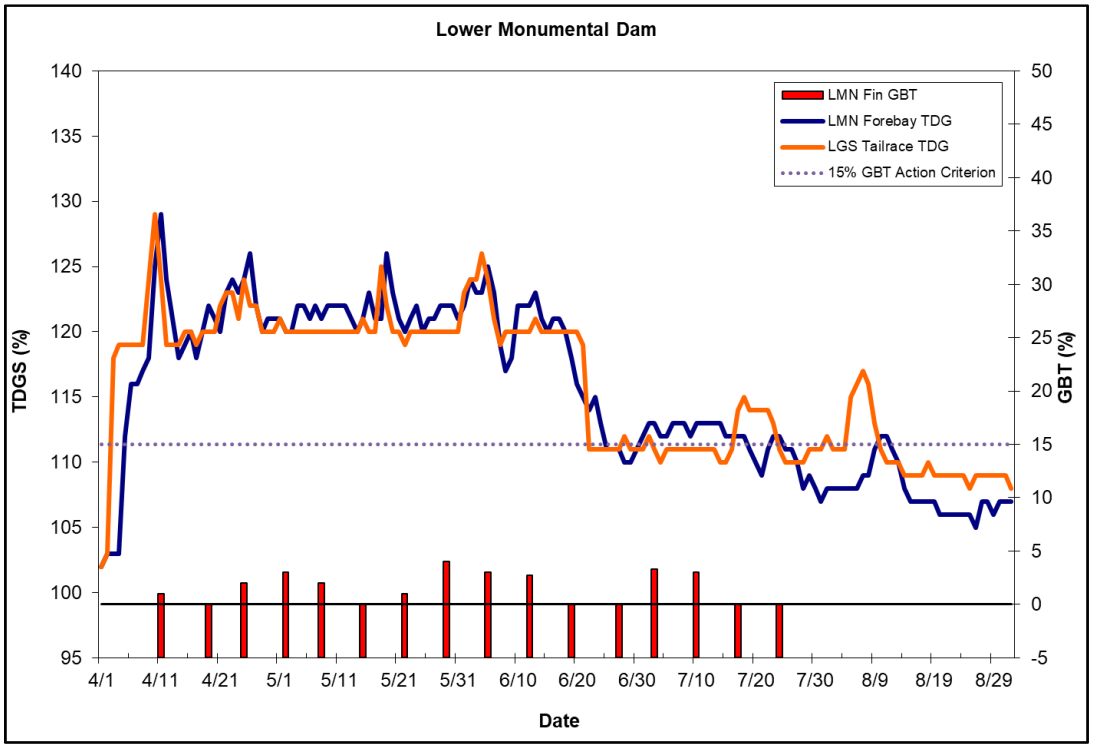
Lower Monumental Dam (LMN)

GBT sampling at LMN occurred from April 11th to July 24th. Sampling was terminated after the sample on July 24th due to decreasing numbers of fish in the sample that precluded the ability to meet sample size requirements. Total dissolved gas levels in the LGS tailrace exceeded the 120% standard on 21 occasions in the spring of 2019. These 21 occasions included three prolonged periods: one three day period in mid-April (April 9-11), one seven day period in late April (Apr. 21-27), and one six day period in early June (June 1-6). The remaining five occasions were single day or two-day exceedances in May and June (Figure J-4). These TDG exceedances were largely due to flows in excess of hydraulic capacity and uncontrolled spill at upstream projects or a special spill operation at LGS that necessitated spilling well above 120% TDG from 1600-0500 (June 1-6). During the summer spill period (June 21-August 31), TDG levels in the LGS tailrace and LMN forebay were below the 115%/120% standard that was applied during that period.

In all, 16 total GBT samples were conducted at LMN in 2019. Of these 16 GBT samples, ten had fish with signs of GBT (Figure J-5, Table J-8). The highest GBT incidence rate in 2019 at LMN was 4%, which occurred on May 29th. Total Dissolved Gas levels in the LMN forebay were 122% at this time and TDG in the LGS tailrace had been 120% over the preceding five days. There were five GBT samples with a GBT incidence rate of approximately 3% (May 2nd, June 5th, June 12th, July 3rd, and July 10th). Total

dissolved gas levels in the LMN forebay were as high as 125% (June 5th) and as low as 113% (July 3rd and July 10th) during these occasions. Finally, all of the 23 total fish that exhibited signs of fin GBT at LMN in 2019 were Rank 1.

Figure J-5
Percent GBT observed in the sample at Lower Monumental Dam in 2019.



Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line).

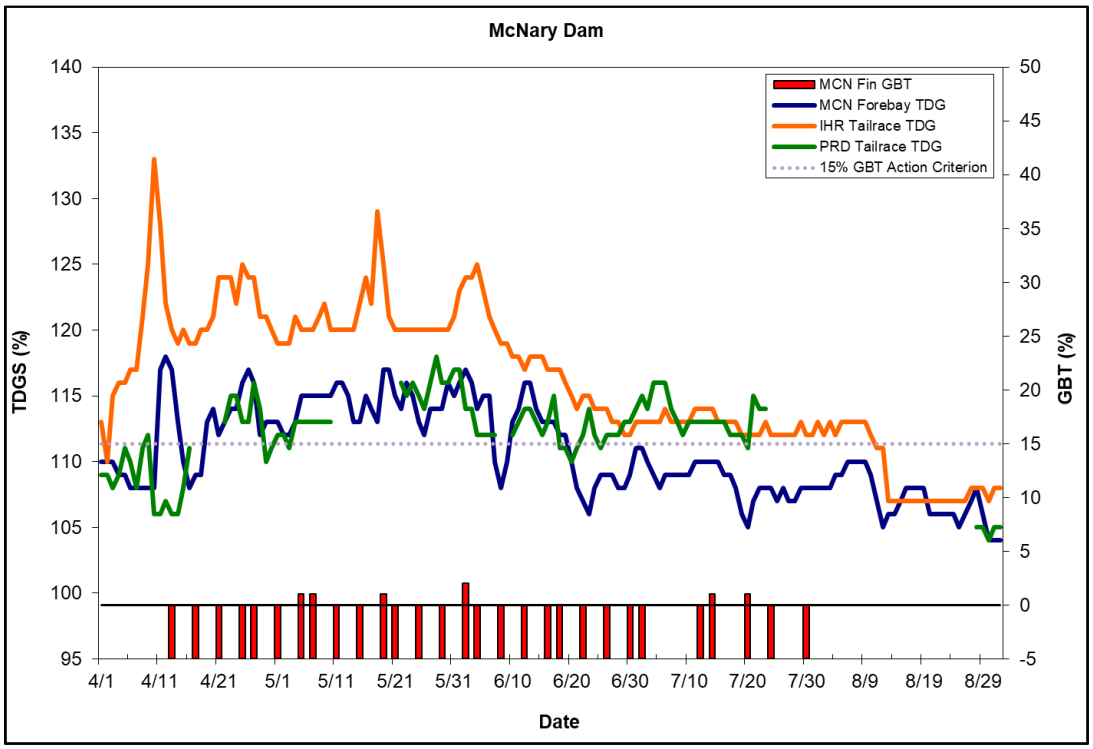
McNary Dam (MCN)

GBT sampling at MCN occurred from April 13th to July 30th. Due to an equipment failure, a GBT sample was not possible from July 2nd through July 11th. Similar to what occurred in previous years, GBT sampling at MCN was reduced from twice per week to once per week due to elevated temperatures and increased mortality rates of recovering GBT-examined fish. The decision to reduce GBT sampling to once per week was made after the GBT sample on July 24th. At that time, TDG levels in the MCN forebay had been below 110% for several days and temperatures in the MCN forebay were approximately 20.2 °C. This modification in the GBT sampling schedule was consistent with the COE's protocols to provide precautionary measures to avoid or minimize any direct or delayed mortality resulting from additional thermal stress when handling juvenile salmonid fishes at water temperatures above 20 °C. MCN was to continue once-per-week sampling through the rest of the voluntary spill season. However, GBT sampling was terminated after the sample on July 30th due to decreasing fish numbers and forebay TDG levels that were at or below the EPA 110% standard.

Total dissolved gas in the Priest Rapids tailrace never exceeded the 120% waiver level in 2019 (Figure J-6). However, due to the above average flows in the Snake River and extremely limited powerhouse capacity at Ice Harbor Dam (IHR) in 2019, TDG levels in IHR tailrace exceeded the 120% standard on 31 total occasions in the spring. Due to several unit outages, powerhouse capacity at IHR was limited to approximately 66 Kcfs in 2019. Therefore, there were several instance of uncontrolled spill at this project. By the summer spill season, TDG levels in the PRD and IHR tailraces and MCN forebay were below the 115%/120% standards that applied during this time.

In all, 29 total GBT samples were conducted at MCN in 2019. Of these, six had fish with signs of fin GBT (Figure J-6, Table J-9). The highest GBT incidence rate at MCN in 2019 was 2%, which occurred on June 2nd. At this time, TDG levels in the MCN forebay were 117% and TDG levels in PRD and IHR tailraces were in the 116-118% and 120-123% range, respectively, over the preceding five days. The other five GBT samples that had signs of fin GBT all had a 1% GBT incidence rate. Finally, all fish exhibiting signs of fin GBT at MCN in 2019 were Rank 1.

Figure J-6
Percent GBT observed in the sample at McNary Dam in 2019.



Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line).

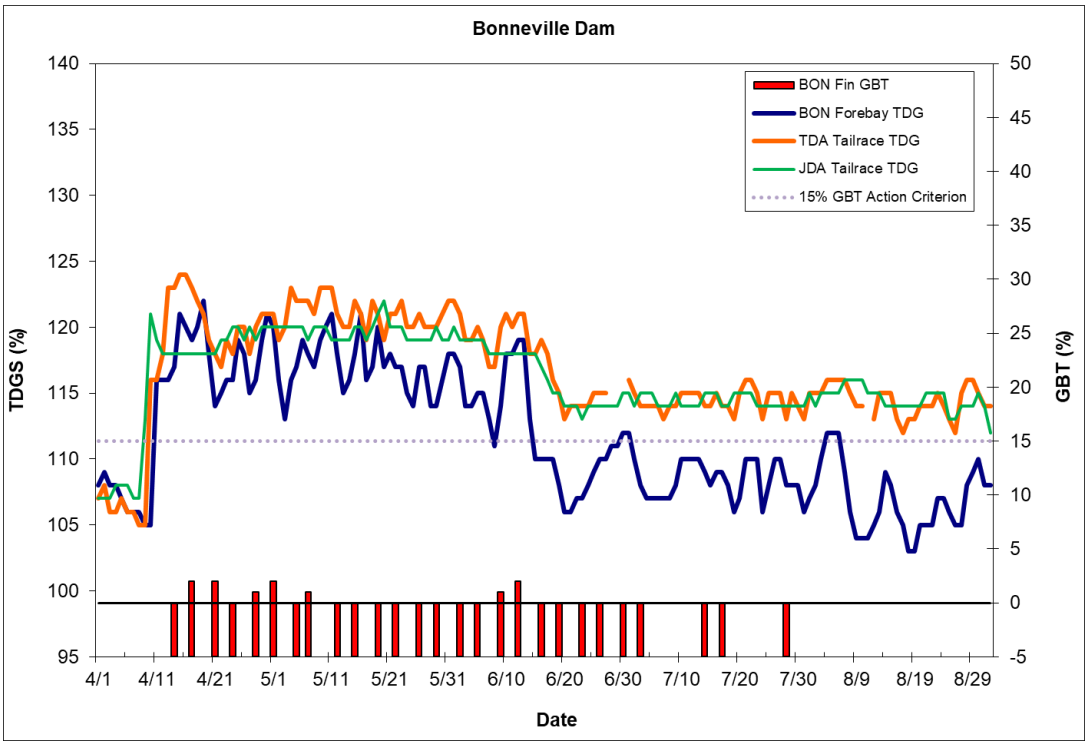
Bonneville Dam (BON)

GBT sampling at BON occurred from April 14th to July 28th. Due to decreasing numbers of subyearling Chinook, GBT sampling in July was limited. Only three additional GBT samples were conducted after the sample on July 3rd. These three samples were July 14th, July 17th, and July 28th. After the July 28th, subyearling Chinook passage was sufficiently low that sampling was terminated for the 2019 season. During this time (July 4-28), TDG in the BON forebay was generally at or below the EPA 110% standard.

During the spring season, TDG in the John Day (JDA) and The Dalles Dam (TDA) tailraces was managed under the Oregon methodology, which bases the 12-hour average TDG on the 12 highest hourly TDG measurements in a single calendar day, regardless of whether they were consecutive or not. However, in the summer season, TDG in these tailraces was managed to the more restrictive of the Oregon and Washington methodologies, which bases the 12-hour average on a rolling 12-hour average with the highest of the rolling averages reported as the 12-hour average for a given day. The 12-hour averages that are provided in Figure J-7 follows the above mentioned conventions for the spring and summer seasons. Total dissolved gas in the tailrace of JDA exceeded the 120% waiver criterion on three occasions (April 10th and May 19th and 20th), with a peak 12-hour average of 122% on May 20th. Total dissolved gas in the tailrace at TDA exceeded the 120% waiver criterion on 34 total occasions. Most of these occasions occurred from mid-April through late May. The peak 12-hour average TDG in the tailrace at TDA was 124%, which occurred on two days in mid-April. By the time summer spill operations began, TDG levels in the tailraces at JDA and TDA were below the 120% TDG standard and TDG in the BON forebay was below the 115% TDG standard that was applied at this time.

In all, 27 total GBT samples were conducted at BON in 2019. Of these 27 samples, seven had fish with signs of fin GBT (Figure J-7, Table J-10). The highest GBT incidence rate at BON in 2019 was 2.0%, which occurred on four separate occasions (April 17th, April 21st, May 1st, and June 12th). Total dissolved gas levels in the BON forebay ranged from 114% to 120% during these dates and TDG levels in the tailraces at JDA and TDA had been in the 118-120% and 117-124% ranges, respectively, over the preceding five days. The other three GBT samples that had fish with signs of fin GBT had incidence rates of 1.0%. Finally, of the 11 total fish that exhibited signs of fin GBT at BON in 2019, all were Rank 1 signs.

Figure J-7
Percent GBT observed in the sample at Bonneville Dam in 2019.



Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line).

Rock Island Dam (RIS)

GBT sampling at RIS occurred from April 23rd to August 1st. Due to generally low numbers of target species in June and July, there were several weeks when the SMP staff at RIS was only able to conduct one GBT sample per week. GBT sampling at RIS was terminated after the sample on August 1st because of the inability to collect the adequate sample for GBT exams.

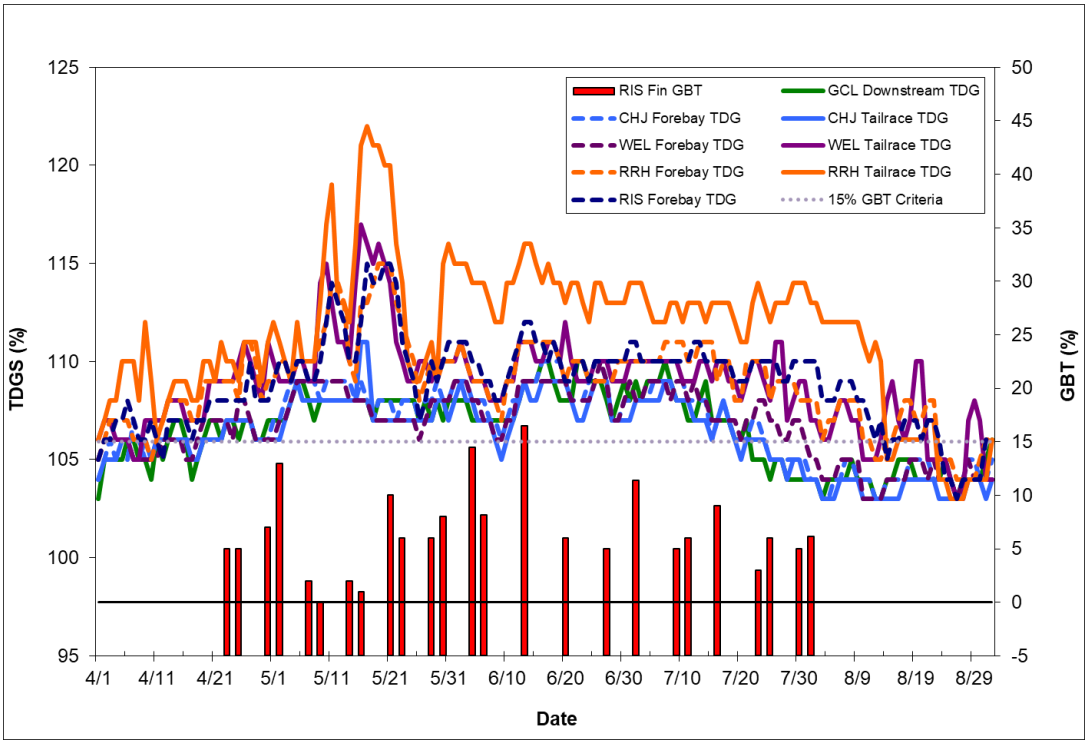
Total dissolved gas levels in the tailraces of Grand Coulee (GCL) and Wells (WEL) dams never exceeded the 120% standard in 2019 (Figure J-8). However, TDG in the Rocky Reach tailrace exceeded the 120% standard on four occasions, all of which occurred in mid-May. Total dissolved gas levels in the forebays at Chief Joseph (CHJ), WEL, RRH, and RIS never exceeded the 115% standard in 2019.

As mentioned above, staff at the FPC and SMP staff at RIS continued the implementation of a modified sampling protocol in 2019. This modified sampling protocol was the same as what was implemented in 2018 and similar to the pilot protocol that had been implemented in 2016 and 2017. Results from 2016-2018 indicated that past GBT incidence rates at RIS are likely biased high and should be considered in the context of the sampling protocol used in those years (i.e., 100% traditionally sampled fish that were held for up to 24-hours). In 2019, efforts to sample "fresh" fish were maximized, under current

budget and scheduling constraints. Results from GBT sampling presented here are for all fish sampled at RIS, regardless of whether they were "fresh" or sampled under traditional means. A more detailed discussion of the modified protocol and evaluation of the data are provided in a separate discussion below (Evaluation of Modified Sampling Protocol at Rock Island).

In all, 25 total GBT samples were conducted at RIS in 2019. Of these, 24 had fish with signs of fin GBT (Figure J-8, Table J-11). GBT incidence rates at RIS ranged from as low as 1% of fish examined exhibiting signs of fin GBT to as high as 16.5% of fish examined exhibiting signs of fin GBT (Figure J-8, Table J-11). The highest incidence of 16.5% GBT occurred on June 13th. Total dissolved gas levels in the RIS forebay were 112% at this time and TDG levels in the RRH tailrace has been in the 112-115% range over the preceding five days. The sample on June 13th was the only GBT sample that exceeded the 15% criteria to trigger reduced spill upstream. However, it does not appear that any measures were taken to reduce spill at RRH as a result of this GBT level. Of the 156 total fish that exhibited signs of fin GBT at RIS in 2019, 142 had Rank 1 signs and the remaining 14 had Rank 2 signs. None of the fish that were observed with signs of fin GBT in 2019 has severe signs (i.e., Rank 3 or 4).

Figure J-8
Percent GBT observed in the sample at Rock Island Dam in 2019.
****Note different scale for y-axis on left****



Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line).

Table J-5 compares the 2019 estimates of the overall percentage of fish with signs of GBT to past years' estimates. This is not meant as a measurement of overall GBT, but is used to easily display the annual relative magnitude of GBT in 2019 compared to past years. We include overall percentages both with and without Rock Island Dam included, due to the fact that this site caused the estimate to be biased high, particularly in high flow years. As can be seen in the table, with Rock Island included, the overall annual incidence of GBT in 2019 was the 7th highest among the last 24 years. Without Rock Island, the 2019 overall annual incidence of GBT was the 10th highest of the last 24 years.

Table J-5
Percent of sampled fish with signs of fin GBT estimated for the total fish observed in each year 1996 to 2019.

Year	Total % Signs	% Signs excluding RIS
1996	3.30	4.20
1997	3.20	4.30
1998	1.00	1.60
1999	0.30	1.40
2000	0.20	0.20
2001	0.001	0.10
2002	0.70	0.70
2003	1.50	0.50
2004	0.18	0.18
2005	0.46	0.11
2006	1.60	1.40
2007	2.40	2.90
2008	0.50	0.70
2009	0.29	0.23
2010	0.36	0.43
2011	2.50	0.95
2012	0.68	0.44
2013	0.31	0.28
2014	0.25	0.17
2015	0.19	0.13
2016	0.18	0.07
2017	4.55	1.38
2018	3.04	1.17
2019	**1.98**	**0.76**

Evaluation of Modified Sampling Protocol at Rock Island

In 2016 and 2017, FPC staff and SMP personnel at RIS implemented a pilot sampling protocol to reduce the amount of time GBT sample fish were held in the trap prior to examination. 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.

Under this pilot protocol, the direct sampling was limited to 1-2 hours in the morning, before the full sample was enumerated. 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, until the target sample size was met. Each "fresh" fish from the GBT sample was flagged with a code in the database for later identification. In 2018, SMP staff at RIS implemented a modified sampling protocol to maximize the number of "fresh" fish in the GBT samples, under current budget and scheduling constraints. This modified sampling protocol included two periods for collecting "fresh" fish: one in the late morning or afternoon and a second in the early morning, just before the sampling period ended. The duration of the "fresh" sampling periods varied and were dependent on several factors, including: staffing schedules, staff availability, and fish numbers. As with the pilot from 2016 and 2017, if the total number of "fresh" 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 was met. This modified sampling protocol to maximize the number of "fresh" fish in the GBT sample was continued in 2019.

The FPC staff has provided three separate analyses of GBT incidence rates of "traditional" versus "fresh" sampled fish at RIS (FPC 2017, FPC 2018, and FPC 2019). Results from these analyses all showed that, on average, "traditional" fish had a higher GBT incidence rates than "fresh" fish. Given this, it appears that historic GBT rates at RIS are likely biased high, as these were collected using only "traditional" fish. Therefore, the FPC concluded that GBT rates at RIS should be considered in the context of the sampling protocol that was implemented at the time of their collection. From the modified sampling protocols that were implemented in 2016-2019, 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. 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 at RIS. Based on the results from these analyses, the FPC recommended that SMP staff at RIS continue to implement the modified sampling protocol to maximize the number of "fresh" fish in the GBT samples in future years.

Historical Summary (1996–2019)

The Gas Bubble Trauma monitoring program has been implemented annually since 1996. There are over twenty years of data available, and as a result of involuntary spill events, data for GBT are available over a wide range of total dissolved gas concentrations. In fact, over this historic record, observations have occurred at tailwater TDG levels as high as 140%. This has allowed the assessment of the impacts of TDG on the salmonid population over a wide range of tailwater TDG conditions. Given the fact that GBT results at RIS are bias high (see previous section), this assessment was limited to FCRPS monitoring sites (LGR, LGS, LMN, MCN, and BON).

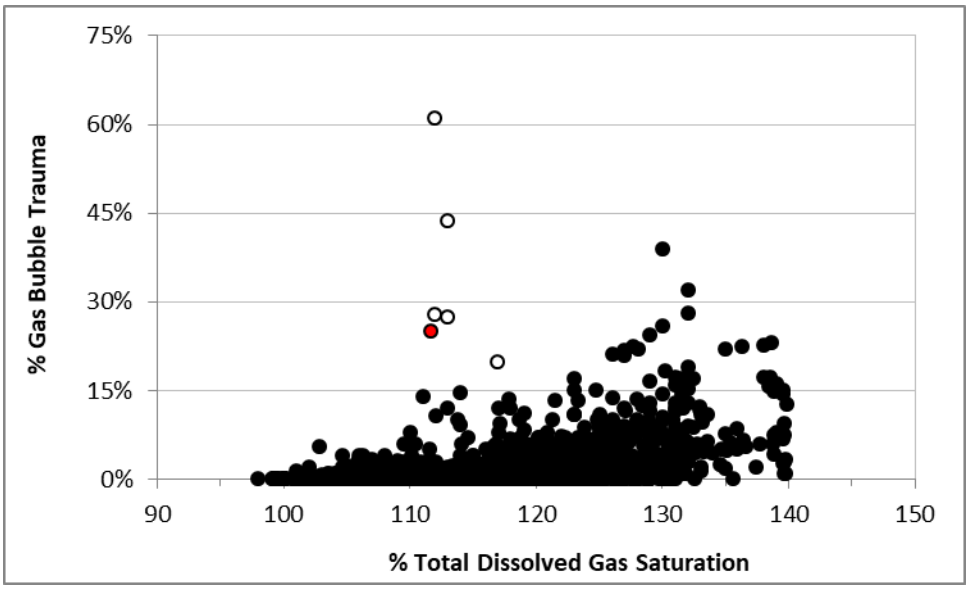
The daily sample size criteria based on the monitoring protocol is 100 fish. In this analysis, some flexibility was considered and all daily samples with greater than 75 fish were included. For each GBT sample in this dataset, we estimated the average TDG from the upstream tailrace. This average tailrace TDG was adjusted for water transit time, which was based on the daily average flow from the day of the GBT sample. There were two exceptions to this. First, for the samples conducted at Bonneville Dam, the tailrace TDG that was used was from the John Day tailrace monitor. This was done because the variability in TDG from the John Day tailrace better represented the variability in the GBT samples taken at BON. Second, for the samples conducted at Lower Granite Dam, the corresponding TDG that was used was from the Lower Granite forebay, on the day that the sample was conducted. This was done because fish entering Lower Granite Dam would have originated from any number of tributaries, including the Clearwater River, Grande Ronde River, Imnaha River, Salmon River, or mainstem Snake River. Total dissolved gas levels for any one of these tributaries may not represent what the run-at-large was exposed to prior to entering the LGR pool. Total dissolved gas in the Lower Granite forebay is at least a measure of the TDG that all fish entering Lower Granite were exposed to upon entry into the FCRPS system. With these data, we evaluated how often the 15% fin GBT incidence criterion has been met over the last 24 years, and at what tailrace TDG levels this occurred

Excluding Rock Island Dam samples, a total of 2,956 daily exams fit into our criteria of ≥75 fish examined over the 24-years of available data. This equated to a total of 334,380 fish examined. The GBT monitoring program has consistently shown over the years that signs of GBT are minimal when TDG is managed to the present dissolved gas standards associated with the implementation of the Federal Columbia River Power System (FCRPS) Biological Opinion Spill program.

In all the years when TDG and GBT data have been collected (2,956 samples meeting our sample size criterion), there have been only 37 instances when the 15% GBT criterion was exceeded. Of those 37 instances, five (open circles in Figure J-9) can be attributed to late migrating steelhead smolts in 2002 and 2007. At the time these steelhead smolts were collected at Little Goose or Lower Monumental dams, approximately 98% of the juvenile steelhead migrating that year had already passed this project. These late migrating fish were observed in the forebay of the dam on the surface, had prolonged migration times, and were likely residualizing (FPC 2007a, FPC 2007c). These fish may be considered anomalous, and were likely present due to the very low flow conditions that occurred those years. Another anomalous GBT incidence rate was recorded at Little Goose Dam in April of 2008, when 25% of the GBT sample was recorded as having signs of GBT in the fins (red circle in Figure J-9). The estimated TDG in the LGR tailrace was 112%. However, it was later determined that the person conducting the exam may have misidentified deformed fin rays as bubbles, particularly in steelhead dorsal fins (USACE 2008, Appendix M). A total of 23 of the 25 fish with signs of GBT were steelhead. Only six of these steelhead had signs of GBT in other fins when the dorsal fin information was excluded. Two of the yearling Chinook from this sample were identified with GBT. With dorsal GBT excluded, the GBT rate for this date was likely closer to 8%. The other 31 instances when the biological criteria were exceeded occurred when TDG was greater than

120%. Of these 31 instances, 28 (90.3%) were observed at TDG concentrations greater than 125%. The following graph (Figure J-9) shows the summary of the 2,956 daily exams as a function of TDG.

Figure J-9
Percent GBT observed as a function of TDG observed in upstream tailrace.

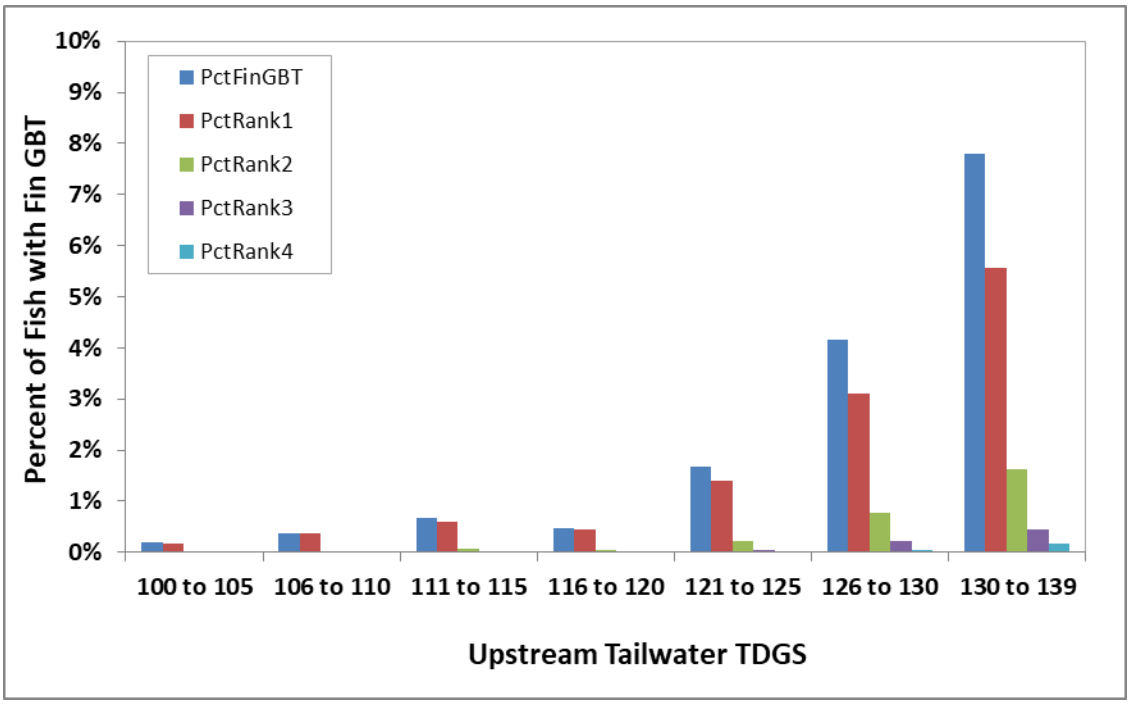


* Open circles indicate observations for late migrating steelhead in 2002 and 2007. Red circle indicates observation in 2008 when deformed fin rays may have been misidentified as GBT.

It is important to note that, although there were 28 instances where the 15% fin GBT criterion was met occurred at tailrace TDG levels of ≥125%, there were 292 additional GBT samples whose associated tailrace TDG levels were ≥125% that had fin GBT incidence rates below the 15% criterion (Figure J-9). These analyses indicate that the action criterion is generally not triggered at TDG levels less than 120% in the tailrace and even rarely triggered at tailrace TDG levels above 125%.

Over the historic record there have been several instances when GBT data were collected during periods of uncontrolled spill that led to higher levels of TDG. This allows fish collected over the years to be sorted into groups that migrated under similar TDG levels (Figure J-10). Figure J-10 summarizes the gas bubble trauma data collected over the span of the GBT Monitoring Program as a function of the TDG levels.

Figure J-10
Percent of all fish collected from 1996–2019 showing signs of GBT at given TDG levels.



From Figure J-10 two things are apparent. First, the incidence of fish observed with signs of GBT and the severity of those signs increases with increasing levels of TDG supersaturation. This is consistent with the research on which the monitoring program was developed. Second, signs of GBT are almost non-existent below 120% TDG, begin increasing slightly between 121% and 125% TDG, and then increase in both incidence and severity above 125% TDG.

Discussion

The Biological Opinion Spill Program is managed using the physical monitoring data collected by TDG monitors in the forebay and tailrace of each FCRPS project. The GBT biological monitoring is meant to complement the physical monitoring program. GBT sampling was successfully accomplished for the 2019 migration season. Under the high flow conditions observed in April and May in the Snake River, TDG levels were occasionally above the 120% tailrace standard and sometimes exceeded 125%. These high TDG levels were largely due to flows in excess of hydraulic capacity in the Snake River. Under the lower flow conditions in the Middle Columbia River, TDG levels were generally at or below the 120% TDG tailrace standard, except at TDA and BON where there were several exceedances of the 120% TDG standard. In general, observed GBT incidents rates in 2019 were low.

The 15% action criterion was met never met at the Snake and Mid-Columbia River sites in 2019 but was met once at the Upper Columbia site. The highest level of GBT

(16.5%) was observed at Rock Island Dam. The highest level observed in the FCRPS was 12.5% at Little Goose Dam on July 16, 2019. However, it is worth noting that this was based on a very limited sample of only 16 examined fish.

Data collected over the past 20 plus years strongly suggest that the Biological Monitoring serves as an effective management tool providing "early warning" of potentially harmful levels of TDG. What we have learned from the historic data is that the "early warning" signs are not triggered at TDG levels less than 120% at the tailrace monitors. Most observations indicating potential harm occurred when TDG levels in the tailrace exceeded 125%.

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Table J-6

Detailed breakdown of GBT exams and signs of fin GBT at Lower Granite Dam in 2019.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/5/2019	100	0	0.0%
4/12/2019	100	0	0.0%
4/19/2019	100	0	0.0%
4/26/2019	100	0	0.0%
5/2/2019	100	0	0.0%
5/10/2019	100	0	0.0%
5/17/2019	100	0	0.0%
5/24/2019	101	0	0.0%
5/31/2019	100	0	0.0%

Table J-7

Detailed breakdown of GBT exams and signs of fin GBT at Little Goose Dam in 2019.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/8/2019	100	0	0.0%
4/16/2019	100	1	1.0%
4/22/2019	100	3	3.0%
4/30/2019	100	1	1.0%
5/7/2019	100	7	7.0%
5/14/2019	100	4	4.0%
5/21/2019	100	2	2.0%
5/28/2019	100	3	3.0%
6/4/2019	100	4	4.0%
6/11/2019	100	0	0.0%
6/18/2019	40	0	0.0%
6/25/2019	100	0	0.0%
7/2/2019	42	0	0.0%
7/9/2019	40	0	0.0%
7/16/2019	16	2	12.5%

Table J-8

Detailed breakdown of GBT exams and signs of fin GBT at Lower Monumental Dam in 2019.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/11/2019	100	1	1.0%
4/19/2019	100	0	0.0%
4/25/2019	100	2	2.0%
5/2/2019	100	3	3.0%
5/8/2019	100	2	2.0%
5/15/2019	100	0	0.0%
5/22/2019	100	1	1.0%
5/29/2019	100	4	4.0%
6/5/2019	100	3	3.0%
6/12/2019	37	1	2.7%
6/19/2019	13	0	0.0%
6/27/2019	53	0	0.0%
7/3/2019	90	3	3.3%
7/10/2019	100	3	3.0%
7/17/2019	78	0	0.0%
7/24/2019	44	0	0.0%

Table J-9

Detailed breakdown of GBT exams and signs of fin GBT at McNary Dam in 2019.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/13/2019	100	0	0.0%
4/17/2019	100	0	0.0%
4/21/2019	100	0	0.0%
4/25/2019	100	0	0.0%
4/27/2019	100	0	0.0%
5/1/2019	100	0	0.0%
5/5/2019	100	1	1.0%
5/7/2019	100	1	1.0%
5/11/2019	100	0	0.0%
5/15/2019	100	0	0.0%
5/19/2019	100	1	1.0%
5/21/2019	100	0	0.0%
5/25/2019	100	0	0.0%
5/29/2019	100	0	0.0%
6/2/2019	100	2	2.0%
6/4/2019	100	0	0.0%
6/8/2019	100	0	0.0%
6/12/2019	100	0	0.0%
6/16/2019	100	0	0.0%
6/18/2019	100	0	0.0%
6/22/2019	100	0	0.0%
6/26/2019	100	0	0.0%
6/30/2019	100	0	0.0%
7/2/2019	100	0	0.0%
7/12/2019	100	0	0.0%
7/14/2019	100	1	1.0%
7/20/2019	100	1	1.0%
7/24/2019	87	0	0.0%
7/30/2019	56	0	0.0%

Table J-10

Detailed breakdown of GBT exams and signs of fin GBT at Bonneville Dam in 2019.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/14/2019	100	0	0.0%
4/17/2019	100	2	2.0%
4/21/2019	100	2	2.0%
4/24/2019	100	0	0.0%
4/28/2019	100	1	1.0%
5/1/2019	100	2	2.0%
5/5/2019	100	0	0.0%
5/7/2019	100	1	1.0%
5/12/2019	100	0	0.0%
5/15/2019	100	0	0.0%
5/19/2019	100	0	0.0%
5/22/2019	100	0	0.0%
5/26/2019	100	0	0.0%
5/29/2019	99	0	0.0%
6/2/2019	100	0	0.0%
6/5/2019	100	0	0.0%
6/9/2019	100	1	1.0%
6/12/2019	100	2	2.0%
6/16/2019	100	0	0.0%
6/19/2019	100	0	0.0%
6/23/2019	100	0	0.0%
6/26/2019	100	0	0.0%
6/30/2019	100	0	0.0%
7/3/2019	100	0	0.0%
7/14/2019	100	0	0.0%
7/17/2019	100	0	0.0%
7/28/2019	41	0	0.0%

Table J-11

Detailed breakdown of GBT exams (total, "traditional", and "fresh" examined) and signs of fin GBT at Rock Island Dam in 2019.

Sample Date	Total Number Examined	Total Percent with Fin GBT	Number Examined "Traditional"	Percent with Fin GBT "Traditional"	Number Examined "Fresh"	Percent with Fin GBT "Fresh"
4/23/2019	100	5.0%	95	5.3%	5	0.0%
4/25/2019	100	5.0%	93	5.4%	7	0.0%
4/30/2019	100	7.0%	80	8.8%	20	0.0%
5/2/2019	100	13.0%	96	13.5%	4	0.0%
5/7/2019	100	2.0%	19	0.0%	81	2.5%
5/9/2019	100	0.0%	---	---	100	0.0%
5/14/2019	100	2.0%	---	---	100	2.0%
5/16/2019	100	1.0%	---	---	100	1.0%
5/21/2019	100	10.0%	42	19.0%	58	3.4%
5/23/2019	100	6.0%	83	7.2%	17	0.0%
5/28/2019	100	6.0%	58	5.2%	42	7.1%
5/30/2019	100	8.0%	69	11.6%	31	0.0%
6/4/2019	76	14.5%	63	15.9%	13	7.7%
6/6/2019	61	8.2%	51	9.8%	10	0.0%
6/13/2019	103	16.5%	69	20.3%	34	8.8%
6/20/2019	100	6.0%	89	5.6%	11	9.1%
6/27/2019	100	5.0%	68	7.4%	32	0.0%
7/2/2019	70	11.4%	63	12.7%	7	0.0%
7/9/2019	100	5.0%	86	5.8%	14	0.0%
7/11/2019	100	6.0%	82	6.1%	18	5.6%
7/16/2019	100	9.0%	98	9.2%	2	0.0%
7/23/2019	100	3.0%	85	3.5%	15	0.0%
7/25/2019	100	6.0%	66	6.1%	34	5.9%
7/30/2019	100	5.0%	74	5.4%	26	3.8%
8/1/2019	81	6.2%	79	6.3%	2	0.0%