



FISH PASSAGE CENTER

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November 15, 2017

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 2017* to both you and Mr. Paul Wagner of National Marine Fisheries Service. This report summarizes data collected during the 2017 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
Laura Hamilton, USACE
Julie Ammann, USACE

Appendix J

Gas Bubble Trauma Monitoring And Data Reporting For 2017

**Fish Passage Center
Portland, Oregon**

Gas Bubble Trauma Monitoring and Data Reporting for 2017

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 Web site 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 2017 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. In 2017, sampling at some sites was terminated prior to the end of August as a result of high temperatures in the Snake and Middle Columbia rivers 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). At BON and RIS, fish for the GBT sample can be held for prolonged periods, 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, at RIS there are few good alternatives to this sampling procedure, and data from Rock Island Dam 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. In an attempt to address the concern over holding times, the FPC and RIS staff implemented a pilot sampling protocol in 2016 and 2017. 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 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 2017 followed the same protocol that was issued in 2015. For more detailed information on the examination procedure, the 2017 GBT Monitoring Protocol is available on the FPC website (ftp://ftp.fpc.org/GBT/GBTManual_Datasheet/GBTMonitoringProtocol_2017.pdf).

2017 Water Conditions

The runoff volume (January–July) for the 2017 water year was above average in both the Middle Columbia and Lower Snake rivers. Runoff (January–July) was 135% of average (1981–2010) at The Dalles Dam and 152% of average at Lower Granite Dam. To put the runoff volumes into perspective, the 2017 January–July runoff volumes at The Dalles and Lower Granite were ranked 8th and 9nd, respectively, over the last 89 years (1929–2017).

Runoff in the Snake River was early, with three peak flow periods; one in mid- to late March at about 180-190 Kcfs, one in early May at about 170-180 Kcfs, and one in early June at about 160-180 Kcfs (Figure J-1). Late spring and early summer flows (mid-June through July 1st) in the Snake River were above the ten-year average while late summer flows (July 1st-August 31st) were at or slightly above the ten-year average. Runoff in the Middle Columbia was also early, with two peak flow periods; one in mid- to late March at about 380-460 Kcfs and one in mid-May to mid-June also at about 380-460 Kcfs

(Figure J-2). Late spring flows were above the ten-year average while summer flows (July through August) were at or below the ten-year average. Flows in the Snake and Middle Columbia rivers were sufficiently high throughout most of the spring that uncontrolled spill events occurred at all projects for at least some period. During this time, total dissolved gas (TDG) levels were above waiver levels, sometimes as high as 130% at some forebay monitors and just above 135% at some tailrace monitors.

Figure J-1.
Average daily flows at Lower Granite Dam
2017, 2016, and the 10-year average

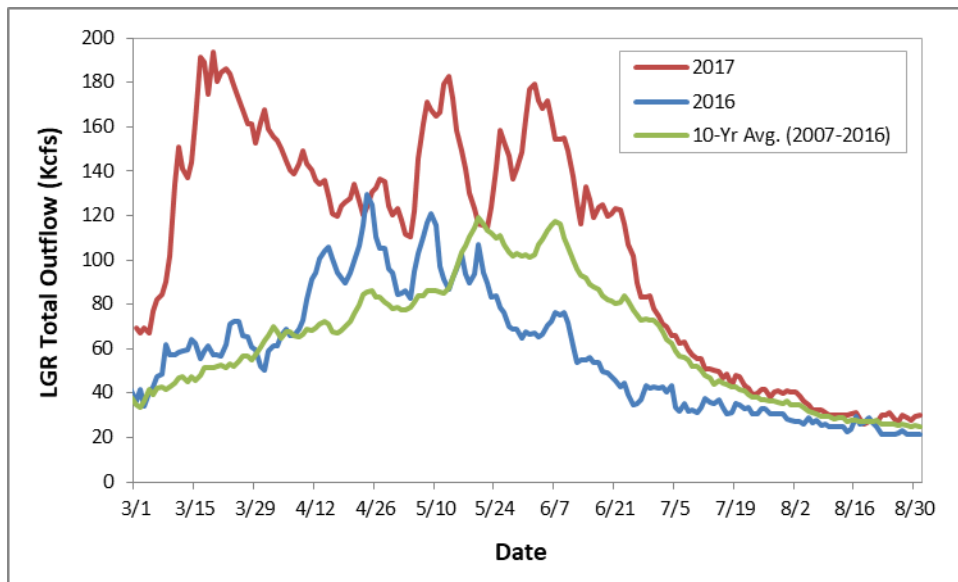


Figure J-2
Average daily flows at McNary Dam
2017, 2016 and the 10-year average



Results

In all, 15,120 juvenile salmonids were examined for GBT between April and August of 2017 (Table J-2). The fish were collected and examined as part of the Smolt Monitoring Program.

Table J-2
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 2017 as part of the Smolt Monitoring Program.

Species	BON	MCN	LMN	LGS	LGR	RIS	Total
Chinook Subyearlings	1,583	1,907	755	1,068	523	2,026	7,862
Chinook Yearlings	1,308	1,008	353	377	337	836	4,219
Steelhead	233	385	591	506	736	588	3,039
Total	3,124	3,300	1,699	1,951	1,596	3,450	15,120

Fin signs were found in 688 or 4.55% of the total fish sampled at all sites (Table J-3), with 527 of those detections occurring at Rock Island Dam. Of the 688 fish that had signs of fin GBT in 2017, 617 (90%) had a maximum fin ranking of 1, where less than 5% of a fin area was covered with bubbles. A total of ten fish (1.5%) had signs of severe GBT (rank 3 or 4), where >26% of a fin area was covered with bubbles. The ten fish with severe GBT were encountered at Bonneville (two fish with rank 4), Lower Monumental (three fish with rank 3), and Rock Island (five fish with rank 3) dams. A more detailed breakdown of GBT exams and signs for 2017 can be found at the end of this appendix (Tables J-5 through J-10).

Table J-3
Number of juvenile salmonids found with fin GBT at dams on the Lower Snake River and on the Columbia River from April to August 2017 as part of the Smolt Monitoring Program.

Species	Fin GBT by Site						Grand Total
	BON	MCN	LMN	LGS	LGR	RIS	
Chinook Subyearlings	21	0	6	8	2	145	182
Chinook Yearlings	46	4	14	3	5	291	363
Steelhead	5	0	24	10	13	91	143
Total	72	4	44	21	20	527	688

The action criteria for GBT is established as 15% of fish showing any signs of fin GBT, or 5% of the fish sampled showing signs of fin GBT greater than or equal to rank 3. The 15% criterion was met only once at the Snake River sites, zero times at the Mid-Columbia River sites, and fifteen times at the Upper Columbia site (Rock Island Dam) in 2017. The single occurrence at the Snake River sites was at Lower Monumental Dam in May. The fifteen instances at Rock Island Dam generally occurred between mid-April and early June. During all of these occurrences, flows in the Snake and Columbia rivers generally exceeded hydraulic capacities at all projects and voluntary spill could not be curtailed. The criterion of 5% severe GBT was never met in 2017.

Lower Granite Dam (LGR)

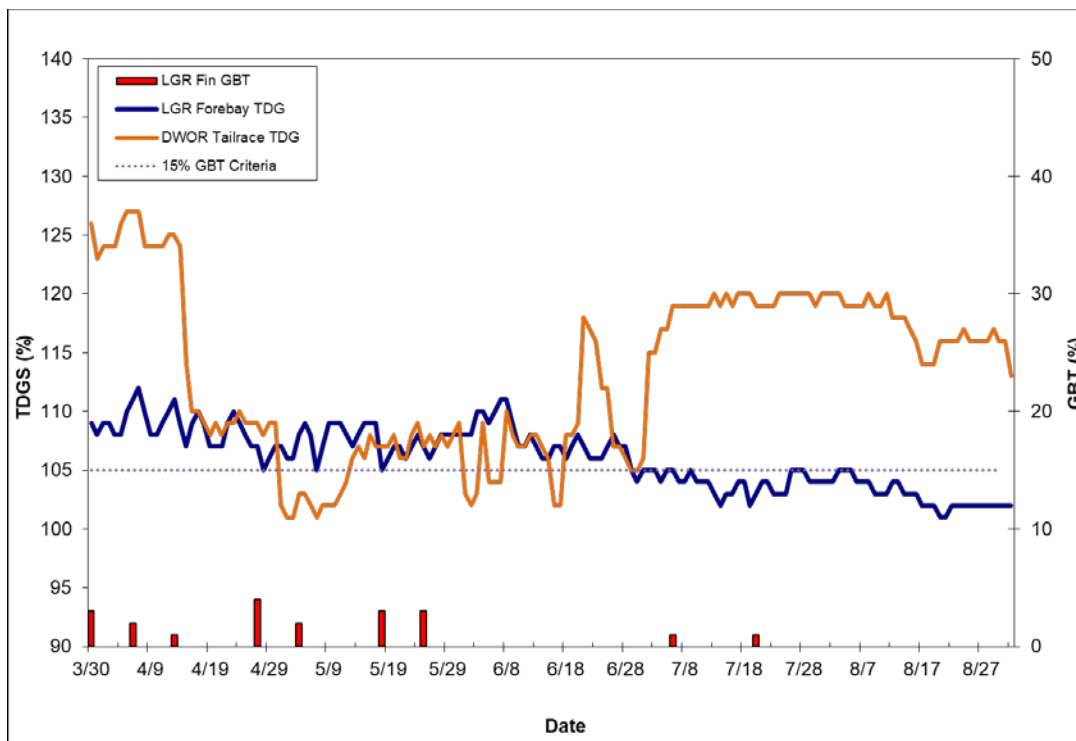
Due to rehabilitation work to Unit #3 at Dworshak Dam (DWR), powerhouse capacity at DWR was limited to 4.5-4.8 Kcfs for most of 2017. Any flow beyond the constrained powerhouse capacity at DWR had to be spilled. As a result of the high run-off in the Clearwater River, spill at DWR resulted in TDG levels as high as 125% in the DWR tailrace and as high as 112% in the LGR forebay (Figure J-3). In an ordinary year, TDG in the LGR forebay is typically below the 110% Environmental Protection Agency (EPA) standard. Accordingly, sampling at this site is usually used to provide a background level of GBT for migrating juvenile salmonids that are first entering the hydrosystem. In anticipation of high TDG in the Clearwater River, GBT sampling at LGR began earlier than usual, with the first sample conducted on March 30th. GBT sampling at LGR is usually terminated when subyearling Chinook begin to pre-dominate the collection. However, because high TDG from DWR spill continued into the summer, GBT monitoring at LGR was extended into the summer, until target sample sizes could no longer be met due to low fish numbers.

In all, 16 total GBT samples were conducted at LGR in 2017, from March 30th to July 27th. The sample on June 8th was curtailed due to anticipated low fish numbers and inability to reach target sample sizes. Of the 16 total GBT samples, nine (53%) had fish with signs of fin GBT (Figure J-3, Table J-5). The highest incidence of GBT at LGR in 2017 was 4% of the sample showing signs of fin GBT, which occurred on April 27th. All signs of fin GBT observed at LGR in 2017 were rank 1.

Figure J-3

Percent GBT observed in the sample at Lower Granite Dam

****Note the different scale on the x-axis to accommodate earlier start to sampling at LGR in 2017****

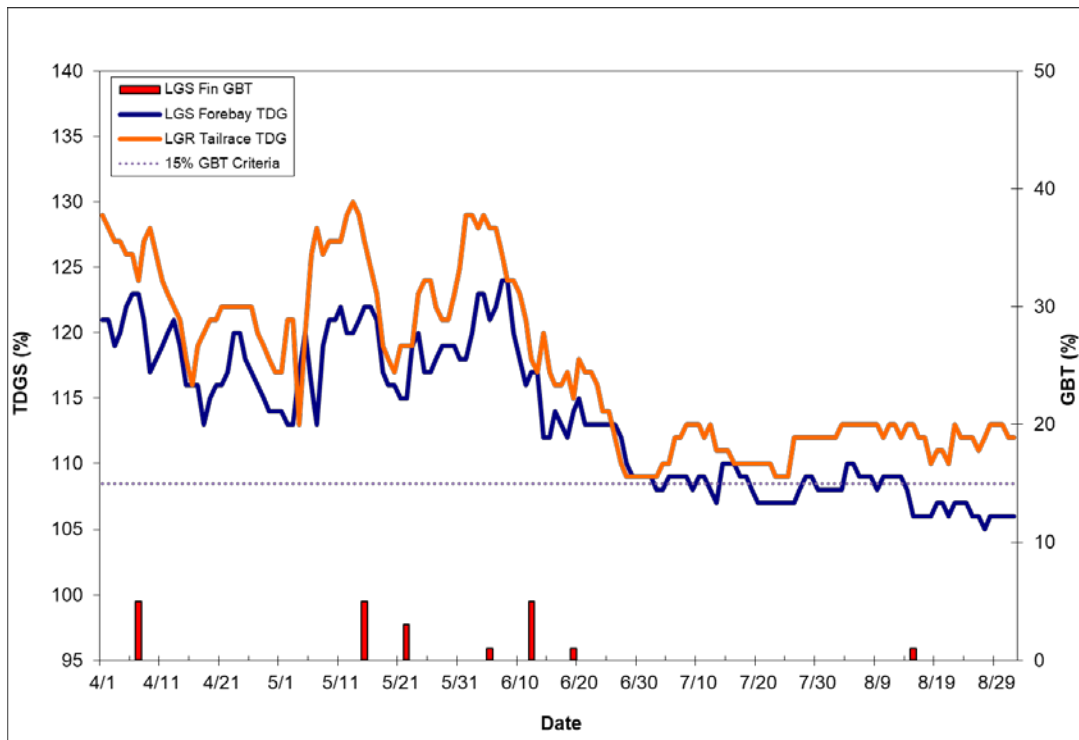


Little Goose Dam (LGS)

GBT sampling at LGS occurred from April 7th to August 21st. Sampling at LGS was terminated after the sample on August 21st due to: decreasing numbers of fish in the sample that precluded adequate sample sizes and TDG levels in the LGS forebay that were below the EPA standard of 110%. Total dissolved gas levels in the LGR tailrace exceeded the 120% criteria for most of the spring period (Figure J-4). Likewise, TDG in the LGS forebay exceeded the 115% standard for most of the spring. These high TDG levels were largely due to the flows in excess of hydraulic capacity at LGR and, therefore, uncontrolled spill at LGR. By mid-June, TDG levels in the LGR tailrace and LGS forebay were generally below the 115%/120% standards.

Twenty-one total GBT samples were conducted at LGS in 2017. Of these 21 GBT samples, seven (33%) had fish with signs of GBT (Figure J-4, Table J-6). The highest incidences of GBT in 2017 were 5% of the sample showing signs of fin GBT. These incidences occurred on three separate occasions: April 7th, May 15th, and June 12th. On these occasions, TDG levels in the LGS forebay were 123%, 122%, and 117%, respectively. In addition, TDG levels in the LMN tailrace had been in the 124-130% range just prior to these occasions. All of the fish that exhibited signs of fin GBT at LGS in 2017 were rank 1 and 2.

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



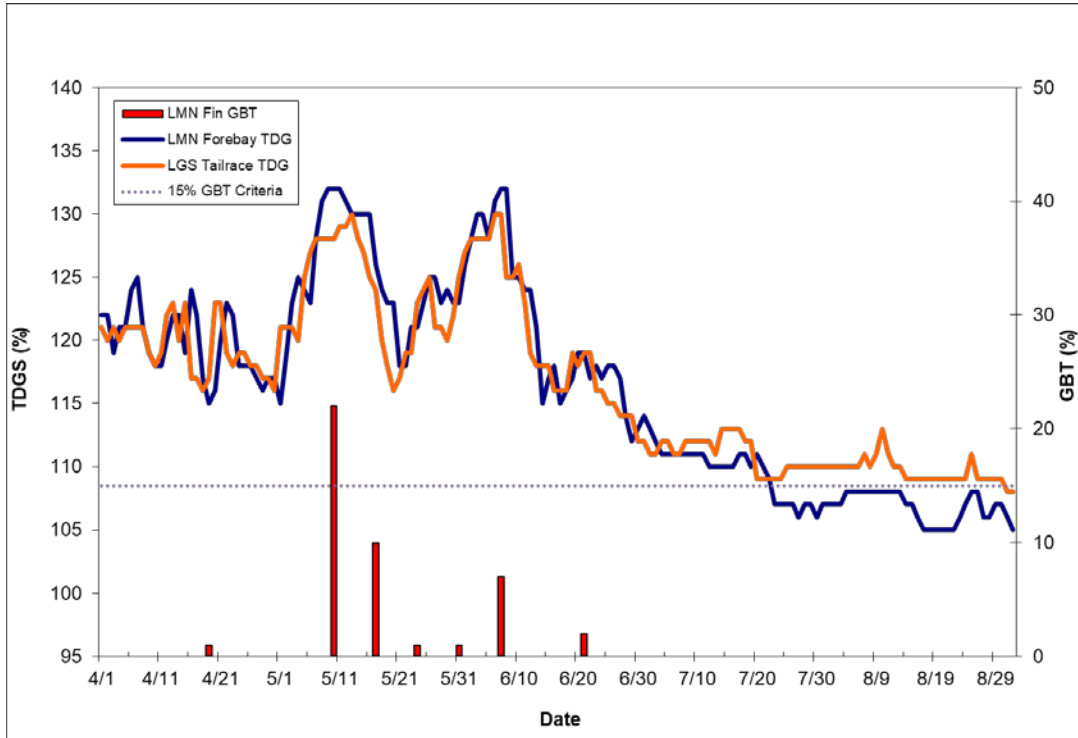
Lower Monumental Dam (LMN)

GBT sampling at LMN occurred from April 6th to August 4th. Sampling was terminated after the sample on August 4th due to: decreasing numbers of fish in the sample and TDG levels in the LMN forebay that were below the EPA standard of 110%. Total dissolved gas levels in the LGS tailrace and LMN forebay exceeded the 115%/120% criteria for most of the spring period (Figure J-4). These high TDG levels were largely due to the flows in excess of hydraulic capacity at LGS and, therefore, uncontrolled spill at LGS. By late June, TDG levels in the LGS tailrace and LMN forebay were below the 115%/120% standards.

In all, 18 total GBT samples were conducted at LMN in 2017. Of these 18 GBT samples, seven (39%) had fish with signs of GBT (Figure J-5, Table J-7). The highest incidence of GBT in 2017 at LMN was 22% of the sample showing signs of fin GBT, which occurred on May 10th. Total Dissolved Gas levels in the LMN forebay were 132% at this time. In addition, TDG levels in the LGS tailrace had been approximately 128% just prior to May 10th. Although the GBT incidence level on May 10th was above the 15% action criteria, no measures were taken to reduce spill, as all Snake River projects were operating under uncontrolled spill due to flows in excess of hydraulic capacity. Finally, of the 44 total fish that exhibited signs of fin GBT at LMN in 2017, three had severe signs (all rank 3). These fish with severe signs were encountered on May 10th and May 17th, when

TDG levels in the LMN forebay were 132% and 126%, respectively. At no point in 2017 did the incidence of severe signs of GBT exceed the 5% action criteria at LMN.

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



McNary Dam (MCN)

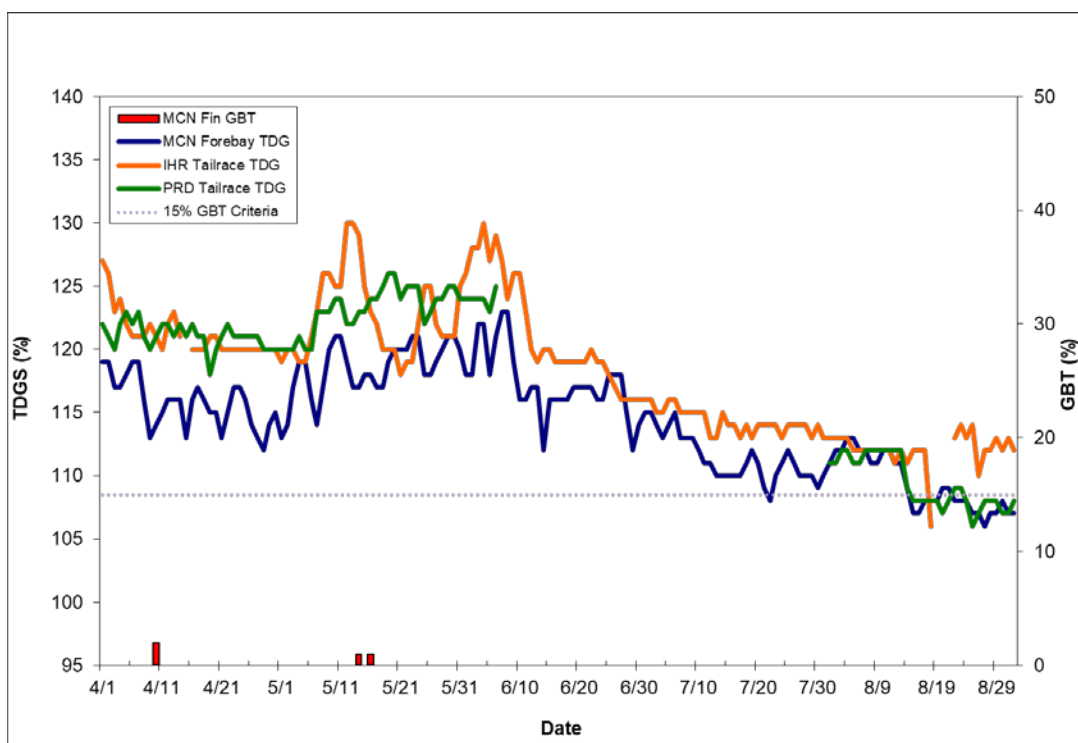
GBT sampling at MCN occurred from April 10th to August 6th. Similar to what occurred in 2015 and 2016, GBT sampling at MCN was reduced from twice per week to once per week due to elevated temperatures and increased mortality rates of recovering GBT-examined fish. This reduction in sampling began on August 2nd. At the time, TDG levels in the MCN forebay had been 112% or below and temperatures in the MCN forebay were approximately 22°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 August 6th due to decreasing fish numbers and forebay TDG levels that were below the EPA 110% standard.

Due the high flows, the TDG monitor in the Priest Rapids Dam (PRD) tailrace was only in operation through June 6th. Total Dissolved Gas levels in the PRD tailrace exceeded the 120% waiver level for much of the period between April 1st and June 6th (Figure J-6). Similarly, TDG levels in the Ice Harbor Dam (IHR) tailrace and MCN

forebay exceeded the 115%/120% standards for most of the spring. These high TDG levels were largely due to flows in excess of hydraulic capacity at PRD and IHR and, therefore, uncontrolled spill at these two projects. By late June, TDG levels in the IHR tailrace and MCN forebay were below the 115%/120% standards.

In all, 33 total GBT samples were conducted at MCN in 2017. Of these, only three (9%) had fish with signs of fin GBT (Figure J-6, Table J-8). The highest incidence of GBT in 2017 was 2% of the sample showing signs of fin GBT, which occurred on April 10th. Finally, all fish exhibiting signs of fin GBT at MCN in 2017 were rank 1 or 2.

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



Bonneville Dam (BON)

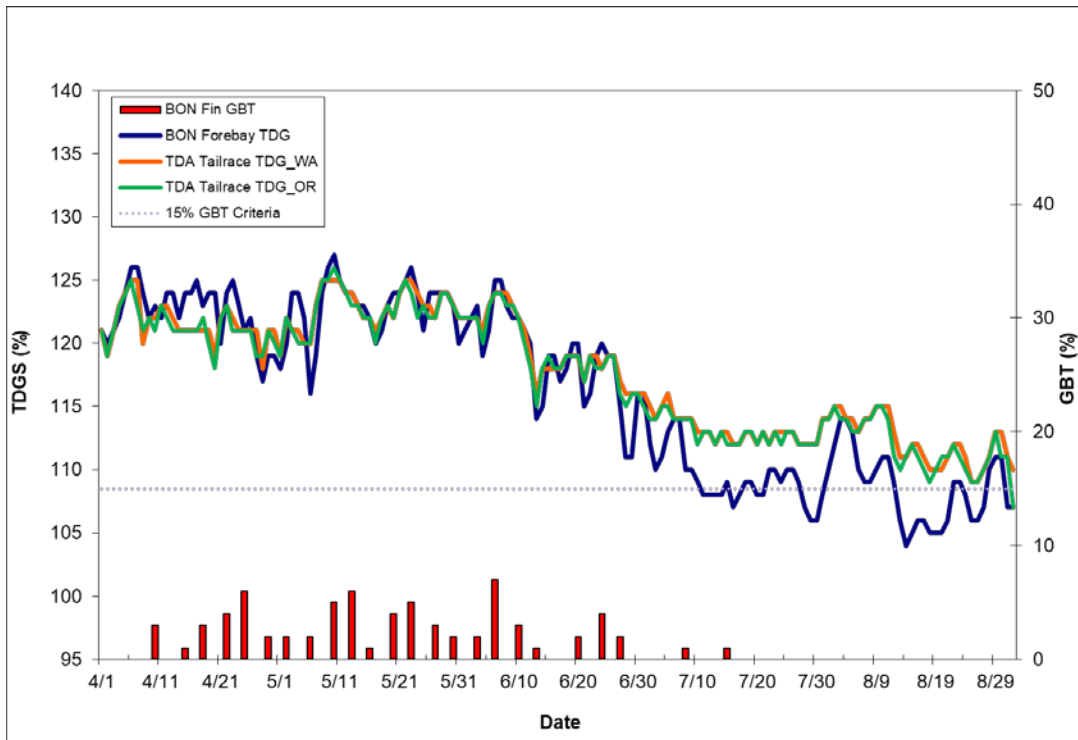
GBT sampling at BON occurred from April 8th to August 19th. As in some previous years, GBT sampling at BON was reduced from twice per week to once per week due to elevated temperatures and increased stress of recovering GBT-examined fish. Once per week GBT sampling began after the sample on July 22nd. At that time, TDG levels in the BON forebay were generally below the EPA 110% standard and temperatures in the BON forebay were approximately 21°C. As with MCN, 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. Due to low fish numbers, the samples on August 5th and August 13th were curtailed.

Sampling was terminated after the sample on August 19th due to: decreasing numbers of fish in the sample that precluded adequate sample sizes and TDG levels in the BON forebay that were generally below the EPA standard of 110%.

Total dissolved gas in The Dalles Dam (TDA) tailrace was managed under both the Oregon and Washington methodologies of estimating a 12-hour average TDG. Under the Oregon methodology, the 12-hour average is based on the 12 highest hourly TDG measurements in a single calendar day, regardless of whether they are consecutive or not. Under the Washington methodology, the 12-hour average is based on rolling 12-hour averages with the highest of the rolling averages reported as the 12-hour average for a given day. The COE managed to the gas level based on the higher of the two methodologies. The 12-hour averages under both of these methodologies are provided in Figure J-7 below. Total dissolved gas in the tailrace of TDA exceeded the 120% waiver level for much of the spring season. Similarly, total dissolved gas in the BON forebay, as calculated using the Washington DOE methodology, exceeded the Washington 115% waiver level for most of the spring season and even some of the summer season. In general, TDG levels in the forebay at BON and the tailrace at TDA were below the 115%/120% standard from early July through the end of the voluntary spill season.

In all, 33 total GBT samples were conducted at BON in 2017. Of these 33 samples, 24 (73%) had fish with signs of fin GBT (Figure J-7). The highest incidence of GBT at BON was 7% of fish in the sample exhibiting signs of fin GBT, which occurred on April 10th. Total dissolved gas levels in the BON forebay were 123% at this time and TDG levels in the tailrace at TDA had been approximately 125% just prior to April 10th. These high TDG levels were largely due to flows in excess of hydraulic capacity at TDA and, therefore, uncontrolled spill at this project. When signs of fin GBT were observed at BON, GBT incidence levels ranged from 1% to 7%. Of the 72 total fish that exhibited signs of fin GBT at BON, two had severe signs. Both of these fish with severe signs were rank 4, with one observed on April 15th and one on April 22nd. Total dissolved gas levels in the BON forebay were 124% on each of these two days.

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



Rock Island Dam (RIS)

GBT sampling at RIS occurred from April 18th to August 17th. GBT sampling at RIS was terminated after the sample on August 17th because of the inability to collect the adequate sample for GBT exams. By this time, TDG levels in the RIS forebay were generally below the EPA standard of 110% standard.

Total dissolved gas levels in the tailraces of Grand Coulee (GCL), Wells (WEL), and Rocky Reach (RRH) exceeded the 120% standard for much of the spring in 2017 (Figure J-8). However, TDG in the Chief Joseph Dam (CHJ) tailrace never exceeded the 120% standard in 2017. Total dissolved gas levels in the forebays at CHJ, WEL, RRH, and RIS all exceeded the 115% standard for most in the spring in 2017. Total dissolved gas levels at upstream monitors were mostly in compliance with the 115%/120% standards by late June or early July.

As mentioned above, staff at the FPC and SMP staff at RIS conducted a pilot sampling protocol in 2016 and 2017 where some GBT fish were sampled “fresh” as they entered the sample trap. 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 pilot protocol and evaluation of the data are provided in a separate discussion below (Evaluation of Pilot Sampling Protocol at Rock Island).

In all, 35 total GBT samples were conducted at RIS in 2017. All 35 of these samples had fish with signs of fin GBT (Figure J-8). GBT incidence rates at RIS ranged from as low as 2% of fish examined exhibiting signs of fin GBT to as high as 53% of fish examined exhibiting signs of fin GBT (Figure J-8, Table J-10). The highest incidence of 53% GBT occurred on April 25th. Total dissolved gas levels in the RIS forebay were 119% at this time and TDG in the RRH tailrace were approximately 125%. Over the entire season, there were fifteen samples where GBT incidences at RIS exceeded the 15% criteria to trigger reduced spill upstream. However, no measures were taken to reduce spill upstream of RIS because all upstream projects were operating under uncontrolled spill due to flows in excess of hydraulic capacities. The last sample where GBT incidence exceeded the 15% criteria was June 8th. As flows decreased in the late spring and into summer, GBT incidence rates at RIS declined (Figure J-8, Table J-10). At no point in 2017 did incidences of severe GBT (i.e., rank 3 or 4) at RIS exceed the 5% criterion. Of the 527 total fish that exhibited signs of fin GBT at RIS in 2017, five had severe signs. All five of these fish with severe signs were rank 3, with two observed in the sample on April 20th, two on April 25th, and one on May 4th. Total dissolved gas levels in the RIS forebay were 119%, 119%, and 115%, respectively on these days. It is worth noting that TDG levels in the Rocky Reach tailrace were approximately 122-125% during this period.

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

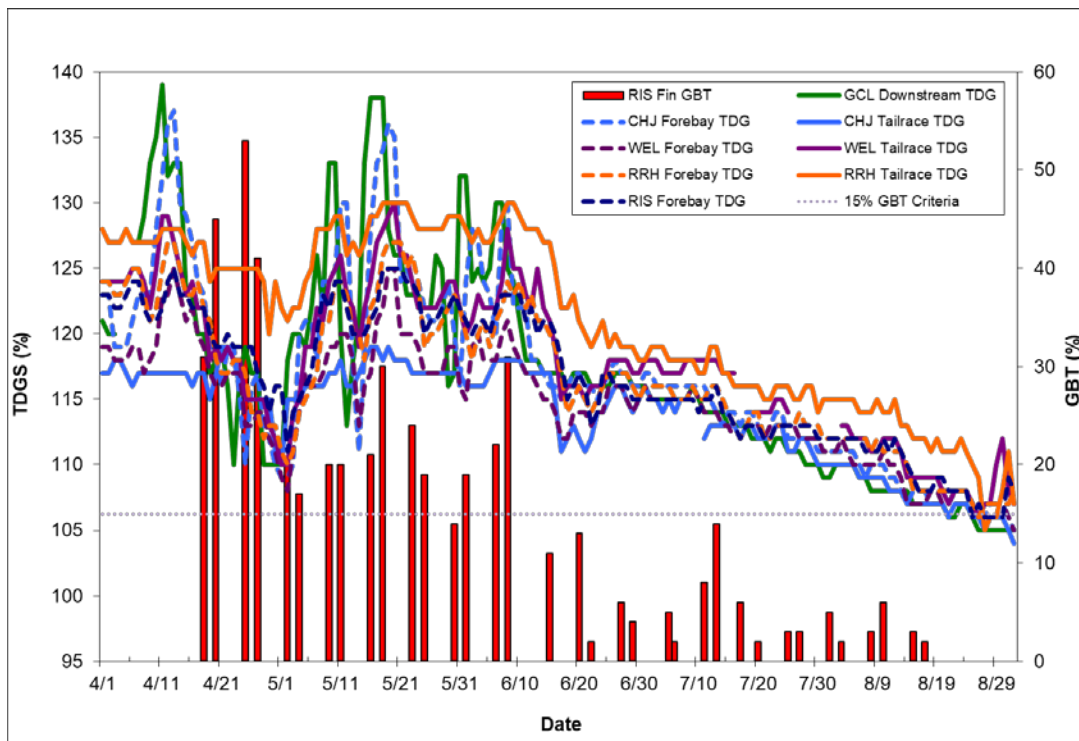


Table J-4 compares the 2017 estimates of the overall percentage of fish with signs of GBT to past years' estimates. This is not meant as a measurement of overall GBT, but is used to easily display the annual relative magnitude of GBT in 2017 compared to past years. We include overall percentage was both with and without Rock Island Dam included, due to the potential of this site causing the estimate to be biased high in some years. As can be seen in the table, with Rock Island included, the overall annual incidence of GBT in 2017 was the highest of the last 22 years. Without Rock Island, the 2017 overall annual incidence of GBT was the 7th highest of the last 22 years.

Table J-4
Percent of sampled fish with signs of fin GBT estimated for
the total fish observed in each year 1996 to 2017.

Year	Total % Signs	% Signs excluding RIS
1996	3.3	4.2
1997	3.2	4.3
1998	1.0	1.6
1999	0.3	1.4
2000	0.2	0.2
2001	0.001	0.1
2002	0.7	0.7
2003	1.5	0.5
2004	0.18	0.18
2005	0.46	0.11
2006	1.6	1.4
2007	2.4	2.9
2008	0.5	0.7
2009	0.29	0.23
2010	0.36	0.43
2011	2.5	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

Evaluation of Pilot 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. 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, until the target sample size was met. Each “fresh” fish from the GBT sample was flagged with a code for later identification.

On October 3, 2017 the FPC issued a memo that summarized an analysis of the GBT incidence rates between “fresh” and “traditional” fish at RIS (FPC 2017). Results from this 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%). A permutation test was conducted to determine whether the difference in GBT rates was statistically significant. The observed difference of 10.8% in GBT incidence was extremely unlikely under the null hypothesis ($p < 0.0001$), indicating that “traditional” fish had significantly higher GBT incidence rates than “fresh” fish.

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, GBT rates at RIS should be considered in the context of the sampling protocol at this site. Based on our review of the results from the pilot protocol, the FPC has recommended that every effort should be made to increase the use of “fresh” fish in GBT samples at RIS. FPC will continue to work with SMP personnel at RIS to accomplish this recommendation in future years, to the extent possible.

Historical Summary (1995–2017)

The Gas Bubble Trauma monitoring program has been implemented annually since 1995. 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.

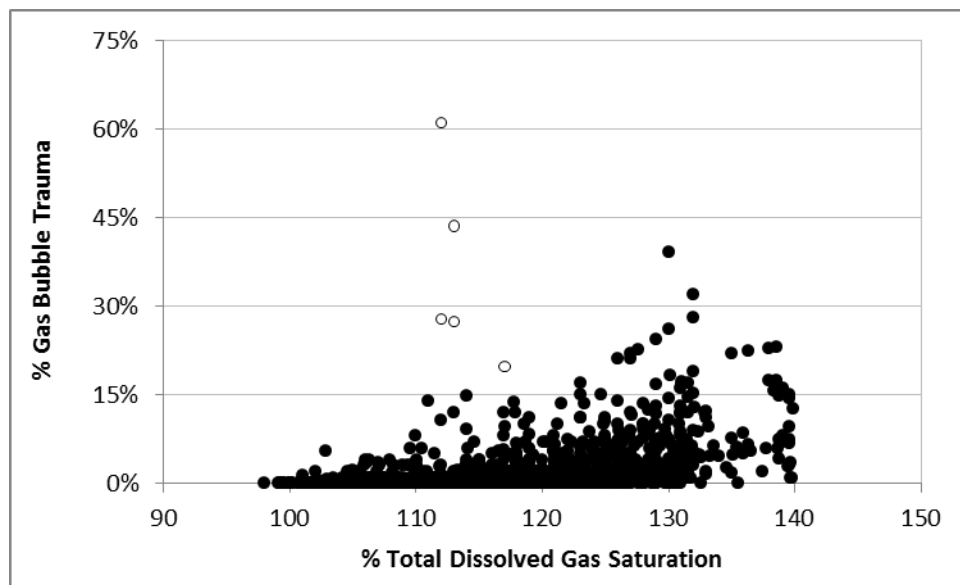
The daily sample size criteria based on the monitoring protocol is 100 fish. In this analysis some flexibility was considered and all daily samples with greater than 75 fish were included. Excluding Rock Island Dam samples, a total of 2,771 daily exams have occurred over the time period, with a total of 316,030 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 (2,771 samples), there have been only 35 instances when the 15% GBT criterion was exceeded. Of those 35 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 Dam 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 2007b). These fish may be considered anomalous, and were likely present due to the very low flow conditions that occurred those years. The other 30 times the biological criteria were exceeded occurred when TDG was greater than 120%. Of these 30 exceedences, 27 (90%) were observed at TDG concentrations greater than 125%. The following graph (Figure J-9) shows the summary of the 2,771 daily exams as a function of TDG.

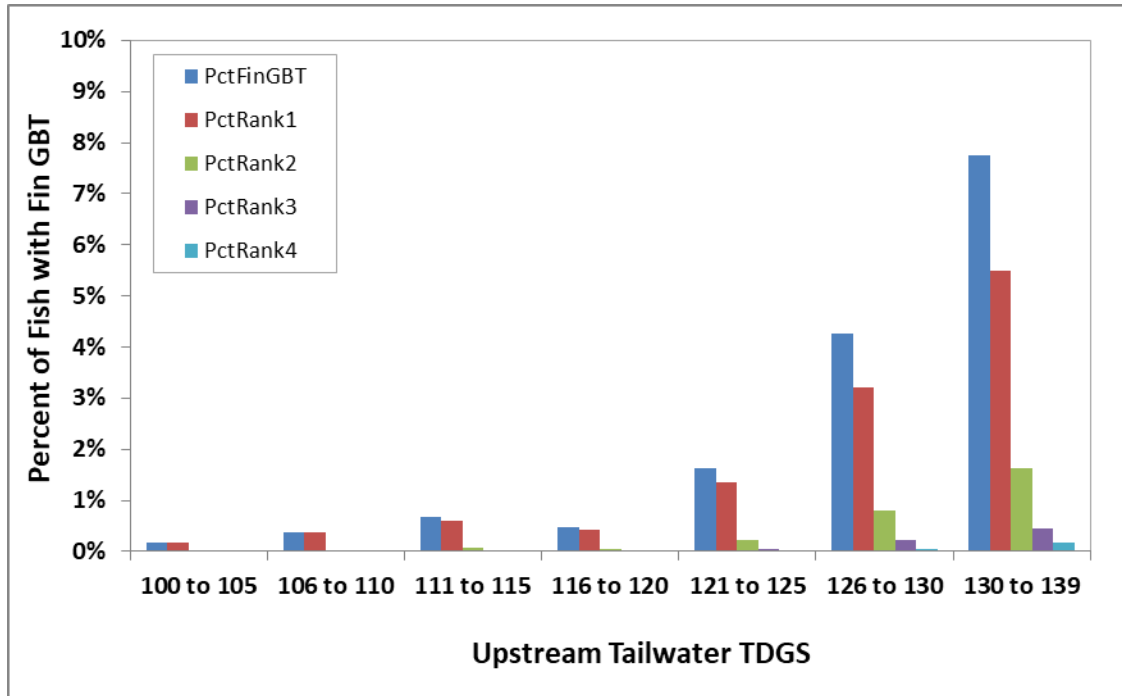
Figure J-9

Percent GBT observed as a function of TDG observed. TDG measured at the tailwater of the upstream project at the Snake River projects and McNary and at John Day Dam tailwater for the Bonneville samples. Open circles indicate observations for late migrating steelhead observed in 2002 and 2007.



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). The following graph 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 1995–2017 showing signs of GBT at given TDG levels.



From Figure J-10 two things are apparent. 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 data collected for TDG levels. The GBT biological monitoring is meant to complement the physical monitoring program. GBT sampling was successfully accomplished for the 2017 migration season. Under the high flow conditions observed in 2017, TDG levels were generally above the 115%/120% waivers for most of the spring period. These high TDG levels were largely due to flows in excess of hydraulic capacity throughout the Columbia River Basin. The generally higher incidence of signs of GBT observed in 2017 reflects the high flow conditions and resulting TDG observations.

The 15% criterion was met only once at the Snake River sites, zero times at the Mid-Columbia River sites, and fifteen times at the Upper Columbia site (Rock Island Dam) in 2017. During all of these occurrences, flows in the Snake and Columbia rivers generally exceeded hydraulic capacities at all projects and voluntary spill could not be curtailed. The criterion of 5% severe GBT was never met in 2017. The highest level of GBT (53.0%) was observed at Rock Island Dam. The highest level observed in the FCRPS was 22.0% at

Lower Monumental Dam on May 10, 2017. Total dissolved gas levels in the Lower Monumental forebay and Little Goose tailrace were both above 125% during this time.

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 tailwater monitors. Most observations indicating potential harm occurred above TDG levels of 125%, as measured at the tailwater TDG monitors.

References

- Fish Passage Center 2007a. Steelhead and GBT at Little Goose and Lower Monumental dams. June 8, 2007 memorandum. <http://www.fpc.org/documents/memos/90-07.pdf>
- Fish Passage Center 2007b. Response to Comments from 6/21/07 Oregon Department of Environmental Quality Meeting, August 24, 2007 memorandum. <http://www.fpc.org/documents/memos/136-07.pdf>
- Fish Passage Center. 2017. Recommendations on Gas Bubble Trauma Monitoring Protocol at Rock Island Dam, October 3, 2017 memorandum. <http://www.fpc.org/documents/memos/45-17.pdf>.
- U.S. Geological Survey (USGS). 1997. Protocol for determining gas bubble trauma in juvenile salmonids. Columbia River Research Laboratory. Cook, Washington
- 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.

Table J-5

Detailed breakdown of GBT exams and signs of fin GBT at Lower Granite Dam in 2017.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
3/30/2017	100	3	3.0%
4/6/2017	103	2	1.9%
4/13/2017	100	1	1.0%
4/20/2017	100	0	0.0%
4/27/2017	100	4	4.0%
5/4/2017	100	2	2.0%
5/11/2017	100	0	0.0%
5/18/2017	100	3	3.0%
5/25/2017	101	3	3.0%
6/1/2017	101	0	0.0%
6/15/2017	100	0	0.0%
6/22/2017	100	0	0.0%
6/29/2017	101	0	0.0%
7/6/2017	101	1	1.0%
7/13/2017	50	0	0.0%
7/20/2017	106	1	0.9%
7/27/2017	33	0	0.0%

Table J-6

Detailed breakdown of GBT exams and signs of fin GBT at Little Goose Dam in 2017.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/7/2017	100	5	5.0%
4/9/2017	100	0	0.0%
4/17/2017	100	0	0.0%
4/23/2017	100	0	0.0%
5/1/2017	100	0	0.0%
5/8/2017	100	0	0.0%
5/15/2017	100	5	5.0%
5/22/2017	100	3	3.0%
5/29/2017	100	0	0.0%
6/5/2017	100	1	1.0%
6/12/2017	100	5	5.0%
6/19/2017	100	1	1.0%
6/26/2017	100	0	0.0%
7/3/2017	77	0	0.0%
7/10/2017	100	0	0.0%
7/17/2017	56	0	0.0%
7/24/2017	100	0	0.0%
8/1/2017	100	0	0.0%
8/8/2017	100	0	0.0%
8/15/2017	100	1	1.0%
8/21/2017	18	0	0.0%

Table J-7
Detailed breakdown of GBT exams and signs of fin GBT at Lower Monumental Dam in 2017.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/6/2017	100	0	0.0%
4/12/2017	100	0	0.0%
4/19/2017	100	1	1.0%
4/27/2017	100	0	0.0%
5/3/2017	100	0	0.0%
5/10/2017	100	22	22.0%
5/17/2017	100	10	10.0%
5/24/2017	100	1	1.0%
5/31/2017	100	1	1.0%
6/7/2017	100	7	7.0%
6/14/2017	100	0	0.0%
6/21/2017	75	2	2.7%
6/28/2017	100	0	0.0%
7/5/2017	100	0	0.0%
7/12/2017	100	0	0.0%
7/19/2017	100	0	0.0%
7/26/2017	100	0	0.0%
8/4/2017	24	0	0.0%

Table J-8
Detailed breakdown of GBT exams and signs of fin GBT at McNary Dam in 2017.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/10/2017	100	2	2.0%
4/14/2017	100	0	0.0%
4/16/2017	100	0	0.0%
4/24/2017	100	0	0.0%
4/26/2017	100	0	0.0%
4/30/2017	100	0	0.0%
5/2/2017	100	0	0.0%
5/8/2017	100	0	0.0%
5/10/2017	100	0	0.0%
5/14/2017	100	1	1.0%
5/16/2017	100	1	1.0%
5/22/2017	100	0	0.0%
5/24/2017	100	0	0.0%
5/30/2017	100	0	0.0%
6/5/2017	100	0	0.0%
6/7/2017	100	0	0.0%
6/11/2017	100	0	0.0%
6/13/2017	100	0	0.0%
6/15/2017	100	0	0.0%
6/21/2017	100	0	0.0%
6/25/2017	100	0	0.0%
6/27/2017	100	0	0.0%
7/3/2017	100	0	0.0%
7/5/2017	100	0	0.0%
7/9/2017	100	0	0.0%
7/11/2017	100	0	0.0%
7/17/2017	100	0	0.0%
7/19/2017	100	0	0.0%
7/23/2017	100	0	0.0%
7/25/2017	100	0	0.0%
7/31/2017	100	0	0.0%
8/2/2017	100	0	0.0%
8/6/2017	100	0	0.0%

Table J-9

Detailed breakdown of GBT exams and signs of fin GBT at Bonneville Dam in 2017.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/8/2017	40	0	0.0%
4/10/2017	41	3	7.3%
4/15/2017	100	1	1.0%
4/18/2017	100	3	3.0%
4/22/2017	100	4	4.0%
4/25/2017	100	6	6.0%
4/29/2017	100	2	2.0%
5/2/2017	100	2	2.0%
5/6/2017	100	2	2.0%
5/10/2017	100	5	5.0%
5/13/2017	100	6	6.0%
5/16/2017	100	1	1.0%
5/20/2017	100	4	4.0%
5/23/2017	100	5	5.0%
5/27/2017	100	3	3.0%
5/30/2017	91	2	2.2%
6/3/2017	100	2	2.0%
6/6/2017	100	7	7.0%
6/10/2017	84	3	3.6%
6/13/2017	100	1	1.0%
6/17/2017	100	0	0.0%
6/20/2017	100	2	2.0%
6/24/2017	100	4	4.0%
6/27/2017	100	2	2.0%
7/1/2017	100	0	0.0%
7/4/2017	100	0	0.0%
7/8/2017	100	1	1.0%
7/11/2017	100	0	0.0%
7/15/2017	100	1	1.0%
7/18/2017	100	0	0.0%
7/22/2017	81	0	0.0%
7/30/2017	100	0	0.0%
8/19/2017	87	0	0.0%

Table J-10
Detailed breakdown of GBT exams and signs of fin GBT at Rock Island Dam in 2017.

Sample Date	Number Examined	Number with Fin GBT	Percent with Fin GBT
4/18/2017	100	31	31.0%
4/20/2017	100	45	45.0%
4/25/2017	100	53	53.0%
4/27/2017	100	41	41.0%
5/2/2017	100	20	20.0%
5/4/2017	100	17	17.0%
5/9/2017	100	20	20.0%
5/11/2017	100	20	20.0%
5/16/2017	100	21	21.0%
5/18/2017	100	30	30.0%
5/23/2017	100	24	24.0%
5/25/2017	100	19	19.0%
5/30/2017	100	14	14.0%
6/1/2017	100	19	19.0%
6/6/2017	100	22	22.0%
6/8/2017	100	31	31.0%
6/15/2017	100	11	11.0%
6/20/2017	100	13	13.0%
6/22/2017	100	2	2.0%
6/27/2017	100	6	6.0%
6/29/2017	100	4	4.0%
7/5/2017	75	5	6.7%
7/6/2017	75	2	2.7%
7/11/2017	100	8	8.0%
7/13/2017	100	14	14.0%
7/17/2017	100	6	6.0%
7/20/2017	100	2	2.0%
7/25/2017	100	3	3.0%
7/27/2017	100	3	3.0%
8/1/2017	100	5	5.0%
8/3/2017	100	2	2.0%
8/8/2017	100	3	3.0%
8/10/2017	100	6	6.0%
8/15/2017	100	3	3.0%
8/17/2017	100	2	2.0%