MEMORANDUM

TO: Charlie Morrill (WDFW)

FROM: Michele DeHart

DATE: December 29, 2017


In response to your request, the Fish Passage Center (FPC) staff has reviewed the last ten years of gas bubble trauma (GBT) monitoring data from the five FCRPS projects where GBT monitoring occurs, over the last ten years (2008-2017). In addition, we also reviewed project operations and total dissolved gas (TDG) data from the upstream project(s). Specific to your request, we summarize how often the 15% GBT action criterion has been met or exceeded over the last ten years and provide an analysis of GBT incidence rates at corresponding tailrace TDG levels. Below is a brief summary of our findings followed by a more detailed discussion.

Because your request was made in support of discussions by the Columbia River System Operation (CRSO) NEPA Environmental Impact Statement (EIS) process, this review is being made available to the entire CRSO Fish Technical Team and the region. In addition, the FPC requests that this memorandum is included in the formal record for the NEPS EIS process for the CRSO EIS because this analysis is relative to consideration of various spill for fish passage operations alternatives.

- This analysis indicates that the GBT action criterion is not triggered at TDG levels less than 120% in the tailrace and even rarely triggered at tailrace TDG levels above 125%.
- Over the last ten years, GBT samples have been conducted at FCRPS facilities under various TDG levels, even as high 140%.
• With these data, we evaluated how often the 15% fin GBT incidence criterion has been met at each of the FCRPS projects over the last ten years, and at what TDG levels.

• Over the last ten years, the action criteria of ≥15% fin GBT incidence has only been met in four times, out of a possible 1,004 GBT samples (where our sample size criterion of ≥75 fish examined were met).
  o One of these instances was an anomaly, as it was later determined that the examiner may have misidentified deformed dorsal fin rays for signs of GBT. When corrected for this mistake, the GBT incidence rate for this sample was ~8%.
  o The remaining three instances occurred when tailrace TDG levels at the upstream project were ≥125%. These high tailrace TDG levels were the result of excess spill due to flows in excess of hydraulic capacity and/or powerhouse/unit outages.

• In addition to the three samples that met or exceeded the 15% GBT action criterion (minus the one anomalous sample), there were 41 other GBT samples whose associated tailrace TDG levels were ≥125% that had fin GBT incidence rates well below the 15% criterion.

Overview

The Gas Bubble Trauma (GBT) monitoring program has been implemented annually since 1995. The objective of the juvenile salmonid gas bubble trauma (GBT) monitoring program is to provide a measure of the exposure to harmful levels of total dissolved gas (TDG) experienced by migrating juvenile salmonids. The monitoring assesses both the incidence and severity of exposure, and provides an “early warning” of potentially harmful levels of TDG. The data are reported to the fisheries management entities and the water quality agencies of Washington and Oregon, and are available to other interested parties through Fish Passage Center weekly reports and daily postings to the FPC Web site during the season (http://www.fpc.org/smolt/gasbubbletrauma.html). The fisheries management entities review the data in-season to determine if modifications to spill are necessary based on the GBT monitoring. The action criteria for GBT is established as 15% of sampled fish showing any signs of fin GBT, or 5% of the fish sampled showing severe signs of fin GBT. Signs of fin GBT are deemed severe when ≥26% of an unpaired fin is covered with bubbles. Spill may be curtailed, if possible, when one or both of these action criteria are met.

Over the last ten years, GBT monitoring has occurred at five of the FCRPS projects. These five projects include Lower Granite, Little Goose, and Lower Monumental dams on the Lower Snake River and McNary and Bonneville dams on the Mid-Columbia River. GBT sampling typically begins soon after the start of the voluntary spill season and continues through the end of the spill season, unless high temperature sampling protocols are implemented and/or sample size criteria cannot be met. The goal of the GBT monitoring program is to sample 100 salmonids each day of sampling at each site. A daily sample size of 100 fish is necessary to assure that the sample observation accurately represents the population incidence of signs of gas bubble trauma. The proportion of each species sampled (limited to Chinook and steelhead) is dependent upon their prevalence at the time of sampling. Yearling Chinook and steelhead dominate the samples in the spring, with samples gradually shifting to subyearling Chinook
predominance in the summer through the end of August. Sampling at Snake River facilities typically occurs once per week while that at Mid-Columbia sites typically occurs twice per week.

Methods

**Summarizing GBT and Upstream Project Operations Data**

Per your request, the FPC summarized GBT monitoring data over the last ten years in figures (see Appendix A), by year and GBT sampling site. In addition to providing GBT data in these figures, we also provide supporting figures of project operations and TDG data from the upstream project(s). Since 2007, the FPC has provided an assessment of actual spill operations compared to what has been specified in the annual Fish Operations Plan (FOP), which generally coincides with 2014 Biological Opinion (BiOp) spill levels. Using the same methodology that was utilized for this spill to the FOP tool, we estimated what the specified BiOp spring spill levels would have been for the FCRPS project immediately upstream of where the GBT sample was taken. To estimate specified BiOp spill at the upstream project, we relied on hourly flows, specified BiOp spill levels from the FOP, and project specific powerhouse minimums (PH Min). Because of PH min requirements, BiOp spill levels cannot always be met at low flows. In these cases, BiOp spill was assumed to be all flows in excess of PH Min and miscellaneous flows. For the figures of LGR GBT data, we plotted actual operations and TDG from Dworshak Dam (DWR), with no estimated BiOp spill, as the BiOp does not call for specific spill levels from DWR.

The Corps of Engineers (COE) holds waivers for the management of total dissolved gas (TDG) in the lower Snake and Mid-Columbia rivers from each of the states of Oregon and Washington. The waiver from the state of Oregon only requires compliance with 120% TDG in the tailrace of each project, while that for the state of Washington requires compliance with 120% TDG in the tailrace and 115% TDG in the next downstream forebay. The one exception to this is Bonneville Dam, where there is no forebay requirement from either state. TDG at this site is solely managed to the tailrace monitor at Cascade Island (or Warrendale when Cascade Island is out of service). The two states also differ in their methodologies on how to estimate the 12-hour average TDG. For Oregon, the 12-hour average estimate is based on the 12 highest hourly TDG measurements in a single calendar day (not necessarily consecutive). For Washington, the 12-hour average is based on 12-hour rolling averages. The highest of the rolling averages is what is reported as the 12-hour average for a given day. The location of a TDG monitor dictates which of these methodologies is used for compliance monitoring. The Washington methodology applies to all the Snake River projects, as well as the Mid-Columbia forebay monitors. On any given day, compliance of the Mid-Columbia tailrace monitors is determined using either the Washington or Oregon methodology, whichever is most restrictive. Unlike the FCRPS projects on the Lower Snake and Mid-Columbia, there is no annual waiver for TDG generated by Dworshak Dam (DWR). Instead, TDG from DWOR is generally managed to the Environmental Protection Agency (EPA) 110% standard. Therefore, supporting graphs for LGR GBT data provide the average TDG in the DWR tailrace (based on Oregon methodology), compared to the 110% EPA standard.
Per your request, the figures provided in Appendix A are similar in form to what was provided in a previous FPC memo to ODFW (FPC 2017b). Therefore, these graphical summaries of GBT data and upstream project operations data are limited to the spring period, as this was the focus of the ODFW request.

**Assessing GBT Monitoring Data and Upstream TDG Levels**

As a result of involuntary spill events, data for GBT are available over a wide range of TDG concentrations. This is true even over the last ten years where observations have occurred at tailrace TDG levels as high as nearly 140%. The wide range of TDG observations over the last ten years allowed us to assess the impacts of TDG on the salmonid population. For this assessment, some flexibility was considered and all daily samples with greater than 75 fish were included. In addition, this assessment was limited to only the FCRPS monitoring sites (Lower Granite, Little Goose, Lower Monumental, McNary, and Bonneville Dam). Unlike the graphical summaries in Appendix A, this assessment utilizes GBT sample data over the entire season, as long as ≥75 fish were examined for GBT.

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

**Results**

As mentioned above, graphical summaries of GBT monitoring and project operations and TDG data from the upstream project(s) are available in Appendix A (Figures A.1-A.50). In addition, we provide a brief summary of each of the instances where the 15% GBT action criterion has been met or exceeded at the FCRPS GBT monitoring facilities over the last 10 years (Table 2). The following discussion is a brief summary of GBT monitoring results from each project over the last ten years.
Table 2. Summary of GBT samples that met or exceeded 15% GBT action criterion, 2008-2017.

<table>
<thead>
<tr>
<th>Project</th>
<th>Date</th>
<th>GBT Rate</th>
<th>Upstream TDG</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGS</td>
<td>4/5/2008</td>
<td>25%</td>
<td>112%</td>
<td>Deformed fin rays misidentified as GBT. Incidence rate likely 8%.</td>
</tr>
<tr>
<td>LGS</td>
<td>6/14/2010</td>
<td>15%</td>
<td>125%</td>
<td>Excess spill at LGR due to flows in excess of hydraulic capacity.</td>
</tr>
<tr>
<td>LMN</td>
<td>5/28/2011</td>
<td>23%</td>
<td>139%</td>
<td>Excess spill at LGS due to high flows and powerhouse outage.</td>
</tr>
<tr>
<td>LMN</td>
<td>5/10/2017</td>
<td>22%</td>
<td>128%</td>
<td>Excess spill at LGS due to flows in excess of hydraulic capacity</td>
</tr>
</tbody>
</table>

*Lower Granite Dam (LGR)*

Graphical summaries for GBT data from LGR, and upstream operations and TDG, can be found in Appendix A (Figures A.1-A.10). GBT sampling at LGR is typically used to provide a background level of GBT for migrating juvenile salmonids that are first entering the hydrosystem. Planned GBT sampling at LGR is typically conducted once per week and only in the spring period since, if TDG were to exceed 115% in the forebay, it would occur due to uncontrolled spill at upstream storage projects during the spring period. However, in 2017, GBT sampling at LGR was extended into the summer. This was necessary because of the rehabilitation work that was being conducted to Unit #3 at DWR. Due to this work, powerhouse capacity at DWR was limited to 4.5-4.8 Kcfs, thus necessitating spill in excess of the 110% TDG standard for most of the spring and possibly even the summer.

Over the last ten years, 101 GBT samples have been conducted at LGR. Of the 101 GBT samples at LGR, 84 met our sample size criteria (≥75 fish examined) for assessing GBT rates and upstream TDG (Figure 1). There have been no instances when GBT incidence rates at LGR have met or exceeded the 15% GBT action criterion. In fact, the highest GBT incidence rate observed at LGR over the last ten years was 4%, which occurred in on April 28, 2017 (Figure A.10). Total dissolved gas levels in the LGR forebay were 105% at this time.
Figure 1. Fin GBT incidence rate (%) at Lower Granite Dam as a function of the 12-hour average TDG in the Lower Granite forebay.

Little Goose Dam (LGS)

Graphical summaries for GBT data from LGS, and upstream operations and TDG, can be found in Appendix A (Figures A.11-A.20). Planned GBT sampling at LGS is typically once per week for the entire spill season, unless the sample size criterion cannot be met. Over the last ten years, 194 GBT samples have been conducted at LGS. Of these 194 GBT samples, 155 met our sample size criteria (≥75 fish examined) for assessing GBT rates and upstream TDG (Figure 2).

There have been two instances when GBT incidence rates at LGS have met or exceeded the 15% GBT action criterion (Table 2). The first instance was April 15, 2008, when 25% of the GBT sample had signs of GBT in the fins (Figure A.11). The estimated TDG in the LGR tailrace was approximately 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 paired fins when the dorsal fin information was excluded. Two yearling Chinook in the sample were identified with GBT. With the dorsal GBT excluded, the GBT rate for this date was likely closer to 8%. The second instance when the GBT incidence rate at LGS met or exceeded the 15% GBT action criterion was on June 14, 2010 (Figure A.13). The GBT incidence rate for this date was 15% and the estimated TDG in the LGR tailrace was approximately 125% (Figure 2). The high TDG in the LGR tailrace was the result of excess spill at LGR, which was due to flows in excess of hydraulic capacity than began in early June (Figure A.13).

There was a third instance where the GBT incidence rate at LGS was close to, but did not meet, the 15% GBT action criterion. On June 13, 2011, the GBT incidence rate at LGS was 14% and the estimated TDG in the LGR tailrace was approximately 126% (Figure 2, Figure A.14). As with the instance in 2010, the high TDG in the LGR tailrace was the result of excess spill at
LGR, which was due to flows in excess of hydraulic capacity than had occurred throughout most of that spring (Figure A.14).

![Graphical summary for GBT data from LMN, and upstream operations and TDG, can be found in Appendix A (Figures A.21-A.30). Planned GBT sampling at LMN is typically once per week for the entire spill season, unless the sample size criterion cannot be met. Over the last ten years, 199 GBT samples have been conducted at LMN. Of these 199 GBT samples, 140 met our sample size criteria (≥75 fish examined) for assessing GBT rates and upstream TDG (Figure 3).

There have been two instances when GBT incidence rates at LMN have met or exceeded the 15% GBT action criterion (Table 2). The first instance was May 28, 2011, when 23% of the GBT sample had signs of GBT in the fins (Figure A.24). The estimated TDG in the LGS tailrace was approximately 139%. The high TDG in the LGS tailrace was the result of high spill levels at LGS, which were due to a week-long powerhouse outage during a period of high flows. During this time, nearly 100% of river flow was spilled at LGS, resulting in spill levels of 136-182 Kcfs and tailrace TDG levels as high as 139% (Figure A.24). In fact, TDG levels in the LMN forebay were also as high as 139% during this period. The second instance when the GBT incidence rate at LMN met or exceeded the 15% GBT action criterion was on May 10, 2017 (Figure A.30). The GBT incidence rate for this date was 22% and the estimated TDG in the LGS tailrace was approximately 128% (Figure 3). The high TDG in the LGS tailrace was the result of excess spill at LGS, which was due to flows in excess of hydraulic capacity than had occurred throughout much of the spring period (Figure A.30).
Figure 3. Fin GBT incidence rate (%) at Lower Monumental Dam as a function of the 12-hour average TDG in the Little Goose tailrace. Tailrace TDG is offset by estimated water transit time from Little Goose to Lower Monumental.

McNary Dam (MCN)

Graphical summaries for GBT data from MCN, and upstream operations and TDG, can be found in Appendix A (Figures A.31-A.40). Planned GBT sampling at MCN is typically twice per week for the entire spill season, unless the high temperature protocol is implemented and/or sample size criterion cannot be met. Over the last ten years, 353 GBT samples have been conducted at MCN. Of these 353 GBT samples, 341 met our sample size criteria (≥75 fish examined) for assessing GBT rates and upstream TDG (Figure 4).

There have been no instances when GBT incidence rates at MCN have met or exceeded the 15% GBT action criterion. The highest GBT incidence rate observed at MCN over the last ten years was 5%, which occurred twice in June of 2011 (Figure 4, Figure A.34). In both of these instances, TDG in the Ice Harbor tailrace was ≥125%. This high TDG was due to excess spill at IHR, which was due to flows in excess of hydraulic capacity (Figure A.24). There was one instance of an 8% GBT incidence rate (April 12, 2012, Figure A.35) but only 37 fish were examined for GBT and, therefore, the sample size criterion was not met.
**Bonneville Dam (BON)**

Graphical summaries for GBT data from BON, and upstream operations and TDG, can be found in Appendix A (Figures A.41-A.50). Planned GBT sampling at BON is typically twice per week for the entire spill season, unless the high temperature protocol is implemented and/or sample size criterion cannot be met. Over the last ten years, 365 GBT samples have been conducted at BON. Of these 365 GBT samples, 284 met our sample size criteria (≥75 fish examined) for assessing GBT rates and upstream TDG (Figure 5).

There have been no instances when GBT incidence rates at BON have met or exceeded the 15% GBT action criterion. The highest GBT incidence rate observed at BON over the last ten years was 7%, which occurred on June 7, 2017 (Figure 5, Figure A.50). The estimated TDG in the John Day (JDA) tailrace was approximately 127% (Figure 5). During this time, spill at JDA was in excess of BiOp specified levels, due to flows in excess of hydraulic capacity. The same was occurring at The Dalles Dam (TDA) (Figure A.50).
Conclusion

Results from the GBT monitoring program over the last ten years indicate that signs of GBT are minimal when TDG is managed to the present 115%/120% TDG gas waiver standards. Furthermore, the action criterion of 15% fin GBT incidence rate has only been met when tailrace TDG levels are at or above 125%, which has only occurred when excess spill is provided due to flows are in excess of hydraulic capacity and/or lack of market. It is worth noting that, although all three incidences where the 15% fin GBT criterion was met occurred at TDG levels of ≥125% (Table 2, anomalous sample excluded), there were 41 other GBT samples whose associated tailrace TDG levels were ≥125% that had fin GBT incidence rates well below the 15% criterion. These analyses indicate that the action criterion is not triggered at TDG levels less than 120% in the tailrace and even rarely triggered at tailrace TDG levels above 125%. The results from the last ten years are consistent with what we have found when considering the 20+ years of GBT data (FPC 2017a).

Literature Cited:


Appendix A
Supporting Figures

Lower Granite Dam GBT Samples .................................................. Figures A.1-A.10
Little Goose Dam GBT Samples ..................................................... Figures A.11-A.20
Lower Monumental Dam GBT Samples ......................................... Figures A.21-A.30
McNary Dam GBT Samples ......................................................... Figures A.31-A.40
Bonneville Dam GBT Samples ..................................................... Figures A.41-A.50
**Figure A.1.** *Top:* Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2008 (April 3-June 20). *Bottom:* Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2008. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.2. **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2009 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2009. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.3. **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2010 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2010. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.4. Top: Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2011 (April 3-June 20). Bottom: Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2011. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.5. **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2012 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2012. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Lower Granite Dam (2013)

Figure A.6. **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2013 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2013. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.7. **Top**: Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2014 (April 3-June 20). **Bottom**: Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2014. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.8. **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2015 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2015. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.9.  **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2016 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2016. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.10  **Top:** Actual flow and spill at Dworshak Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2017 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Granite Dam (left axis) and average total dissolved gas at Dworshak Dam tailrace and Lower Granite Dam forebay (right axis) in 2017. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits/standards (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.11  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2008 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2008. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Dagger (†) denotes anomalous GBT sample (see text for details). All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.12  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2009 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2009. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.13  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2010 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2010. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.14  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2011 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2011.  Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.15  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2012 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2012. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.16  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2013 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2013. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.17  Top: Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2014 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2014. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.18  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2015 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2015. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.19  **Top:** Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2016 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2016. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.20  *Top:* Actual flow and spill at Lower Granite Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2017 (April 3-June 20).  *Bottom:* Gas Bubble Trauma incidence rate (%) at Little Goose Dam (left axis) and average total dissolved gas at Lower Granite Dam tailrace and Little Goose Dam forebay (right axis) in 2017. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.21  **Top:** Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2008 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2008. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.22  Top: Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2009 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2009. Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.23  
**Top:** Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2010 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2010. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.24  Top: Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2011 (April 3-June 20). Bottom: Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2011. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.25  **Top:** Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2012 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2012. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Lower Monumental Dam (2013)

Figure A.26  **Top:** Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2013 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2013.  Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.

Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Lower Monumental Dam (2014)

Figure A.27  Top: Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2014 (April 3-June 20). Bottom: Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2014. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.28  **Top:** Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2015 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2015.  Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.29  Top: Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2016 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2016. Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Lower Monumental Dam (2017)

Figure A.30  **Top:** Actual flow and spill at Little Goose Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2017 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Lower Monumental Dam (left axis) and average total dissolved gas at Little Goose Dam tailrace and Lower Monumental Dam forebay (right axis) in 2017. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.31  Top: Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2008 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2008.  Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.32  Top: Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2009 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2009. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.33  **Top:** Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2010 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2010. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.34  **Top:** Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2011 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2011.  Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.35  **Top:** Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2012 (April 3-June 20).  **Bottom:** Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2012. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.36 Top: Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2013 (April 3-June 20). Bottom: Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2013. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.37  Top: Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2014 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2014.  Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.38  Top: Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2015 (April 3-June 20).  Bottom: Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2015. Note that the y-axis for GBT incidence rate starts at -5%.  This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line).  For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.39  **Top:** Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2016 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2016. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.40 **Top:** Actual flow and spill at Ice Harbor Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary forebay (right axis) in 2017 (April 3-June 20). **Bottom:** Gas Bubble Trauma incidence rate (%) at McNary Dam (left axis) and average total dissolved gas at Ice Harbor and Priest Rapids tailraces and McNary Dam forebay (right axis) in 2017. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. All GBT samples depicted in graph met sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.41  **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2008 (April 10-June 15). **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2008. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.42  **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2009 (April 10-June 15).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2009. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.43 **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2010 (April 10-June 15). **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2010. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
**Bonneville Dam (2011)**

**Figure A.44 Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2011 (April 10-June 15). **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2011. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.45  **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2012 (April 10-June 15). **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2012. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.46  **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2013 (April 10-June 15).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2013.  Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph.  Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Bonneville Dam (2014)

**Figure A.47 Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2014 (April 10-June 15). **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2014. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Bonneville Dam (2015)

Figure A.48  **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2015 (April 10-June 15).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2015. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.49  **Top:** Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2016 (April 10-June 15).  **Bottom:** Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2016. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.
Figure A.50  Top: Actual flow and spill at The Dalles Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville forebay (right axis) in 2017 (April 10-June 15).  Bottom: Gas Bubble Trauma incidence rate (%) at Bonneville Dam (left axis) and average total dissolved gas at The Dalles and John Day tailraces and Bonneville Dam forebay (right axis) in 2017. Note that the y-axis for GBT incidence rate starts at -5%. This was done in order to display all GBT sample data, including days where GBT incidence rates were 0% (i.e., black horizontal line). For convenience, TDG waiver limits (blue and green dotted horizontal lines) and the 15% GBT action criterion (black dotted horizontal line) are provided in each graph. Asterisk denotes samples that did not meet the sample size criterion (≥75 fish examined) for inclusion in assessment of GBT and upstream TDG levels.