

# **Appendix H**

## **2021 Fish Passage Summary**



# FISH PASSAGE CENTER

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November 1, 2021

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 2021* to you and Ms. Claire McGrath of NOAA Fisheries. This report summarizes data collected during the 2021 spring and summer spill seasons.

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

Sincerely,

Michele DeHart  
Fish Passage Center Manager

CC: Claire McGrath, NOAA Fisheries  
Julie Ammann, USACE  
Alexis Mills, USACE

# Gas Bubble Trauma Monitoring and Data Reporting for 2021

## Overview

### *Salmonid GBT Monitoring*

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. Data from GBT Monitoring samples are recorded using a data entry program (GBT.net) developed and maintained by the Fish Passage Center (FPC). Data are transmitted to the FPC, within 24-hours of collection, where they are processed into our servers and are made available to the fisheries management entities, water quality agencies of Washington and Oregon, and the public via web queries and reports ([https://www.fpc.org/smolt/Q\\_smolt\\_smoltgbt\\_subsite.php](https://www.fpc.org/smolt/Q_smolt_smoltgbt_subsite.php)). 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 2021 for GBT was conducted at Upper Columbia, Middle Columbia, and Snake River sites, as part of the Smolt Monitoring Program (SMP). 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 because 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 GBT.

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 of 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 2021. Details of this modified protocol and an evaluation of past 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. Table H-1 provides the frequency, duration, and method of collection for the salmonid GBT Monitoring Program, under the current protocol.

**Table H-1**  
**Summary of salmonid GBT Monitoring sampling schedule in spring and summer, 2021**

| <b>Region</b>   | <b>Site</b> | <b>Frequency of Sampling</b> | <b>Duration of Sampling</b> | <b>Method of Collection</b> |
|-----------------|-------------|------------------------------|-----------------------------|-----------------------------|
| Snake           | LGR         | Once per week                | April-June                  | Separator                   |
|                 | LGS         | Once per week                | April-August                | Separator                   |
|                 | LMN         | Once per week                | April-August                | Separator                   |
| Middle Columbia | MCN         | Twice per week               | April-August                | Separator                   |
|                 | BON         | Twice per week               | April-August                | Sample Tank                 |
| Upper Columbia  | RIS         | Twice per week               | April-August                | Sample Tank/Entering Trap   |

At LGR, salmonid GBT monitoring only occurs in the spring. This is done to limit handling of listed subyearling Chinook when TDG levels above the project are generally very low. Sampling at each of the three Snake River sites occurs once per week. Every effort is made to limit overlap in sampling dates between sites. For example, the sampling days at LGR, LGS, and LMN are staggered throughout the week. Sites are encouraged to coordinate sampling schedules to accomplish this staggered schedule. Salmonid GBT sampling at each of the Mid-Columbia and Upper Columbia sites occurs twice per week. Sampling at BON may be temporarily reduced to once per week when Spring Creek NFH releases subyearling fall Chinook tules above the project. This is done to limit handling of these listed fish and is only necessary for 2-3 days post-release.

To standardize handling and reporting practices among sites and to provide accounting for Endangered Species Act permitting purposes, the FPC modified the GBT handling protocol in 2015. Monitoring in 2021 followed the same protocol that was issued in 2015. For more detailed information on the examination procedure, the 2020 GBT Monitoring Protocol is available on the FPC website (FPC 2021).

***Non-Salmonid GBT Monitoring***

In the spring of 2021, there were three separate projects to conduct GBT monitoring on native non-salmonids. This was the first year that GBT monitoring of native non-salmonids occurred under these three projects. The primary effort was conducted by the US Geological Survey (USGS) and involved conducting weekly GBT samples in the tailraces of three FCRPS projects; BON, MCN, and Ice Harbor Dam (IHR) (Table H-2). However, this USGS GBT monitoring program also conducted a single sample below LGS. Collections for the USGS project were conducted using purse seining and backpack electrofishing. As the season progressed, there was concern over the number of salmonids that were being collected in the purse seines, so the primary collection method was backpack electrofishing. Collections for the USGS project were limited to areas in the tailraces of each of the above-mentioned projects.

**Table H-2**  
**Summary of non-salmonid GBT Monitoring sampling schedule in spring 2021**

| <b>Region</b>   | <b>Agency</b> | <b>Site (Tailrace)</b> | <b>Frequency of Sampling</b> | <b>Method(s) of Collection</b> |
|-----------------|---------------|------------------------|------------------------------|--------------------------------|
| Snake           | USGS          | LGS                    | Single Sample                | Electrofishing                 |
|                 | USGS          | IHR                    | Once per week                | Electrofishing/Seine           |
| Middle Columbia | USGS          | MCN                    | Once per week                | Electrofishing/Seine           |
|                 | USGS          | BON                    | Once per week                | Electrofishing/Seine           |
|                 | PSMFC/ODFW    | BON                    | Occasional                   | Boat Electrofishing            |
|                 | PSMFC/WDFW    | JDA                    | Occasional                   | Dam Angling                    |

The other two efforts for monitoring GBT in native non-salmonids were feasibility studies conducted by the Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), and Pacific States Marine Fisheries Commission (PSMFC; Table H-2). One involved utilizing crews from the ODFW Pikeminnow Project to collect non-salmonids for GBT samples during boat electrofishing efforts below BON while the other feasibility study involved utilizing crews from the WDFW Dam Angling Project to collect non-salmonids for GBT samples. The dam angling effort was intended to occur in the tailraces of BON and John Day Dam (JDA), and possibly The Dalles Dam (TDA). However, there was little success collecting fish below BON, via angling, so no GBT samples were conducted there and no GBT samples were collected below TDA in 2021. For both feasibility studies, PSMFC personnel from the SMP conducted the actual GBT exams.

The GBT.net data entry program was modified to allow for the collection of GBT data on non-salmonids and to incorporate the new non-salmonid monitoring sites. GBT data for salmonids and non-salmonids were submitted to the FPC in the same XML file format but stored in the separate databases.

### ***Examination and Ranking Procedure***

Prior to the start of the season, FPC staff conducted GBT training for both the salmonid and non-salmonid GBT monitoring crews. Non-salmonid monitoring crews were instructed to follow the same examination protocol and GBT ranking system as the salmonid GBT monitoring program. Detailed instructions for non-salmonid GBT monitoring personnel were included in the 2021 GBT Sampling Protocol (FPC 2021).

Examinations for GBT were conducted using variable magnification (6x to 40x) dissecting microscopes. 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 H-3). Additional information was recorded for each fish during the examination, including species, age, fork length, fin clips, and tags present.

**Table H-3**  
**Ranking criteria used in monitoring for signs of gas bubble trauma.**

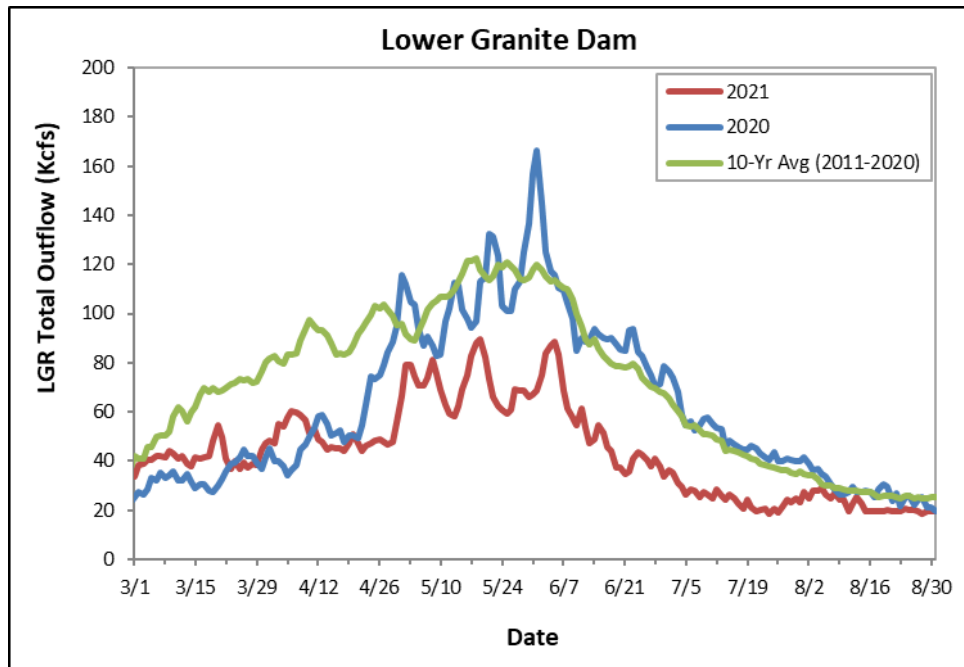
| <b>Rank</b> | <b>Sign</b>  |
|-------------|--|
| 0           | no bubbles present                                   |
| 1           | up to 5% of a fin area or eye covered with bubbles   |
| 2           | 6% to 25% of a fin area or eye covered with bubbles  |
| 3           | 26% to 50% of a fin area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

## **2021 Water Conditions and Spill Operations**

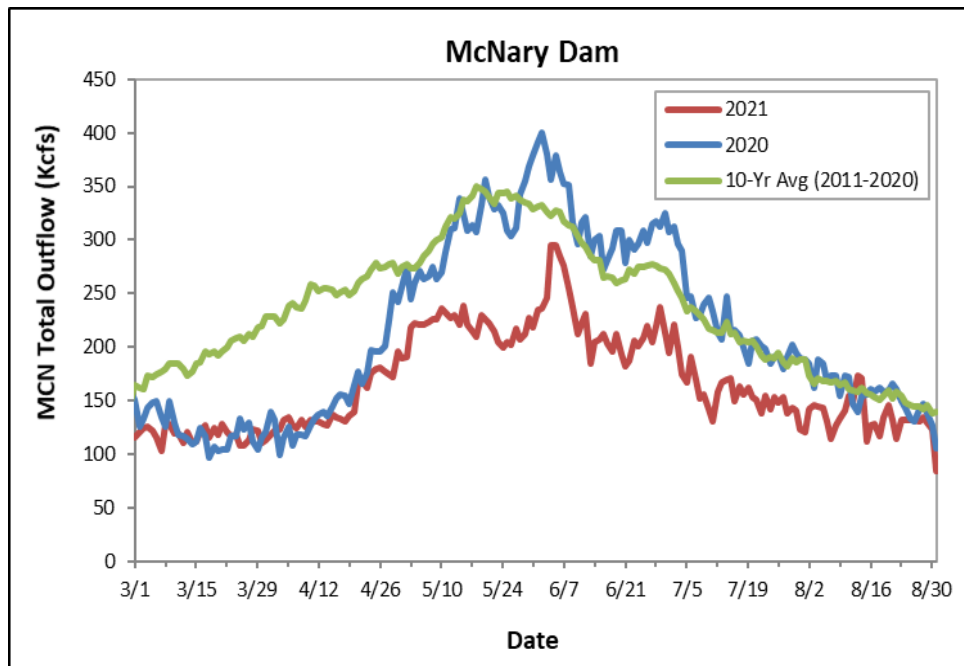
The runoff volume (January–July) for the 2021 water year was below average in the Middle Columbia and Snake Rivers. Runoff (January–July) was 81% of average (1981–2010) at The Dalles Dam and 67% of average at Lower Granite Dam. To put the runoff volumes into perspective, the 2021 January–July runoff volumes at The Dalles and Lower Granite were ranked 77<sup>th</sup> and 82<sup>nd</sup>, respectively, over the last 93 years (1929–2021).

In 2021, runoff in the Snake River followed a more typical shape, with peak flows in May and early June (Figure H-1). However, due to the low runoff volume, flows in March through July were well below average and only close to average in August. There were three distinct spikes in flows throughout the month of May and into early June (May 3-9, May 17<sup>th</sup>, and June 6<sup>th</sup>; Figure H-1). Daily average flows at Lower Granite Dam peaked on May 19<sup>th</sup>, at approximately 90 Kcfs. Given the 125% tailrace TDG standard that was implemented during the spring spill season, flows in the Lower Snake River were not sufficiently high to spill to the 125% TDG spill caps. Instead, spill during gas cap periods was limited to all flows above powerhouse minimum requirements (i.e., “minimum generation, spill the rest”). Furthermore, there were no instances of spill above the 125% TDG spill caps (i.e., uncontrolled spill). Soon after the third peak on June 6<sup>th</sup>, flows at Lower Granite Dam began to decrease rapidly through the rest of June and much of July.

**Figure H-1.**  
Average daily flows at Lower Granite Dam in 2021, 2020, and the 10-year average



**Figure H-2**  
Average daily flows at McNary Dam in 2021, 2020, and the 10-year average



Runoff in the Middle Columbia was also more typical in shape. However, like the Snake River, flows in March through July were below average and only close to average

by early to mid-August (Figure H-2). Flows at McNary Dam peaked on June 5<sup>th</sup>, at approximately 295 Kcfs. Given the 125% tailrace TDG standard that was implemented during the spring, flows in 2021 were not sufficiently high to spill to the 125% TDG spill caps. Furthermore, there were no instances of spill above the 125% TDG spill caps (i.e., uncontrolled spill). After peaking on June 5<sup>th</sup>, flows at McNary Dam began to decrease (Figure H-2).

On March 31, 2021, the 2021 Fish Operations Plan (FOP) was issued. The 2021 FOP described the U.S. Army Corps of Engineers' (Corps) planned operations for juvenile fish passage at the four Lower Snake River and four Mid-Columbia River dams for the spring and summer fish migration seasons. Like the previous two years, the 2021 FOP called for "Flex Spill" operations at most of the FCRPS projects during the spring spill season. At most projects, the "Flex Spill" operation in 2021 consisted of spill to the estimated 125% tailrace total dissolved gas (TDG) spill caps for sixteen hours per day and "performance standard" spill for the remaining eight hours per day (Table H-4). The three exceptions to this were John Day, The Dalles, and Bonneville dams. The spring spill operation at John Day Dam was to spill to a "Max FOP" spill volume for sixteen hours per day and performance standard spill (32% of instantaneous flows) for eight hours per day. The "Max FOP" spill volume at John Day was the estimated daily 120% tailrace TDG spill cap. The spring spill operation at The Dalles Dam was to spill 40% of instantaneous flows, 24-hours per day. Finally, at Bonneville Dam, spring spill was to a "Max FOP" spill volume of 150 Kcfs for sixteen hours per day and performance standard spill (100 Kcfs) for eight hours per day. At all projects with a "Flex Spill" operation, the eight hours of "performance standard" spill would occur in up to two blocks per calendar day, an AM block and a PM block.

For the spring spill season, the COE estimated the 125% tailrace TDG and/or "Max FOP" spill caps for each FCRPS project, on a daily basis. Where applicable, projects were operated to these estimated 125% tailrace TDG and/or "Max FOP" spill caps for the 16-hours of gas cap or "Max FOP" spill. The daily 125% tailrace TDG and "Max FOP" spill caps were published on the TMT website (<http://pweb.crohms.org/tmt/documents/ops/spill/caps/>).

There was no "Flex Spill" in the summer spill season, as all spill operations were 24-hours per day. However, under the 2021 FOP, summer spill operations were broken into two periods. The first period consisted of a single spill operation from the beginning of the summer spill season (June 16<sup>th</sup> in the Mid-Columbia River and June 21<sup>st</sup> in the Snake River) to August 14<sup>th</sup>. The second period consisted of a different spill operation from August 15<sup>th</sup> through August 31<sup>st</sup> (Table H-4). It is worth noting that the summer spill operations at Lower Granite and Little Goose were modified under a System Operational Request ([SOR 2021-3](#)). These modifications consisted of reducing spill to spillway weirs only (or equivalent volume, 7-8 Kcfs) from 0900-2300 hours and returning to FOP spill levels for the other hours. These modifications were implemented from July 3<sup>rd</sup> through July 26<sup>th</sup>. These modifications were made to address extreme low flows and high temperatures in the river.

**Table H-4**

**2021 spring and summer spill operations at Snake and Mid-Columbia FCRPS projects under the 2021 Fish Operations Plan.**

| Project | Spring "Flex Spill"<br>(Snake: Apr. 3-June 20)<br>(Mid-Columbia: Apr. 10-June 15) |                                     | Summer Spill<br>(Snake: June 21-Aug. 31)<br>(Mid-Columbia: June 15-Aug. 31) |                 |
|---------|---|-------------------------------------|---|-----------------|
|         | Gas Cap Spill<br>(16 hrs/day)   | Perf. Standard Spill<br>(8 hrs/day) | Prior to Aug. 15  | Aug. 15-Aug 31  |
| LGR     | 120% Gas Cap  | 20 Kcfs                             | 18 Kcfs   | SW of ~7 Kcfs   |
| LGS     | 120% Gas Cap  | 30%                                 | 30%   | SW of ~7 Kcfs   |
| LMN     | 120% Gas Cap  | 30 Kcfs (bulk pattern)              | 17 Kcfs   | SW of ~7 Kcfs   |
| IHR     | 120% Gas Cap  | 30%                                 | 30%   | SW of ~8.5 Kcfs |
| MCN     | 120% Gas Cap  | 48%                                 | 57%   | 20 Kcfs         |
| JDA     | 120% Gas Cap  | 32%                                 | 35%   | 20 Kcfs         |
| TDA     | 120% Gas Cap  | 40%                                 | 40%   | 30%             |
| BON     | 120% Gas Cap  | 100 Kcfs                            | 95 Kcfs   | 50 Kcfs         |

In 2020, the states of Oregon and Washington modified their TDG water quality standards for FCRPS projects in the Snake and Mid-Columbia rivers. For the spring spill season, TDG was managed to a 125% tailrace TDG standard where the 12-hour average TDG could not exceed 125%. In addition, the state of Oregon had a 2-hour average TDG standard of 127% while Washington had a 2-hour standard of 126% TDG. As part of their new 125% tailrace TDG standard, the Washington Department of Ecology (DOE) and Oregon Department of Environmental Quality (DEQ) specified that a minimum sample size requirement of 50 salmonids and 50 non-salmonids must be examined for GBT Monitoring, per week, per zone (i.e., Snake Zone vs. Mid-Columbia River Zone). In addition, Washington adopted the methodology of calculating the 12-hour average TDG based on the 12 highest hourly TDG measurements in a single calendar day (not necessarily consecutive). This methodology for estimating the 12-hour average TDG was applied in both the spring and summer spill seasons. Finally, when summer spill began in June, the State of Washington's 115% forebay TDG requirement was reinstated and the tailrace TDG standard was reduced to 120% for both states.

As mentioned above, the 125% tailrace TDG standard applied to FCRPS projects only. Therefore, the TDG water quality standard in the Upper Columbia River was 120% in the tailrace and 115% in the downstream forebay. This standard applied to both the spring and summer spill seasons in the Upper Columbia River.

## Results

In all, 11,016 juvenile salmonids were examined for GBT between April and August of 2021, as part of the Smolt Monitoring Program (Table H-5). Of these 11,016 salmonids that were examined in 2021, 44.8% were yearling Chinook, 32.8% were subyearling Chinook, and 22.4% were steelhead.

**Table H-5**

**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 2021 as part of the Smolt Monitoring Program.**

| <b>Species</b>       | <b>BON</b>   | <b>MCN</b>   | <b>LMN</b>   | <b>LGS</b>   | <b>LGR</b> | <b>RIS</b>   | <b>Total</b>  |
|----------------------|--------------|--------------|--------------|--------------|------------|--------------|---------------|
| Chinook Subyearlings | 1,264        | 1,144        | 534          | 576          | 0          | 1,417        | 4,935         |
| Chinook Yearlings    | 1,036        | 929          | 258          | 276          | 218        | 893          | 3,610         |
| Steelhead            | 323          | 604          | 359          | 389          | 277        | 519          | 2,471         |
| <b>Total</b>         | <b>2,623</b> | <b>2,677</b> | <b>1,151</b> | <b>1,241</b> | <b>495</b> | <b>2,829</b> | <b>11,016</b> |

A total of 3,324 non-salmonids were examined for GBT between April and June of 2021 (Table H-6). These non-salmonids represented 14 different species. The most common non-salmonid species collected and examined were sculpin and northern pikeminnow, which represented approximately 52% and 31% of the total non-salmonids examined in 2021, respectively. The third most common species was the three-spined stickleback, which represented approximately 11% of the non-salmonids examined.

**Table H-6**

**Number of non-salmonids collected and examined for signs of GBT by non-salmonid GBT monitoring crews in the Lower Snake and Mid-Columbia rivers during the 2021 spring spill season.**

| <b>Species</b>           | <b>JDA</b> | <b>BON (ODFW)</b> | <b>BON (USGS)</b> | <b>IHR</b>   | <b>MCN</b> | <b>LGS</b> | <b>Total</b> |
|--------------------------|------------|-------------------|-------------------|--------------|------------|------------|--------------|
| Pac. Lamprey Ammocoete   | 0          | 0                 | 1                 | 1            | 0          | 0          | <b>2</b>     |
| Smallmouth Bass*         | 0          | 0                 | 0                 | 0            | 0          | 29         | <b>29</b>    |
| Longnose Dace            | 0          | 0                 | 4                 | 0            | 0          | 0          | <b>4</b>     |
| Largescale Sucker        | 0          | 45                | 4                 | 1            | 0          | 0          | <b>50</b>    |
| Mountain Whitefish       | 0          | 3                 | 1                 | 72           | 1          | 0          | <b>77</b>    |
| Starry Flounder          | 0          | 0                 | 1                 | 0            | 0          | 0          | <b>1</b>     |
| Peamouth                 | 0          | 8                 | 1                 | 0            | 0          | 0          | <b>9</b>     |
| Redside Shiner           | 0          | 0                 | 0                 | 0            | 2          | 0          | <b>2</b>     |
| Sculpin                  | 1          | 1                 | 573               | 528          | 597        | 20         | <b>1,720</b> |
| Speckled Dace            | 0          | 0                 | 2                 | 0            | 20         | 0          | <b>22</b>    |
| White Sturgeon           | 1          | 0                 | 0                 | 0            | 0          | 0          | <b>1</b>     |
| Three-spined Stickleback | 0          | 1                 | 303               | 0            | 56         | 0          | <b>360</b>   |
| Northern Pikeminnow      | 21         | 1                 | 116               | 675          | 216        | 0          | <b>1,029</b> |
| Sucker Sp.               | 0          | 4                 | 6                 | 1            | 7          | 0          | <b>18</b>    |
| <b>Total</b>             | <b>23</b>  | <b>63</b>         | <b>1,012</b>      | <b>1,278</b> | <b>899</b> | <b>49</b>  | <b>3,324</b> |

\* indicates non-native species

Although the primary objective of the non-salmonid GBT monitoring program was to collect and examine native non-salmonids for GBT, some juvenile salmonids were also collected and examined in a few of the USGS samples. In all, 108 subyearling Chinook

were collected and examined by the USGS crew over the spring spill season, all of which were collected below Bonneville Dam.

Among the 11,016 salmonids that were examined by SMP crews at FCRPS projects in 2021, signs of fin GBT were observed in 164 individuals (1.5%), with 81 of those occurring at Rock Island Dam (Table H-7). Of the 164 salmonids that had signs of fin GBT in 2021, 155 (94.5%) had a maximum fin ranking of 1, where less than 5% of a fin area was occluded with bubbles. Seven total salmonids (4.3%) had a maximum fin ranking of 2, where 6-25% of the fin area was occluded with bubbles. Finally, two salmonids (1.2%) had a maximum fin ranking of 3, where 26-50% of the fin area was occluded with bubbles. Severe GBT is considered anything where  $\geq 26\%$  of a fin area occluded with bubbles. Therefore, only two salmonids examined in 2021 exhibited severe signs of GBT. A more detailed breakdown of GBT exams and signs for 2021 can be found in Tables H-9 through H-18.

**Table H-7**  
**Number of juvenile salmonids found with fin GBT at dams on the Lower Snake River and on the Columbia River from April to August 2021 as part of the Smolt Monitoring Program.**

| Species              | Fin GBT by Site |     |     |     |     |     | Grand Total |
|----------------------|-----------------|-----|-----|-----|-----|-----|-------------|
|                      | BON             | MCN | LMN | LGS | LGR | RIS |             |
| Chinook Subyearlings | 7               | 0   | 22  | 25  | 0   | 31  | 85          |
| Chinook Yearlings    | 2               | 0   | 4   | 5   | 0   | 43  | 54          |
| Steelhead            | 1               | 4   | 7   | 5   | 1   | 7   | 25          |
| Total                | 10              | 4   | 33  | 35  | 1   | 81  | 164         |

Of the 3,324 total non-salmonids that were examined for GBT in 2021, 35 (1.05%) had signs of fin GBT (Table H-8). Of these, 30 had Rank 1 signs of fin GBT, three had Rank 2 signs, and two had Rank 4 signs. In addition to the signs of fin GBT that were observed, several fish were observed with signs of GBT in non-protocol areas (i.e., somewhere other than the unpaired fins). Details of these non-protocol signs are covered in the site-specific summaries below. Finally, of the 108 total subyearling Chinook that were examined for GBT by the USGS crew, zero had signs of fin GBT.

**Table H-8**  
**Number of non-salmonids found with fin GBT in the Lower Snake and Mid-Columbia rivers**  
**during the 2021 spring spill season.**

| <b>Species</b>           | <b>JDA</b> | <b>BON<br/>(ODFW)</b> | <b>BON<br/>(USGS)</b> | <b>IHR</b> | <b>MCN</b> | <b>LGS</b> | <b>Total</b> |
|--------------------------|------------|-----------------------|-----------------------|------------|------------|------------|--------------|
| Pac. Lamprey Ammocoete   | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Smallmouth Bass*         | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Longnose Dace            | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Largescale Sucker        | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Mountain Whitefish       | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Starry Flounder          | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Peamouth                 | 0          | 2                     | 0                     | 0          | 0          | 0          | 2            |
| Redside Shiner           | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Sculpin                  | 0          | 0                     | 0                     | 6          | 24         | 0          | 30           |
| Speckled Dace            | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| White Sturgeon           | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Three-spined Stickleback | 0          | 1                     | 1                     | 0          | 0          | 0          | 2            |
| Northern Pikeminnow      | 0          | 0                     | 0                     | 0          | 0          | 0          | 0            |
| Sucker Sp.               | 0          | 1                     | 0                     | 0          | 0          | 0          | 1            |
| <b>Total</b>             | <b>0</b>   | <b>4</b>              | <b>1</b>              | <b>6</b>   | <b>24</b>  | <b>0</b>   | <b>35</b>    |

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  $\geq 26\%$  of an unpaired fin is covered with bubbles (i.e., Rank 3 or 4). Voluntary spill may be reduced, if possible, when one or both action criteria are met. These action criteria were developed based on lab studies on salmonids 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](#)). To our knowledge, similar lab studies have not been conducted on non-salmonid species. However, the same action criteria apply to the non-salmonid species. The 15% criterion was never met in 2021. The criterion of 5% severe GBT was also never met in 2021.

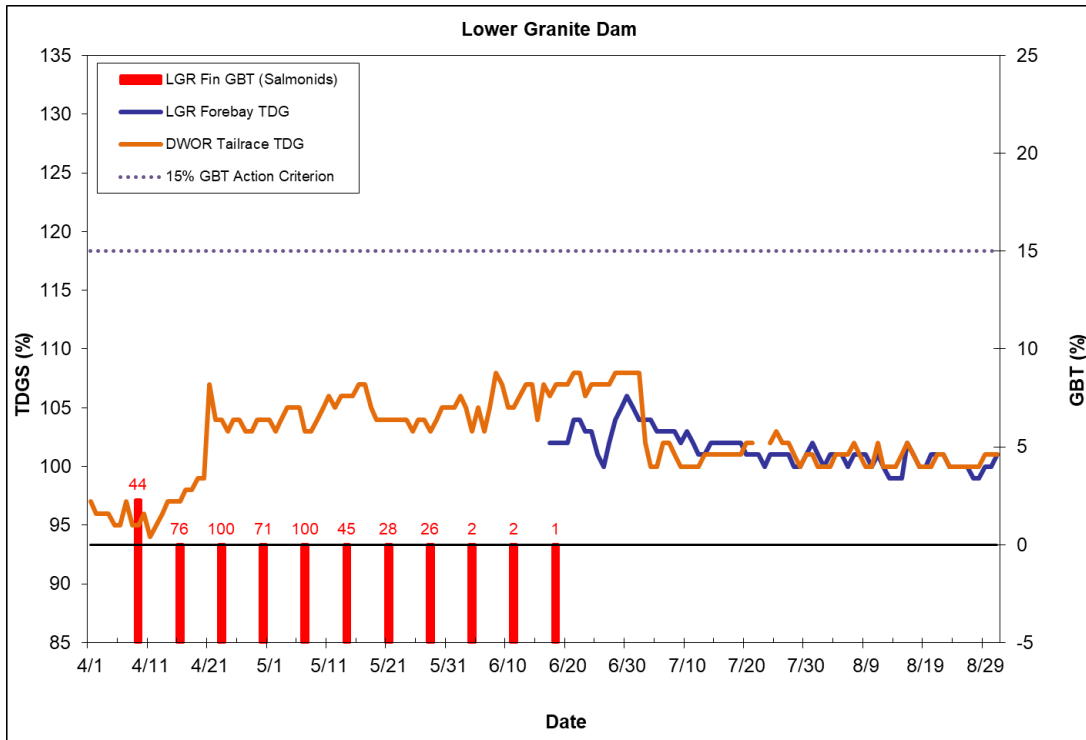
As mentioned above, the salmonid GBT monitoring program has a target sample size of 100 salmonids per GBT sample. The non-salmonid GBT monitoring program adopted this target sample size. The Washington Department of Ecology (DOE) and Oregon Department of Environmental Quality (DEQ) 125% tailrace TDG standards have a minimum sample size requirement of 50 fish per week, per zone (i.e., Snake River vs. Mid-Columbia). For this report, we summarize sample sizes in three ways. First, we evaluated whether the sample target of 100 fish per sample was met. Second, we evaluate whether a target of 50 fish per sample was met. Finally, we evaluate whether the minimum sample

size requirement of 50 fish per week, per zone, was met. For this third method, we considered a week as Sunday-Saturday.

**Lower Granite Dam (LGR)**

Salmonid GBT sampling at LGR is usually used to provide a background level of GBT for migrating juvenile salmonids that are first entering the hydrosystem. GBT sampling at LGR began on April 9<sup>th</sup> and ran through June 18<sup>th</sup>. The last several samples (June 4<sup>th</sup>, June 11<sup>th</sup>, and June 18<sup>th</sup>) at LGR had very low sample sizes. This was because of decreased passage of yearling Chinook and steelhead by June and the fact that LGR does not examine subyearling Chinook for GBT. This is done to minimize handling of these listed species. Non-salmonid GBT monitoring did not occur at LGR in 2021.

**Figure H-3**  
**Percent GBT observed in the salmonid (red bars) samples at Lower Granite Dam and 12-hour average TDG at the Dworshak tailrace (orange lines) and Lower Granite forebay (blue line) in 2021.**



Notes: 1) the y-axis for GBT incidence rate starts at -5% in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line) and 2) red numbers over the bars indicate the total salmonids examined for GBT.

The 12-hour average TDG in the Dworshak Dam (DWR) tailrace never exceeded the 110% Environmental Protection Agency (EPA) standard in the spring of 2021 (Figure H-3). It should be noted that the TDG monitor in the LGR forebay was not installed until June 18<sup>th</sup>. Therefore, TDG measurements for the LGR forebay are unavailable prior to this date. For the period of June 18<sup>th</sup> through August 31<sup>st</sup>, the 12-hour average TDG in the

LGR forebay never exceeded 115%. In fact, the maximum 12-hour average over this period was 106% (Figure H-3).

Eleven total salmonid GBT samples were conducted at LGR in 2021, from April 8<sup>th</sup> to June 18<sup>th</sup>. Among these eleven GBT samples, 495 target salmonids were examined, and one fish had signs of fin GBT (Figure H-3, Table H-9). The signs observed in this single fish were Rank 1. This single fish with fin GBT was observed in the first sample of the season (April 9<sup>th</sup>). Because only 44 total fish were examined in this sample, this single fish equated to a GBT incidence rate of 2.3%. No signs of severe GBT were observed at LGR in spring of 2021.

The target sample size of 100 salmonids examined per GBT sample was met in only two samples (April 23<sup>rd</sup> and May 7<sup>th</sup>). The target sample size of 50 fish per GBT sample was met in four total samples (April 16<sup>th</sup>, April 23<sup>rd</sup>, April 30<sup>th</sup>, and May 7<sup>th</sup>). Finally, when considered collectively with LGS and LMN, the DOE and DEQ minimum sample size requirement of 50 salmonids per week, per zone, was met in the Snake River Zone all spring spill season.

**Table H-9**

**Detailed breakdown of salmonid GBT exams and signs of fin GBT at Lower Granite Dam in 2021.**

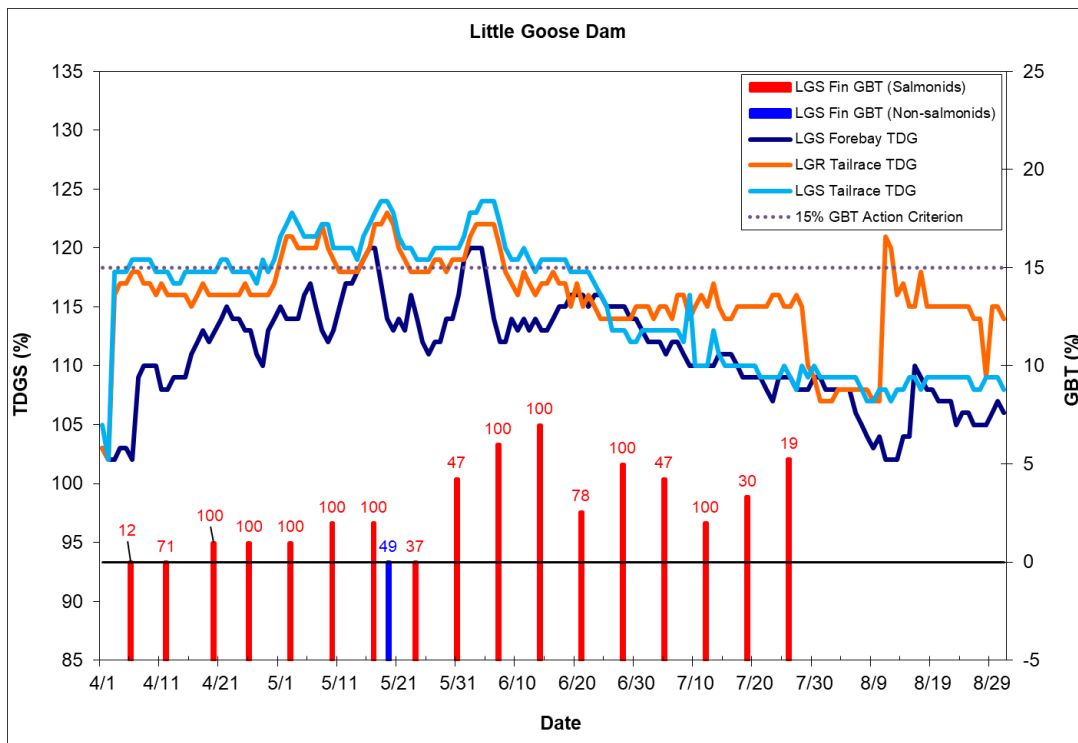
| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT |
|-------------|-----------------|---------------------|----------------------|
| 4/9/2021    | 44              | 1                   | 2.3%                 |
| 4/16/2021   | 76              | 0                   | 0.0%                 |
| 4/23/2021   | 100             | 0                   | 0.0%                 |
| 4/30/2021   | 71              | 0                   | 0.0%                 |
| 5/7/2021    | 100             | 0                   | 0.0%                 |
| 5/14/2021   | 45              | 0                   | 0.0%                 |
| 5/21/2021   | 28              | 0                   | 0.0%                 |
| 5/28/2021   | 26              | 0                   | 0.0%                 |
| 6/4/2021    | 2               | 0                   | 0.0%                 |
| 6/11/2021   | 2               | 0                   | 0.0%                 |
| 6/18/2021   | 1               | 0                   | 0.0%                 |

***Little Goose Dam (LGS)***

Gas Bubble Trauma monitoring for salmonids at LGS occurred from April 6<sup>th</sup> to July 26<sup>th</sup>. Salmonid sampling at LGS was terminated after the sample on July 26<sup>th</sup> 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 never exceeded the 125% tailrace standard (Figure H-4). In fact, the maximum 12-hour average TDG in the LGR tailrace was 123%, which occurred on May 19<sup>th</sup>. Total dissolved gas levels in the LGS tailrace never exceeded the 125% standard. The maximum 12-hour TDG in the LGS tailrace was 124%, which occurred several times throughout mid-May and early June (Figure H-4).

During the summer spill period (June 21-August 31), TDG levels in the LGR tailrace exceeded the 120% tailrace TDG standard on one day (August 11<sup>th</sup>). This single exceedance coincided with planned Doble testing at LGR where all flows above station service (~5 Kcfs) were spilled for most of the day. In addition, the 115% forebay standard was exceeded for three days in the beginning of the summer spill season. These exceedances of the forebay standard were likely due to TDG from the last few days of the spring “flex spill” operation at LGR. The 12-hour average TDG in the LGS forebay was at or below 115% by June 25<sup>th</sup>, where it remained for the rest of the summer spill season.

**Figure H-4**  
**Percent GBT observed in the salmonid (red bars) and non-salmonid (blue bars) samples at Little Goose Dam and 12-hour average TDG at the Lower Granite tailrace (orange line), Little Goose forebay (dark blue line), and Little Goose tailrace (light blue line) in 2021.**



Notes: 1) the y-axis for GBT incidence rate starts at -5% in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line) and 2) red and blue numbers over the bars indicate the total salmonids (red) and non-salmonids (blue) examined for GBT.

Seventeen total salmonid GBT samples were conducted at LGS in 2021. Among the 17 GBT samples at LGS, 1,241 total salmonids were examined for GBT and 14 GBT samples had at least one salmonid exhibiting signs of fin GBT (Figure H-4, Table H-10). All signs of fin GBT observed at LGS in 2021 were Rank 1 signs. The highest GBT incidence rate at LGS in 2021 occurred on June 14<sup>th</sup>, where 7.0% of the examined salmonids exhibited signs of fin GBT. The 12-hour average TDG in the LGR tailrace had been in the 116-120% range over the entire week preceding this sample. Among the remaining 13

GBT samples where signs of fin GBT were present, GBT incidence rates ranged from 1.0% to 6.0% and zero samples had signs of severe GBT.

The target sample size of 100 salmonids examined per GBT sample was met in only nine of the 17 total samples at LGS. The DEQ and DOE minimum sample size requirement of 50 salmonids per week was met in all but six samples. The six samples that did not meet these minimum sample size requirements were the first sample (April 6<sup>th</sup>), the samples on May 24<sup>th</sup>, May 31<sup>st</sup>, and July 5<sup>th</sup>, and the last two samples (July 19<sup>th</sup> and 26<sup>th</sup>; Table H-10). Finally, when considered collectively with LGR and LMN, the DOE and DEQ minimum sample size requirement of 50 salmonids per week, per zone, was met in the Snake River Zone all spring spill season. There was one week in the summer (July 25-July 31) when the minimum sample size of 50 salmonids per week was not met in the Snake River Zone. This was the last week when salmonid GBT sampling occurred in the Snake River Zone, as sampling was terminated due to low sample sizes, high temperatures, and generally low TDG at this time.

**Table H-10**  
Detailed breakdown of salmonid GBT exams and signs of fin GBT at Little Goose Dam in 2021.

| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT |
|-------------|-----------------|---------------------|----------------------|
| 4/6/2021    | 12              | 0                   | 0.0%                 |
| 4/12/2021   | 71              | 0                   | 0.0%                 |
| 4/20/2021   | 100             | 1                   | 1.0%                 |
| 4/26/2021   | 100             | 1                   | 1.0%                 |
| 5/3/2021    | 100             | 1                   | 1.0%                 |
| 5/10/2021   | 100             | 2                   | 2.0%                 |
| 5/17/2021   | 100             | 2                   | 2.0%                 |
| 5/24/2021   | 37              | 0                   | 0.0%                 |
| 5/31/2021   | 47              | 2                   | 4.3%                 |
| 6/7/2021    | 100             | 6                   | 6.0%                 |
| 6/14/2021   | 100             | 7                   | 7.0%                 |
| 6/21/2021   | 78              | 2                   | 2.6%                 |
| 6/28/2021   | 100             | 5                   | 5.0%                 |
| 7/5/2021    | 47              | 2                   | 4.3%                 |
| 7/12/2021   | 100             | 2                   | 2.0%                 |
| 7/19/2021   | 30              | 1                   | 3.3%                 |
| 7/26/2021   | 19              | 1                   | 5.3%                 |

Although LGS was not originally planned for non-salmonid GBT monitoring, one non-salmonid GBT sample was conducted in the LGS tailrace on May 19<sup>th</sup>. This non-salmonid sample was conducted by USGS personnel, at the request of the Corps of Engineers and Bonneville Power Administration. A total of 49 non-salmonids were examined in this single GBT sample and zero signs of fin GBT were observed (Figure H-4). Among the species present were small mouth bass (29 total) and sculpin (20 total). It should be noted that small mouth bass are non-native species and the non-salmonid GBT monitoring program was originally intended to only examine native non-salmonids. No

bubbles were observed in non-protocol locations (i.e., areas other than non-paired fins). Finally, all non-salmonids collected in this single sample were collected through backpack electrofishing.

### ***Lower Monumental Dam (LMN)***

Only salmonid GBT monitoring occurred at LMN in 2021. GBT sampling at LMN occurred from April 8<sup>th</sup> to July 29<sup>th</sup>. Sampling was terminated after the sample on July 29<sup>th</sup> due to increased temperatures, decreased TDG levels in the Snake River, and decreasing numbers of fish in the sample that precluded the ability to meet sample size requirements. Total dissolved gas levels in the LGS tailrace never met or exceeded the 125% standard in 2021 (Figure H-5). In fact, the maximum 12-hour average TDG level in the LGS tailrace was 124%, which occurred on a few occasions from mid-May through early June. During the summer spill period (June 21-August 31), TDG levels in the LGS tailrace never exceeded the 120% tailrace TDG standard. However, the 115% forebay standard was exceeded for the first 10 days of the summer spill season. Many of these exceedances were likely due to the generally slow water transit times and TDG from the spring “flex spill” operations at LGS.

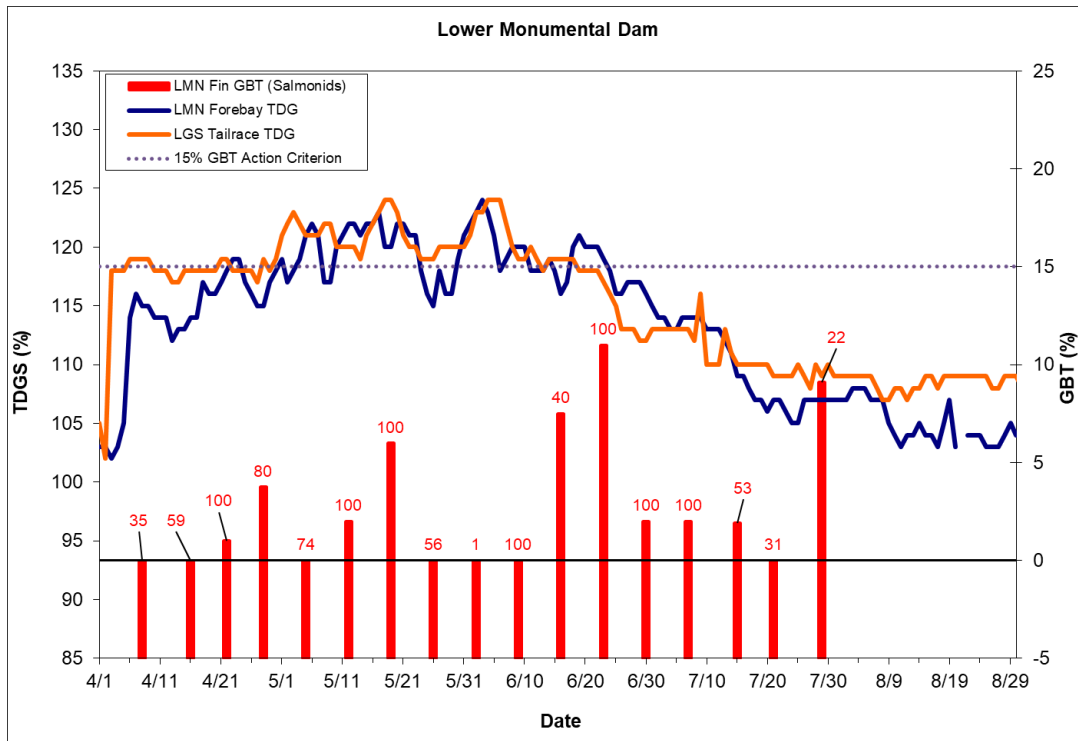
In all, 17 total GBT samples were conducted at LMN in 2021. Of these 17 GBT samples at LMN, 1,151 total salmonids were examined for GBT and 10 GBT samples had at least one salmonid exhibiting signs of fin GBT (Figure H-5, Table H-11). The highest GBT incidence rate in 2021 at LMN was 11.0%, which occurred on June 23<sup>rd</sup>. Total dissolved gas in the LGS tailrace had been in the 118-119% range over the week preceding this June 23 GBT sample, while TDG in the LMN forebay was in the 116-121% range (Figure H-5). Among the remaining nine GBT samples where signs of fin GBT were present, GBT incidence rates ranged from 1.0% to 9.1%. It should be noted that many of the higher GBT incidence rates observed in these nine samples had low sample sizes that did not meet the minimum sample size requirement of 50 fish per exam (Table H-11). No signs of severe GBT were observed at LMN in 2021. In fact, all 33 salmonids that exhibited signs of fin GBT at LMN in 2021 had Rank 1 signs.

The target sample size of 100 salmonids examined per GBT sample was met in only seven of the 17 total GBT samples at LMN (Table H-11). The 10 samples that did not meet this target sample size were the first two samples in April (April 8<sup>th</sup> and 16<sup>th</sup>), the samples on April 28<sup>th</sup> and May 5<sup>th</sup>, the samples on May 26<sup>th</sup> and June 2<sup>nd</sup>, the sample on June 16<sup>th</sup>, and the last three samples (July 15<sup>th</sup>, 21<sup>st</sup>, and 29<sup>th</sup>). The DOE and DEQ minimum sample size requirement of 50 salmonids per week was met in all but five samples in 2021. The five samples that did not meet this requirement were the first sample (April 8<sup>th</sup> with 35 total examined), the sample on June 5<sup>th</sup> (with only 1 salmonid examined), the sample on June 19<sup>th</sup> (with 40 salmonids examined), and the last two samples (July 24<sup>th</sup> with 31 examined and July 29<sup>th</sup> with 22 examined; Table H-11). Finally, when considered collectively with LGR and LMN, the DOE and DEQ minimum sample size requirement of 50 salmonids per week, per zone, was met in the Snake River Zone all spring spill season. There was one week in the summer (July 25-July 31) when the minimum sample size of 50 salmonids per week was not met in the Snake River Zone.

This was the last week when salmonid GBT sampling occurred in the Snake River Zone, as sampling was terminated due to low sample sizes, high temperatures, and generally low TDG at this time.

**Figure H-5**

**Percent GBT observed in the salmonid (bars) samples at Lower Monumental Dam and 12-hour average TDG at the Little Goose tailrace (orange line) and Lower Monumental forebay (blue line) in 2021.**



Notes: 1) the y-axis for GBT incidence rate starts at -5% in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line) and 2) red numbers over the bars indicate the total salmonids examined for GBT.

**Table H-11**

**Detailed breakdown of salmonid GBT exams and signs of fin GBT at Lower Monumental Dam in 2021.**

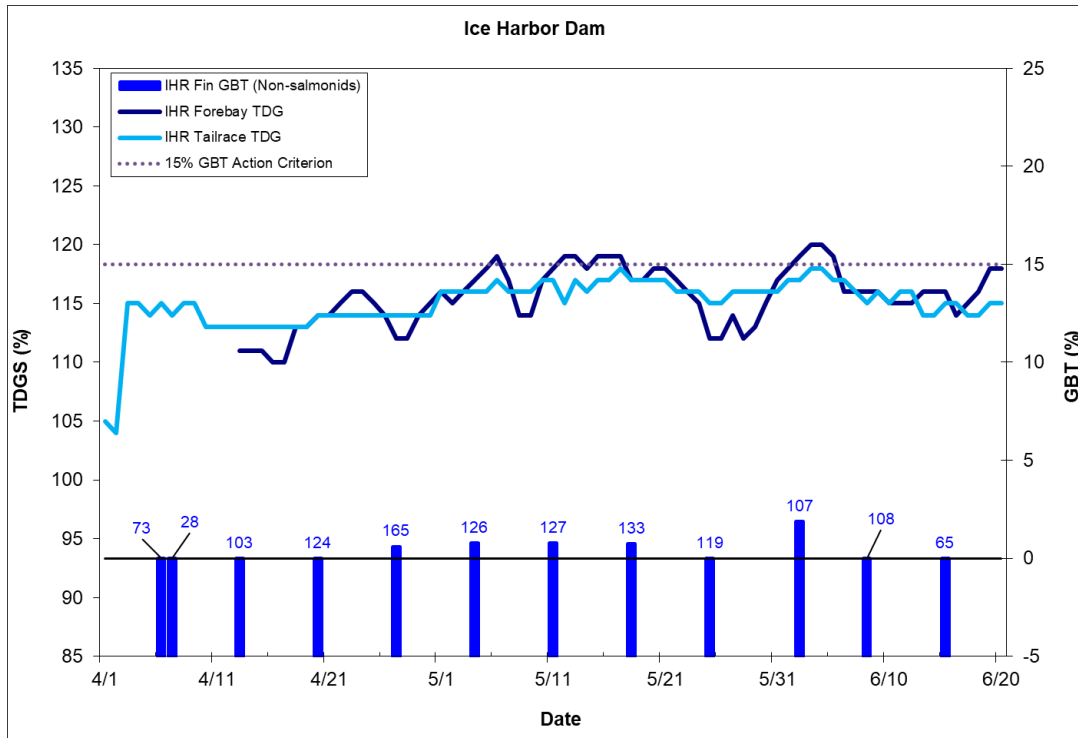
| <b>Sample Date</b> | <b>Number Examined</b> | <b>Number with Fin GBT</b> | <b>Percent with Fin GBT</b> |
|--------------------|------------------------|----------------------------|-----------------------------|
| 4/8/2021           | 35                     | 0                          | 0.0%                        |
| 4/16/2021          | 59                     | 0                          | 0.0%                        |
| 4/22/2021          | 100                    | 1                          | 1.0%                        |
| 4/28/2021          | 80                     | 3                          | 3.8%                        |
| 5/5/2021           | 74                     | 0                          | 0.0%                        |
| 5/12/2021          | 100                    | 2                          | 2.0%                        |
| 5/19/2021          | 100                    | 6                          | 6.0%                        |
| 5/26/2021          | 56                     | 0                          | 0.0%                        |
| 6/2/2021           | 1                      | 0                          | 0.0%                        |
| 6/9/2021           | 100                    | 0                          | 0.0%                        |
| 6/16/2021          | 40                     | 3                          | 7.5%                        |
| 6/23/2021          | 100                    | 11                         | 11.0%                       |
| 6/30/2021          | 100                    | 2                          | 2.0%                        |
| 7/7/2021           | 100                    | 2                          | 2.0%                        |
| 7/15/2021          | 53                     | 1                          | 1.9%                        |
| 7/21/2021          | 31                     | 0                          | 0.0%                        |
| 7/29/2021          | 22                     | 2                          | 9.1%                        |

***Ice Harbor Dam (IHR)***

IHR is not a Smolt Monitoring Program site and, therefore, salmonid GBT monitoring does not occur there. However, the IHR tailrace was chosen as one of the non-salmonid GBT monitoring sites for the USGS program. Non-salmonid GBT sampling below IHR occurred from April 6<sup>th</sup> through June 15<sup>th</sup>. In general, non-salmonid GBT sampling in the IHR tailrace occurred once per week, over the entire spring spill period. However, two samples were conducted during the first week. Total dissolved gas levels in the IHR tailrace never exceeded the 125% tailrace standard in 2021. In fact, the maximum 12-hour average TDG level in the IHR tailrace was 118%, which occurred on a few occasions from mid-May through early June (Figure H-6).

Twelve total non-salmonid GBT samples were conducted in the IHR tailrace by USGS personnel in the spring of 2021. Among these 12 samples, 1,278 total non-salmonids were examined, and six total fish had signs of fin GBT (Figure H-6, Table H-12). In all, eight total species of non-salmonids were sampled below IHR and examined for GBT. These included Pacific lamprey ammocoetes, largescale suckers, mountain whitefish, sculpin, northern pikeminnow, and sucker sp. The most common species sampled below IHR were northern pikeminnow and sculpin, each of which represented approximately 53% and 41% of the total non-salmonids examined, respectively. All six fish that exhibited signs of fin GBT were sculpin and all were Rank 1 signs. Of the 12 non-salmonid GBT samples conducted below IHR, five had at least one fish with signs of fin GBT (Figure H-6, Table H-12). The highest GBT incidence rate was 1.9%, which occurred on June 2<sup>nd</sup>. GBT incidence rates for the four remaining samples where fin GBT was observed ranged from 0.6% to 0.8%. No signs of severe GBT were observed at IHR in 2021.

**Figure H-6**  
**Percent GBT observed in the non-salmonid (blue bars) samples in the Ice Harbor tailrace and 12-hour average TDG at the Ice Harbor forebay (dark blue line) and Ice Harbor tailrace (light blue line) in 2021.**



Notes: 1) the y-axis for GBT incidence rate starts at -5% in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line) and 2) blue numbers over the bars indicate the total non-salmonids examined for GBT.

The target sample size of 100 non-salmonids examined per GBT sample was met in all but three samples (Table H-12). The target sample size of 50 non-salmonids per GBT sample was met in all but one sample (April 7<sup>th</sup> where 28 total non-salmonids were examined). When considered collectively with the single non-salmonid sample in the LGS tailrace, the DOE and DEQ minimum sample size requirement of 50 non-salmonids per week, per zone, was met in the Snake River Zone all spring spill season.

**Table H-12**

**Detailed breakdown of non-salmonid GBT exams and signs of GBT at the Ice Harbor Dam tailrace in 2021.**

| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT | Species Examined <sup>A</sup> | Number with Non-Protocol GBT |
|-------------|-----------------|---------------------|----------------------|-------------------------------|------------------------------|
| 4/6/2021    | 73              | 0                   | 0.0%                 | SC, NP                        | 0                            |
| 4/7/2021    | 28              | 0                   | 0.0%                 | NP                            | 0                            |
| 4/13/2021   | 103             | 0                   | 0.0%                 | SC, NP                        | 0                            |
| 4/20/2021   | 124             | 0                   | 0.0%                 | SC, NP                        | 0                            |
| 4/27/2021   | 165             | 1                   | 0.6%                 | SC, NP, MW                    | 0                            |
| 5/4/2021    | 126             | 1                   | 0.8%                 | SC, NP                        | 1                            |
| 5/11/2021   | 127             | 1                   | 0.8%                 | SC, NP, MW                    | 1                            |
| 5/18/2021   | 133             | 1                   | 0.8%                 | SC, NP, MW                    | 2                            |
| 5/25/2021   | 119             | 0                   | 0.0%                 | SC, NP, MW                    | 3                            |
| 6/2/2021    | 107             | 2                   | 1.9%                 | SC, NP                        | 4                            |
| 6/8/2021    | 108             | 0                   | 0.0%                 | AP, LU, SC, NP, MW            | 1                            |
| 6/15/2021   | 65              | 0                   | 0.0%                 | SC, NP, SU                    | 0                            |

<sup>A</sup> Non-salmonid Species Codes: SC = Sculpin, NP = Northern Pike/minnow, MW = Mountain Whitefish, AP = Pacific Lamprey Ammocoete, LU = Largescale Sucker, SU = Sucker Sp.

As mentioned above, the USGS crew observed signs of bubbles in non-protocol locations (i.e., locations other than the unpaired fins) in some of the non-salmonid GBT samples. Bubbles in non-protocol locations do not count towards the GBT monitoring action criteria. Among the samples conducted below IHR, 12 total fish were observed with bubbles in non-protocol locations. These 12 total fish were all sculpin and were spread out over six of the 12 samples conducted below IHR (Table H-12).

Finally, of the 1,278 total non-salmonids collected and examined from samples taken below IHR, 1,131 (88.5%) were collected through backpack electrofishing and 147 (11.5%) were collected through purse seines. All non-salmonids that exhibited signs of fin GBT were collected with backpack electrofishing and all fish with bubbles in non-protocol locations were also collected with backpack electrofishing.

### ***McNary Dam (MCN)***

Salmonid GBT sampling at MCN occurred from April 13<sup>th</sup> to August 5<sup>th</sup>. Like recent 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 6<sup>th</sup>. At that time, TDG levels in the MCN forebay had been at or below 110% for three days and temperatures in the MCN forebay had been quickly increasing and were above 68°F. 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 salmonids at water temperatures above 68°F. MCN was to continue once-per-week sampling through the rest of the voluntary spill season. However, GBT sampling was



In all, 29 total salmonid GBT samples were conducted at MCN in 2021, with 2,677 total salmonids examined (Figure H-7, Table H-13). Among the 29 total salmonid GBT samples, four had at least one salmonid with signs of fin GBT. All four of the samples that had fish with signs of fin GBT had GBT incidence rates of 1.0%. All salmonids that exhibited signs of fin GBT at MCN had Rank 1 signs.

**Table H-13**  
Detailed breakdown of salmonid GBT exams and signs of fin GBT at McNary Dam in 2021.

| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT |
|-------------|-----------------|---------------------|----------------------|
| 4/13/2021   | 100             | 0                   | 0.0%                 |
| 4/17/2021   | 100             | 0                   | 0.0%                 |
| 4/21/2021   | 100             | 0                   | 0.0%                 |
| 4/23/2021   | 100             | 0                   | 0.0%                 |
| 4/27/2021   | 100             | 1                   | 1.0%                 |
| 5/1/2021    | 100             | 0                   | 0.0%                 |
| 5/5/2021    | 100             | 0                   | 0.0%                 |
| 5/7/2021    | 100             | 0                   | 0.0%                 |
| 5/11/2021   | 100             | 0                   | 0.0%                 |
| 5/15/2021   | 100             | 1                   | 1.0%                 |
| 5/19/2021   | 100             | 0                   | 0.0%                 |
| 5/21/2021   | 100             | 1                   | 1.0%                 |
| 5/25/2021   | 100             | 0                   | 0.0%                 |
| 5/29/2021   | 100             | 0                   | 0.0%                 |
| 6/2/2021    | 78              | 0                   | 0.0%                 |
| 6/4/2021    | 100             | 1                   | 1.0%                 |
| 6/8/2021    | 100             | 0                   | 0.0%                 |
| 6/12/2021   | 100             | 0                   | 0.0%                 |
| 6/16/2021   | 100             | 0                   | 0.0%                 |
| 6/18/2021   | 100             | 0                   | 0.0%                 |
| 6/22/2021   | 100             | 0                   | 0.0%                 |
| 6/26/2021   | 100             | 0                   | 0.0%                 |
| 6/30/2021   | 100             | 0                   | 0.0%                 |
| 7/2/2021    | 100             | 0                   | 0.0%                 |
| 7/6/2021    | 100             | 0                   | 0.0%                 |
| 7/14/2021   | 100             | 0                   | 0.0%                 |
| 7/22/2021   | 33              | 0                   | 0.0%                 |
| 7/28/2021   | 50              | 0                   | 0.0%                 |
| 8/5/2021    | 16              | 0                   | 0.0%                 |

The target sample size of 100 salmonids examined per GBT sample was met in all but four of the salmonid GBT samples at MCN (Table H-13). The minimum sample size of 50 salmonids per GBT sample was met in all but two salmonid samples at MCN (July 22<sup>nd</sup> and August 5<sup>th</sup>). Finally, when considered collectively with BON, the DOE and DEQ minimum sample size requirement of 50 salmonids per week, per zone, was met every

week, except the first week (Apr. 4-10). However, this is because spring spill in the Mid-Columbia Zone started on Saturday, April 10<sup>th</sup> and, therefore, only one salmonid GBT sample was conducted in this zone this week (at BON). Only three salmonids were collected and examined in this single sample.

MCN was also chosen as one of the non-salmonid GBT monitoring sites for the USGS program. Non-salmonid GBT sampling below MCN occurred once per week, from April 12<sup>th</sup> through June 15<sup>th</sup>. Ten total non-salmonid GBT samples were conducted in the MCN tailrace by USGS personnel in the spring of 2021. Among these 10 samples, 899 total non-salmonids were examined, and 24 total fish had signs of fin GBT (Table H-14). In all, seven total species of non-salmonids were sampled below MCN and examined for GBT. These included: mountain whitefish, sculpin, northern pikeminnow, three-spined stickleback, speckled dace, reidside shiner, and sucker sp. The most common species sampled below MCN were sculpin and northern pikeminnow, each of which represented approximately 66% and 24% of the total non-salmonids examined, respectively. All 24 fish that exhibited signs of fin GBT were sculpin. Of these 24 fish, 20 (83%) had Rank 1 signs, two (8%) had Rank 2 signs, and two (8%) had Rank 4 signs.

**Table H-14**  
Detailed breakdown of non-salmonid GBT exams and signs of GBT at the McNary Dam tailrace in 2021.

| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT | Species Examined <sup>A</sup> | Number with Non-Protocol GBT |
|-------------|-----------------|---------------------|----------------------|-------------------------------|------------------------------|
| 4/12/2021   | 83              | 0                   | 0.0%                 | SC, SD, SK, NP, SU            | 0                            |
| 4/19/2021   | 101             | 0                   | 0.0%                 | SC, SD, SK, NP, SU            | 0                            |
| 4/26/2021   | 81              | 4                   | 4.9%                 | SC, SD, SK, NP, SU            | 0                            |
| 5/3/2021    | 54              | 1                   | 1.9%                 | SC, SD, SK, NP, SU            | 0                            |
| 5/10/2021   | 76              | 3                   | 3.9%                 | SC, SD                        | 9                            |
| 5/17/2021   | 60              | 0                   | 0.0%                 | MW, SC, SK, NP, SU            | 2                            |
| 5/24/2021   | 65              | 4                   | 6.2%                 | SC, SK, SU                    | 7                            |
| 6/1/2021    | 110             | 4                   | 3.6%                 | SC, SK                        | 13                           |
| 6/7/2021    | 120             | 3                   | 2.5%                 | SC, SK, NP                    | 13                           |
| 6/14/2021   | 149             | 5                   | 3.4%                 | RS, SC, SK, NP                | 9                            |

<sup>A</sup> Non-salmonid Species Codes: SC = Sculpin, SD = Speckled Dace, SK = Three-spined Stickleback, NP = Northern Pikeminnow, MW = Mountain Whitefish, RS = Redside Shiner, SU = Sucker Sp.

Of the 10 non-salmonid GBT samples conducted below MCN in spring 2021, seven had at least one fish with signs of fin GBT (Figure H-7, Table H-14). The highest GBT incidence rate was 6.2%, which occurred on May 24<sup>th</sup>. GBT incidence rates for the six remaining samples where fin GBT was observed ranged from 1.9% to 4.9%. Finally, the samples from May 3<sup>rd</sup> and May 10<sup>th</sup> each had one fish with severe GBT (i.e., Rank 3 or 4). The severe GBT incidence rates for these two samples were 1.9% and 1.3%, respectively.

The target sample size of 100 non-salmonids examined per GBT sample was met in only four samples (Table H-14). The target sample size of 50 non-salmonids examined per GBT sample was met in all 10 samples. Finally, when considered collectively with JDA and BON, the DOE and DEQ minimum sample size requirement of 50 non-salmonids per week, per zone, was met every week that non-salmonid sampling occurred in the Mid-Columbia Zone.

As with the samples conducted below IHR, the USGS crew observed signs of bubbles in non-protocol locations (i.e., locations other than the unpaired fins) in some of the non-salmonid GBT samples below MCN. Bubbles in non-protocol locations do not count towards the GBT monitoring action criteria. In all, 53 total fish were observed with bubbles in non-protocol locations. All 53 fish were sculpin and were spread out over six of the 10 samples conducted below MCN (Table H-14).

Finally, of the 899 total non-salmonids collected and examined from samples taken below MCN, 850 (94.5%) were collected through backpack electrofishing and 49 (5.5%) were collected through purse seines. All non-salmonids that exhibited signs of fin GBT were collected with backpack electrofishing and all fish with bubbles in non-protocol locations were also collected with backpack electrofishing.

### ***John Day Dam (JDA)***

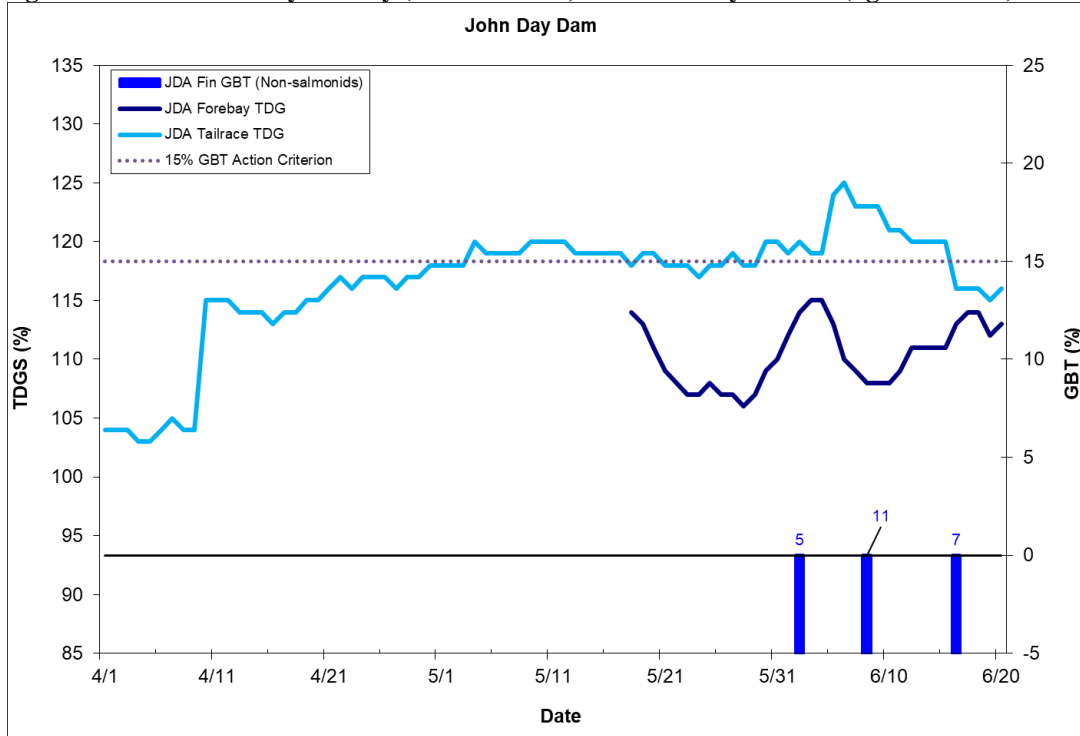
Although JDA is a Smolt Monitoring Program site, salmonid GBT monitoring does not occur there. However, the JDA tailrace was chosen as one of the non-salmonid GBT monitoring sites for the WDFW/PSMFC feasibility study on collecting and examining native non-salmonid through the Pikeminnow Dam Angling Program. Only three GBT samples were conducted under this part of the feasibility study (June 2<sup>nd</sup>, June 8<sup>th</sup>, and June 16<sup>th</sup>). Total dissolved gas levels in the JDA tailrace never exceeded the 125% tailrace standard in 2021. However, TDG in the JDA tailrace did meet 125% on one occasion, June 6<sup>th</sup> (Figure H-8).

Among the three non-salmonid GBT samples conducted below JDA, only 23 total non-salmonids were examined and no signs of fin GBT were observed (Table H-15). In all, three species of non-salmonids were sampled below JDA and examined for GBT. These included sculpin, northern pikeminnow, and white sturgeon. The most common species sampled below JDA was northern pikeminnow, which represented approximately 91% of the total non-salmonids examined. All non-salmonids collected for this feasibility study were collected through dam angling.

The target sample size of 100 non-salmonids examined per GBT sample was never met by this feasibility study, nor was the target sample size of 50 non-salmonids per GBT sample (Table H-15). But, when considered collectively with BON and MCN, the DOE and DEQ minimum sample size requirement of 50 non-salmonids per week, per zone, was met every week that sampling occurred in the Mid-Columbia Zone.

**Figure H-8**

Percent GBT observed in the non-salmonid (blue bars) samples in the John Day tailrace and 12-hour average TDG at the John Day forebay (dark blue line) and John Day tailrace (light blue line) in 2021.



Notes: 1) the y-axis for GBT incidence rate starts at -5% in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line) and 2) blue numbers over the bars indicate the total non-salmonids examined for GBT.

**Table H-15**

Detailed breakdown of non-salmonid GBT exams and signs of GBT at the John Day Dam tailrace in 2021.

| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT | Species Examined <sup>A</sup> |
|-------------|-----------------|---------------------|----------------------|-------------------------------|
| 6/2/2021    | 5               | 0                   | 0.0%                 | SC, NP                        |
| 6/8/2021    | 11              | 0                   | 0.0%                 | SG, NP                        |
| 6/16/2021   | 7               | 0                   | 0.0%                 | NP                            |

<sup>A</sup> Non-salmonid Species Codes: SC = Sculpin, NP = Northern Pikeminnow, SG = White Sturgeon

**Bonneville Dam (BON)**

Salmonid GBT sampling at BON occurred from April 10<sup>th</sup> to July 25<sup>th</sup>. Salmonid GBT sampling at BON typically occurs twice-per-week. However, sampling is typically suspended when Spring Creek NFH releases occur, to minimize handling of these listed fish. Therefore, no salmonid GBT samples were conducted on April 17<sup>th</sup> or April 24<sup>th</sup>, as these two days coincided with Spring Creek NFH releases. Due to decreasing fish numbers, high temperatures, and generally low TDG levels, GBT sampling at BON was



highest GBT incidence rate at BON in 2021 was 5.9%, which occurred on April 14<sup>th</sup>. However, it should be noted that this GBT incidence rate was based on one fish exhibiting signs of fin GBT, out of a total of 17 salmonids examined. Total dissolved gas in the JDA tailrace had been in the 104%-115% range and TDG in the tailrace at TDA had been in the 104%-117% range over the week preceding the April 14<sup>th</sup> sample (Figure H-9). Among the other five salmonid GBT samples where signs of fin GBT were observed at BON, GBT incidence rates ranged from 1.0% to 3.0%. Of the 10 total salmonids that exhibited signs of fin GBT at BON in 2021, nine exhibited Rank 1 signs and one exhibited Rank 3 signs. Rank 3 signs are considered severe GBT. This individual with severe GBT was observed in the sample from June 3<sup>rd</sup>. The overall GBT incidence rate for the sample on June 3<sup>rd</sup> was 3.0% and the severe GBT incidence rate was 1.0% (Table H-16).

**Table H-16**

**Detailed breakdown of salmonid GBT exams and signs of fin GBT at Bonneville Dam in 2021.**

| Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT |
|-------------|-----------------|---------------------|----------------------|
| 4/10/2021   | 3               | 0                   | 0.0%                 |
| 4/14/2021   | 17              | 1                   | 5.9%                 |
| 4/21/2021   | 100             | 0                   | 0.0%                 |
| 4/26/2021   | 100             | 0                   | 0.0%                 |
| 4/28/2021   | 100             | 0                   | 0.0%                 |
| 5/2/2021    | 100             | 0                   | 0.0%                 |
| 5/5/2021    | 100             | 0                   | 0.0%                 |
| 5/9/2021    | 100             | 0                   | 0.0%                 |
| 5/12/2021   | 100             | 0                   | 0.0%                 |
| 5/16/2021   | 100             | 1                   | 1.0%                 |
| 5/19/2021   | 100             | 1                   | 1.0%                 |
| 5/23/2021   | 100             | 0                   | 0.0%                 |
| 5/26/2021   | 100             | 0                   | 0.0%                 |
| 5/30/2021   | 100             | 0                   | 0.0%                 |
| 6/3/2021    | 100             | 3                   | 3.0%                 |
| 6/6/2021    | 100             | 0                   | 0.0%                 |
| 6/9/2021    | 100             | 3                   | 3.0%                 |
| 6/13/2021   | 100             | 0                   | 0.0%                 |
| 6/16/2021   | 94              | 0                   | 0.0%                 |
| 6/20/2021   | 100             | 0                   | 0.0%                 |
| 6/23/2021   | 100             | 0                   | 0.0%                 |
| 6/27/2021   | 100             | 1                   | 1.0%                 |
| 6/30/2021   | 100             | 0                   | 0.0%                 |
| 7/4/2021    | 100             | 0                   | 0.0%                 |
| 7/7/2021    | 100             | 0                   | 0.0%                 |
| 7/11/2021   | 100             | 0                   | 0.0%                 |
| 7/15/2021   | 100             | 0                   | 0.0%                 |
| 7/19/2021   | 100             | 0                   | 0.0%                 |
| 7/21/2021   | 7               | 0                   | 0.0%                 |
| 7/25/2021   | 2               | 0                   | 0.0%                 |

The target sample size of 100 salmonids examined per GBT sample was met in all but five salmonid GBT samples (Table H-16). Of the five salmonid GBT samples that did not meet the 100 fish sample size requirement, two occurred in the beginning (April 10<sup>th</sup> and 14<sup>th</sup>) of the season and two occurred at the end (July 21<sup>st</sup> and 25<sup>th</sup>) of the season. The fifth occurred on June 16<sup>th</sup>, where the sample size requirement was nearly met (i.e., 94 total salmonids examined). All but four of the salmonid GBT samples at BON met the DOE and DEQ minimum sample size requirement of 50 salmonids. The four samples that did not meet the 50 fish requirement were the two at the beginning and two at the end of the season. Finally, when considered collectively with MCN, the DOE and DEQ minimum sample size requirement of 50 salmonids per week, per zone, was met every week, except the first week (Apr. 4-10). However, this is because spring spill in the Mid-Columbia Zone started on Saturday, April 10<sup>th</sup> and, therefore, only one salmonid GBT sample was conducted in this zone this week (at BON). Only three salmonids were collected and examined in this single sample.

BON was also chosen as a non-salmonid GBT monitoring site for both the USGS program and the ODFW/PSMFC feasibility study. Under the USGS program, non-salmonid GBT sampling below BON occurred once per week, from April 15<sup>th</sup> through June 17<sup>th</sup>. Ten total non-salmonid GBT samples were conducted in the BON tailrace by USGS personnel in the spring of 2021 (Figure H-9, Table H-17). Among these 10 USGS samples, 1,012 total non-salmonids were examined, and one fish had signs of fin GBT (Table H-17). In all, eleven total species of non-salmonids were sampled and examined for GBT by USGS personnel below BON. These included: Pacific lamprey ammocoetes, long-nosed dace, largescale sucker, mountain whitefish, starry flounder, peamouth, sculpin, speckled date, three-spined stickleback, northern pikeminnow, and sucker sp. The most common species sampled by USGS below BON were sculpin, three-spined stickleback, and northern pikeminnow, each of which represented approximately 57%, 30%, and 11% of the total non-salmonids examined, respectively. The one fish that exhibited signs of fin GBT was a three-spined stickleback that was examined on May 13<sup>th</sup>. This single fish had Rank 2 signs. The May 13<sup>th</sup> sample was the only USGS sample where signs of fin GBT were observed among the non-salmonids. The GBT incidence rate for this sample was 1.0% (Table H-17). No signs of severe fin GBT were observed by USGS crews.

In addition to examining non-salmonids collected below BON, USGS also collected and examined subyearling Chinook below BON on five separate occasions (Table H-17). In all, 108 subyearling Chinook were sampled across these five USGS GBT samples, each ranging from 1 to 35 total fish examined per sample. No signs of fin GBT were observed in the subyearling Chinook that were collected and examined by USGS.

The ODFW/PSMFC feasibility study conducted three total non-salmonid GBT samples below BON in 2021. These three samples occurred on May 19<sup>th</sup>, May 21<sup>st</sup>, and May 28<sup>th</sup>. Among these three samples, 63 total non-salmonids were examined, and four total fish had signs of fin GBT (Table H-17). In all, seven total species of non-salmonids were sampled by ODFW/PSMFC and examined for GBT. These included: largescale sucker, mountain whitefish, peamouth, sculpin, three-spined stickleback, northern

pikeminnow, and sucker sp. The most common species sampled by ODFW/PSMFC below BON were largescale suckers, which represented approximately 71% of the total non-salmonids examined, respectively. The four fish that exhibited signs of fin GBT were peamouth (two fish), three-spined stickleback (1 fish), and sucker sp. (1 fish). All four of these fish had Rank 1 signs. The maximum GBT incidence rate from these ODFW/PSMFC samples was 11.8%, which occurred on May 21<sup>st</sup> (Table H-17). It should be noted that only 17 fish were collected and examined in this sample and, therefore, the 11.8% GBT incidence rate was based on two fish with signs of fin GBT. Only one other ODFW/PSMFC sample (May 19<sup>th</sup>) had signs of fin GBT and the GBT incidence rate from that sample was 6.5%, out of a total sample of 31 fish examined.

**Table H-17**

**Detailed breakdown of non-salmonid GBT exams and signs of GBT at the Bonneville Dam tailrace in 2021. Exams are grouped by sampling program (USGS and PSMFC/ODFW). Shaded rows represent days where the USGS non-salmonid GBT monitoring crew also collected and examined subyearling Chinook for GBT. Subyearling Chinook data are summarized separately in these rows.**

| Program        | Sample Date | Number Examined | Number with Fin GBT | Percent with Fin GBT | Species Examined <sup>A</sup> | Number with Non-Protocol GBT |
|----------------|-------------|-----------------|---------------------|----------------------|-------------------------------|------------------------------|
| USGS           | 4/15/2021   | 57              | 0                   | 0.0%                 | PM, SC, SK, NP, SU            | 0                            |
|                | 4/22/2021   | 57              | 0                   | 0.0%                 | LD, SC, SK, NP, SU            | 0                            |
|                | 4/29/2021   | 101             | 0                   | 0.0%                 | LU, SC, SD, SK, NP            | 1                            |
|                | 5/6/2021    | 93              | 0                   | 0.0%                 | LD, SC, SK, NP, SU            | 0                            |
|                | 5/13/2021   | 101             | 1                   | 1.0%                 | AP, SC, SK, NP                | 3                            |
|                | 5/13/2021   | 1               | 0                   | 0.0%                 | CH0                           | 0                            |
|                | 5/20/2021   | 101             | 0                   | 0.0%                 | LD, SC, SK, NP, SU            | 0                            |
|                | 5/20/2021   | 35              | 0                   | 0.0%                 | CH0                           | 0                            |
|                | 5/28/2021   | 106             | 0                   | 0.0%                 | LU, SC, SK, NP                | 0                            |
|                | 5/28/2021   | 24              | 0                   | 0.0%                 | CH0                           | 0                            |
|                | 6/4/2021    | 169             | 0                   | 0.0%                 | MW, SC, SK, NP                | 0                            |
|                | 6/10/2021   | 102             | 0                   | 0.0%                 | SC, SK, NP                    | 0                            |
|                | 6/10/2021   | 21              | 0                   | 0.0%                 | CH0                           | 0                            |
|                | 6/17/2021   | 125             | 0                   | 0.0%                 | SF, SC, SK, NP                | 1                            |
| 6/17/2021      | 27          | 0               | 0.0%                | CH0                  | 0                             |                              |
| ODFW/<br>PSMFC | 5/19/2021   | 31              | 2                   | 6.5%                 | LU, PM, SC, NP, SU            |                              |
|                | 5/21/2021   | 17              | 2                   | 11.8%                | LU, SK, SU                    |                              |
|                | 5/28/2021   | 15              | 0                   | 0.0%                 | LU, MW                        |                              |

<sup>A</sup> Non-salmonid Species Codes: PM = Peamouth, SC = Sculpin, SK = Three-spined Stickleback, NP = Northern Pikeminnow, LD = Long-nosed Dace, MW = Mountain Whitefish, SU = Sucker Sp., LU = Largescale Sucker, SD = Speckled Dace, AP = Pacific Lamprey Ammocoete, SF = Starry Flounder

The target sample size of 100 non-salmonids examined per GBT sample was met in seven of the ten USGS non-salmonid samples but was never met in the ODFW/PSMFC samples (Table H-17). The target sample size of 50 non-salmonids examined per GBT sample was met in all the USGS samples but never met in the ODFW/PSMFC samples. When considered collectively with JDA and MCN, the DOE and DEQ minimum sample size requirement of 50 non-salmonids per week, per zone, was met every week that non-salmonid sampling occurred in the Mid-Columbia Zone.

The USGS crew observed signs of bubbles in non-protocol locations (i.e., locations other than the unpaired fins) in some of the non-salmonid GBT samples below BON. Bubbles in non-protocol locations do not count towards the GBT monitoring action criteria. In all, five total fish were observed with bubbles in non-protocol locations. All five fish were sculpin and were spread out over three of the 10 samples conducted below BON (Table H-17).

Of the 1,202 total non-salmonids collected and examined by USGS, 750 (74%) were collected through backpack electrofishing and 262 (26%) were collected through purse seines. The one non-salmonid that exhibited signs of fin GBT in the USGS samples was collected with backpack electrofishing and all five fish with bubbles in non-protocol locations were also collected with backpack electrofishing. Of the 108 total subyearling Chinook collected and examined by USGS, 107 were collected through seining and one was collected through backpack electrofishing. Finally, all 63 non-salmonids that were collected and examined by ODFW/PSMFC were collected with boat electrofishing.

### ***Rock Island Dam (RIS)***

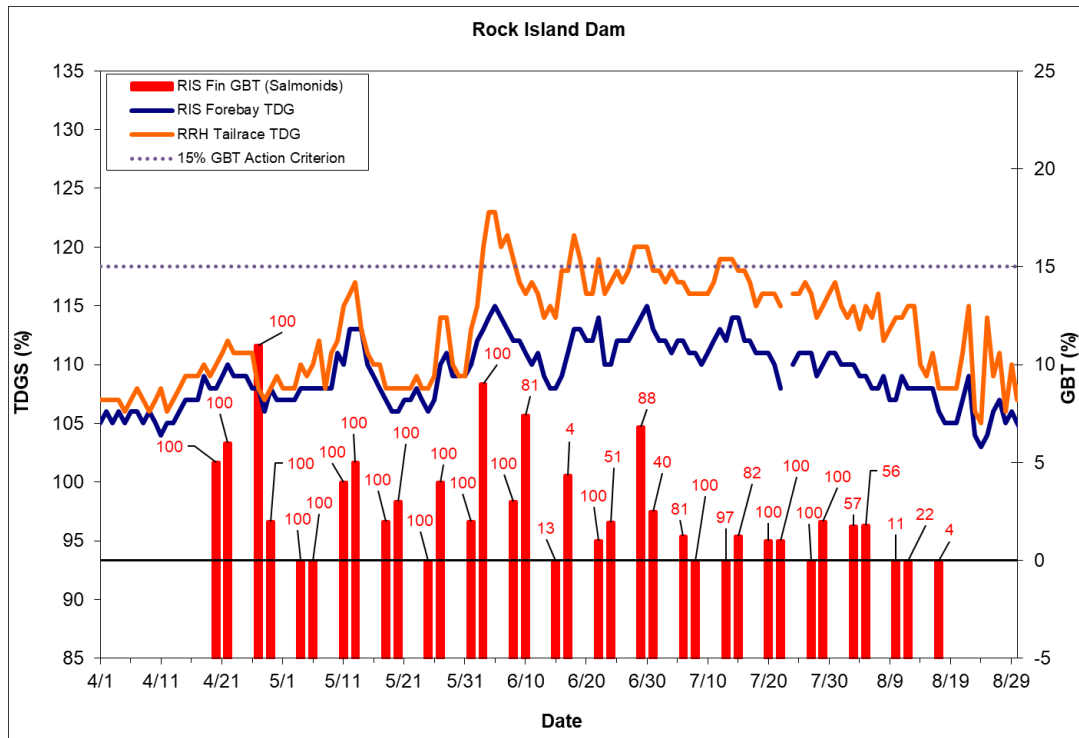
Non-salmonid GBT monitoring is only necessary if/when projects operate their spill programs to the 125% tailrace TDG standard. Given that the 125% TDG standard did not apply to the Upper Columbia River, there was no need for non-salmonid GBT monitoring in the Upper Columbia. In 2021, salmonid GBT sampling at RIS occurred from April 20<sup>th</sup> to August 17<sup>th</sup>. Due to rapidly decreasing subyearling Chinook collections, GBT sampling at RIS was terminated after the sample on August 17<sup>th</sup>.

Total dissolved gas levels in the Rocky Reach (RRH) tailrace exceeded the 120% standard for a total of four days in 2021 (Figure H-10). In general, these exceedances occurred over a span of four days in June (June 4-7), where the 12-hour average TDG in the RRH tailrace ranged from 120%-123% (Figure H-10). Total dissolved gas levels in the Rock Island (RIS) forebay never exceeded the 115% standard in 2021. However, the 12-hour average TDG did meet 115% on two occasions (June 5<sup>th</sup> and 30<sup>th</sup>).

As mentioned earlier, staff at the FPC and SMP staff at RIS continued the modified GBT sampling protocol in 2021. This modified sampling protocol was the same as what was first implemented in 2018 and similar to the pilot protocol that had been implemented in 2016 and 2017. Results from 2016-2019 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 2021, 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 2016-2019 data are provided in a separate discussion below (Evaluation of Modified Sampling Protocol at Rock Island).

**Figure H-10**  
**Percent GBT observed in the salmonid samples at Rock Island Dam (red bard) and 12-hour average TDG at the Rocky Reach tailrace (orange line) and Rock Island forebay (blue line) in 2021.**



Notes: 1) the y-axis for GBT incidence rate starts at -5% in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., solid black horizontal line) and 2) red numbers over the bars indicate the total salmonids examined for GBT.

In all, 35 total GBT samples were conducted at RIS in 2021 and 2,829 total salmonids were examined for GBT (Figure H-10; Table H-18). Of the 35 GBT samples, 25 had one or more salmonids with signs of fin GBT. When signs of GBT were present, GBT incidence rates at RIS ranged from as low as 1.0% of examined salmonids exhibiting signs of fin GBT to as high as 11.0% of examined salmonids exhibiting signs of fin GBT (Figure H-10, Table H-18). The highest incidence of 11.0% GBT occurred on April 27<sup>th</sup>. Total dissolved gas levels in the RIS forebay had been in the 108%-110% range over the week prior to this exam and TDG levels in the RRH tailrace had been in the 109%-110% range. Of the 81 total fish that exhibited signs of fin GBT at RIS in 2021, 73 had Rank 1 signs, seven had Rank 2 signs, and one had Rank 3 signs. Rank 3 signs are considered severe GBT. This individual with severe GBT was observed in the sample from April 27<sup>th</sup>. As

mentioned above, the overall GBT incidence rate for the sample on April 27<sup>th</sup> was 11.0% and the severe GBT incidence rate was 1.0% (Table H-18).

**Table H-18**  
Detailed breakdown of salmonid GBT exams (total, “traditional”, and “fresh” examined) and signs of fin GBT at Rock Island Dam in 2021.

| 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” |
|-------------|-----------------------|----------------------------|-------------------------------|------------------------------------|-------------------------|------------------------------|
| 4/20/2021   | 100                   | 5.0%                       | 100                           | 5.0%                               | 0                       | ---                          |
| 4/22/2021   | 100                   | 6.0%                       | 98                            | 6.1%                               | 2                       | 0.0%                         |
| 4/27/2021   | 100                   | 11.0%                      | 65                            | 15.4%                              | 35                      | 2.9%                         |
| 4/29/2021   | 100                   | 2.0%                       | 21                            | 4.8%                               | 79                      | 1.3%                         |
| 5/4/2021    | 100                   | 0.0%                       | 17                            | 0.0%                               | 83                      | 0.0%                         |
| 5/6/2021    | 100                   | 0.0%                       | 0                             | ---                                | 100                     | 0.0%                         |
| 5/11/2021   | 100                   | 4.0%                       | 0                             | ---                                | 100                     | 4.0%                         |
| 5/13/2021   | 100                   | 5.0%                       | 0                             | ---                                | 100                     | 5.0%                         |
| 5/18/2021   | 100                   | 2.0%                       | 16                            | 6.3%                               | 84                      | 1.2%                         |
| 5/20/2021   | 100                   | 3.0%                       | 0                             | ---                                | 100                     | 3.0%                         |
| 5/25/2021   | 100                   | 0.0%                       | 0                             | ---                                | 100                     | 0.0%                         |
| 5/27/2021   | 100                   | 4.0%                       | 33                            | 12.1%                              | 67                      | 0.0%                         |
| 6/1/2021    | 100                   | 2.0%                       | 88                            | 2.3%                               | 12                      | 0.0%                         |
| 6/3/2021    | 100                   | 9.0%                       | 34                            | 11.8%                              | 66                      | 7.6%                         |
| 6/8/2021    | 100                   | 3.0%                       | 62                            | 4.8%                               | 38                      | 0.0%                         |
| 6/10/2021   | 81                    | 7.4%                       | 63                            | 7.9%                               | 18                      | 5.6%                         |
| 6/15/2021   | 13                    | 0.0%                       | 12                            | 0.0%                               | 1                       | 0.0%                         |
| 6/17/2021   | 46                    | 4.3%                       | 42                            | 4.8%                               | 4                       | 0.0%                         |
| 6/22/2021   | 100                   | 1.0%                       | 84                            | 1.2%                               | 16                      | 0.0%                         |
| 6/24/2021   | 51                    | 2.0%                       | 40                            | 2.5%                               | 11                      | 0.0%                         |
| 6/29/2021   | 88                    | 6.8%                       | 77                            | 7.8%                               | 11                      | 0.0%                         |
| 7/1/2021    | 40                    | 2.5%                       | 37                            | 0.0%                               | 3                       | 33.3%                        |
| 7/6/2021    | 81                    | 1.2%                       | 76                            | 1.3%                               | 5                       | 0.0%                         |
| 7/8/2021    | 100                   | 0.0%                       | 90                            | 0.0%                               | 10                      | 0.0%                         |
| 7/13/2021   | 97                    | 0.0%                       | 93                            | 0.0%                               | 4                       | 0.0%                         |
| 7/15/2021   | 82                    | 1.2%                       | 73                            | 1.4%                               | 9                       | 0.0%                         |
| 7/20/2021   | 100                   | 1.0%                       | 83                            | 1.2%                               | 17                      | 0.0%                         |
| 7/22/2021   | 100                   | 1.0%                       | 87                            | 1.1%                               | 13                      | 0.0%                         |
| 7/27/2021   | 100                   | 0.0%                       | 83                            | 0.0%                               | 17                      | 0.0%                         |
| 7/29/2021   | 100                   | 2.0%                       | 95                            | 2.1%                               | 5                       | 0.0%                         |
| 8/3/2021    | 57                    | 1.8%                       | 53                            | 1.9%                               | 4                       | 0.0%                         |
| 8/5/2021    | 56                    | 1.8%                       | 51                            | 2.0%                               | 5                       | 0.0%                         |
| 8/10/2021   | 11                    | 0.0%                       | 7                             | 0.0%                               | 4                       | 0.0%                         |
| 8/12/2021   | 22                    | 0.0%                       | 20                            | 0.0%                               | 2                       | 0.0%                         |
| 8/17/2021   | 4                     | 0.0%                       | 2                             | 0.0%                               | 2                       | 0.0%                         |

The target sample size of 100 salmonids examined per GBT sample was met in 21 of the 35 salmonid GBT samples at RIS (Table H-18). All but six of the salmonid GBT samples at RIS met the DOE and DEQ minimum sample size requirement of 50 salmonids. Among the six samples that did not meet the 50 fish requirement, three occurred in mid-

June and early July and three occurred at the end of the GBT sampling season. Finally, the DOE and DEQ minimum sample size requirement of 50 salmonids per week, per zone, was met in nearly every week that GBT sampling occurred at RIS. The two exceptions were the last two week of sampling (August 8-14 and August 15-21), when 33 and 4 total salmonids were examined per week, respectively.

**Table H-19**  
**Percent of sampled salmonids with signs of fin GBT estimated for**  
**the total fish observed in each year 1996 to 2021.**

| <b>Year</b> | <b>Total %<br/>Signs</b> | <b>% Signs<br/>excluding RIS</b> |
|-------------|--------------------------|----------------------------------|
| 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                             |
| 2020        | 1.57                     | 0.77                             |
| <b>2021</b> | <b>1.49</b>              | <b>1.01</b>                      |

Finally, Table H-19 compares the 2021 estimates of the overall percentage of salmonids with signs of fin 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 2021 compared to past years. We include overall percentages both with and without Rock Island Dam included, given 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 2021 was the 11<sup>th</sup> highest among the last

26 years. Without Rock Island, the 2021 overall annual incidence of GBT was the 9<sup>th</sup> highest of the last 26 years.

## **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 and 2019, 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 2020.

The FPC staff has provided three separate analyses of GBT incidence rates of “traditional” versus “fresh” sampled fish at RIS over the years ([FPC 2017](#), [FPC 2018](#), and [FPC 2019](#)). Results from these analyses have all demonstrated that, on average, “traditional” fish had 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 (1996–2021)

The Gas Bubble Trauma monitoring program has been implemented on salmonids annually since 1996. There are 26 years of data available and, because of involuntary spill events and recent changes to TDG standards, data for salmonid 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 GBT monitoring protocol, is 100 salmonids. In this analysis, some flexibility was considered and all daily samples with greater than 75 salmonids 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 and forebay elevation 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. It should be noted that the 2021 samples conducted at LGR could not be used in this analysis. This is because the forebay monitor in the LGR forebay was not installed until June 18<sup>th</sup> and, therefore, we had no way of matching the data from GBT samples to TDG levels in the LGR forebay. This will continue to be an issue in future years if installation of the forebay monitors continues to be delayed. With these data, we evaluated how often the 15% fin GBT incidence criterion has been met over the last 26 years, and at what tailrace TDG levels this occurred.

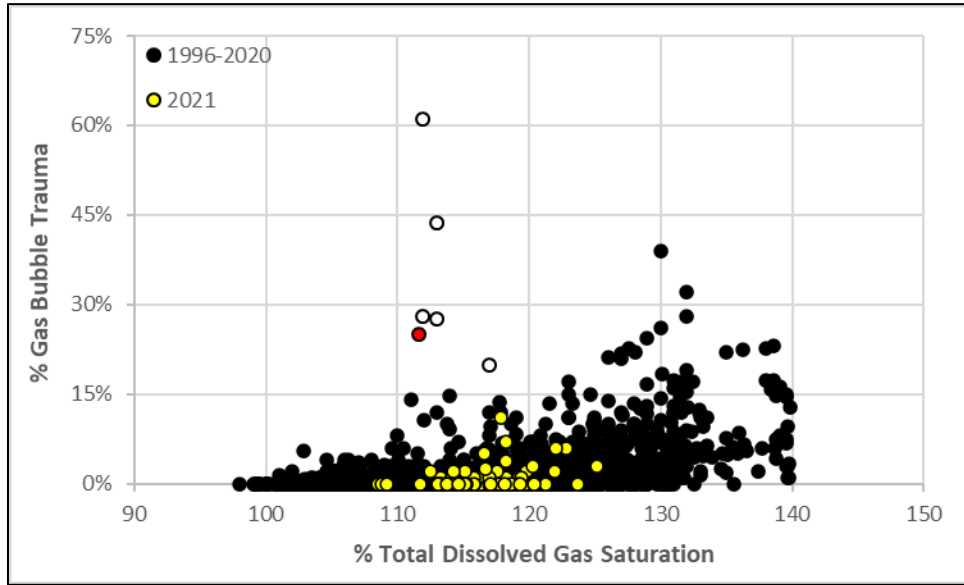
Excluding Rock Island Dam samples, a total of 3,116 daily exams fit into our criteria of  $\geq 75$  fish examined over the 26 years of available data, where GBT data could be batched to upstream TDG data. This equated to a total of 350,182 fish examined. The GBT monitoring program has consistently shown over the years that signs of GBT are minimal when TDG is managed to the total dissolved gas standards that have been used over the years for 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 (3,116 samples meeting our sample size criterion), there have been only 37 instances when the 15% GBT

criterion was exceeded (Figure H-11). Of those 37 instances, five (open circles in Figure H-11) 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 H-11). 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 15% GBT criterion was exceeded occurred when TDG was greater than 120%. Of these 31 instances, 28 (90.3%) were observed at TDG concentrations greater than 125%. As noted earlier, the 15% GBT action criterion was not met in 2021 (yellow circles in Figure H-11), despite the new 125% tailrace TDG standard that was utilized for the spring spill season. However, it is worth noting that TDG rarely reached 125% in 2021, due to the low flows and inability to spill to the 125% tailrace spill caps.

Of the 3,116 GBT samples that met the sample size criteria for this historic review, 325 had TDG levels of  $\geq 125\%$ . Of these 325 samples with corresponding TDG levels of  $\geq 125\%$ , only 28 (or 8.6%) had GBT incidence rates that met or exceeded the 15% fin GBT criterion. This means that the remaining 297 GBT samples (or 91.4%) had fin GBT incidence rates below the 15% action criterion (Figure H-11). These analyses indicate that the 15% fin GBT 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%.

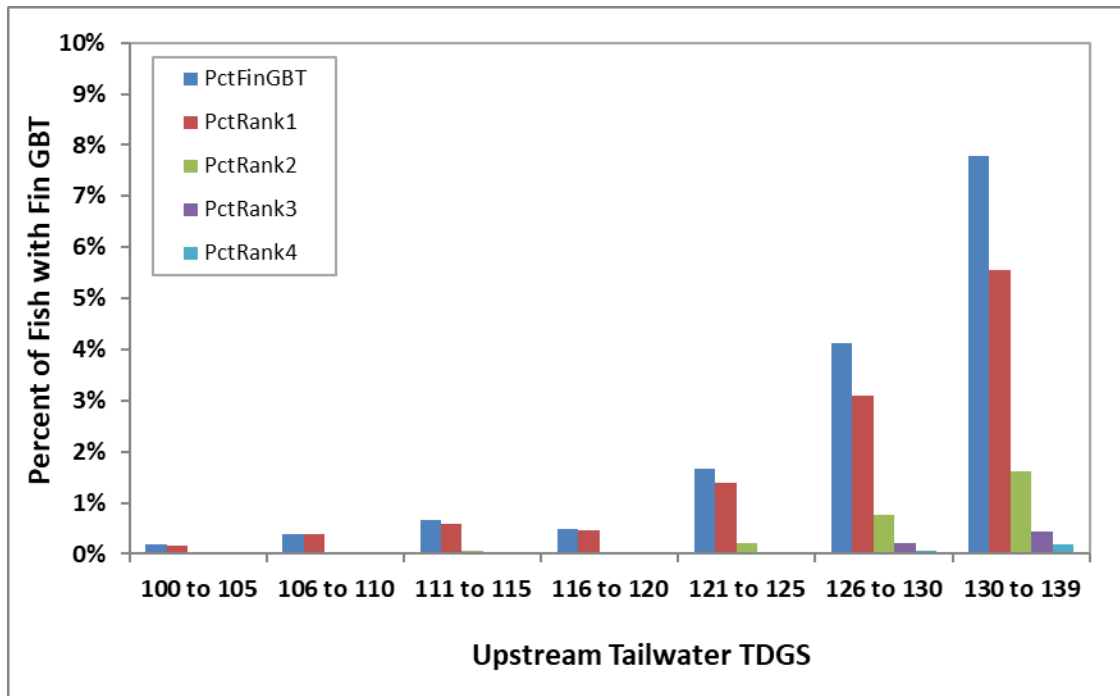
**Figure H-11**  
**Percent GBT observed as a function of TDG observed in upstream tailrace in 1996-**  
**2020 (black circles) and 2021 (yellow circles).**



\* 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.

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 H-12). From Figure H-12 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.

**Figure H-12**  
**Percent of all fish collected from 1996–2021 showing signs of GBT at given TDG levels.**



**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 2021 migration season. In accordance with operations outlined by the 2021 FOP, the water quality standards were modified to 125% tailrace TDG in the spring and 115%/120% (Washington) or 120% tailrace (Oregon) in the summer. Flows in the Lower Snake and Mid-Columbia rivers were manageable in 2021 and there was no spill above the estimated 125% TDG spill caps due to high flows. In fact, due to the low flows, spill to the 125% TDG spill caps was rarely met in 2021.

For both the salmonid and non-salmonid GBT samples, the action criterion of 15% fin GBT was never met in 2021. In addition, the action criterion of 5% severe fin GBT was also never met in 2021. The highest GBT incidence rate observed in salmonids in 2021 was 11.0%, which occurred once at Lower Monumental Dam (June 23<sup>rd</sup>) and once at Rock Island Dam (April 27<sup>th</sup>). The highest GBT incidence rate observed in non-salmonids in 2021 was 11.8%, which was observed by the PSMFC/ODFW personnel sampling non-salmonid below Bonneville Dam on May 21<sup>st</sup>. It should be noted that this incidence rate of 11.8% is based on two fish exhibiting signs of fin GBT, out of only 17 total fish examined.

Data collected over the past 26 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%.

## References

- Fish Passage Center (FPC). 2007a. Steelhead and GBT at Little Goose and Lower Monumental dams. June 8, 2007 memorandum to the files. <http://www.fpc.org/documents/memos/90-07.pdf>
- FPC. 2007b. Questions regarding Gas Bubble Trauma. June 18, 2007 memorandum to Agnes Lut (Oregon DEQ). <http://www.fpc.org/documents/memos/98-07.pdf>.
- FPC. 2007c. Response to Comments from 6/21/07 Oregon Department of Environmental Quality Meeting. August 24, 2007 memorandum to Liz Hamilton (NWSFI) and Ron Boyce (ODFW). <http://www.fpc.org/documents/memos/136-07.pdf>
- FPC. 2017. Recommendations on Gas Bubble Trauma Monitoring Protocol at Rock Island Dam. October 3, 2017 memorandum to Steve Williams (PSMFC), Lance Keller (Chelan PUD), and Scott Hopkins (Chelan PUD). <https://www.fpc.org/documents/memos/45-17.pdf>.
- FPC. 2018. Results from Gas Bubble Trauma Monitoring Protocol at Rock Island Dam, 2018. September 25, 2018 memorandum to Lance Keller (Chelan PUD) and Scott Hopkins (Chelan PUD). <http://www.fpc.org/documents/memos/64-18.pdf>.
- FPC. 2019. Results from Gas Bubble Trauma Monitoring Protocol at Rock Island Dam, 2019. September 23, 2019 memorandum to Lance Keller (Chelan PUD) and Scott Hopkins (Chelan PUD). <http://www.fpc.org/documents/memos/36-19.pdf>.
- FPC. 2021. Gas Bubble Trauma Monitoring Protocol and GBT.net Data Entry User’s Manual. Manual Version – 2021 Season, Updated March 24, 2021. <https://www.fpc.org/documents/metadata/GBTMonitoringProtocol.pdf>
- System Operational Request. 2021-3. Requested operations to mitigate for and reduce high water temperatures in the lower Snake River reservoirs. July 1, 2021 SOR submitted to TMT for discussion on July 2, 2021. <https://www.fpc.org/documents/sors/sor21/SOR%202021-3.pdf>
- U.S. Army Corps of Engineers. 2008. 2008 Dissolved Gas and Water Temperature Monitoring Report, Columbia River Basin. Columbia Basin Water Management Division, Reservoir Control Center, Water Quality Unit. December 2008. Appendix M. [http://pweb.crohms.org/tmt/wqnew/tdg\\_and\\_temp/2008/](http://pweb.crohms.org/tmt/wqnew/tdg_and_temp/2008/)

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.