Project 35013

Species- and Site-specific Impacts of Gas Supersaturation on Aquatic Animals

Sponsor: USGS, CRRL
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(1) ISRP: paragraph 1, last sentence "...is the research likely to lead to alternative proposals that are already aimed at reducing gas in the river?"

The proposal was submitted primarily at the request of the state water quality agencies to address critical uncertainties the answers to which are needed to consider changing the TDG standard. I am sure that if the standard is changed, the hydropower operators will adjust the degas program. I cannot anticipate what form those alternatives might take.

(2) ISRP: paragraph 2, 4th sentence: "The FWP is not mentioned but should be referenced in the response".

This proposal addresses many elements of the FWP by examining whether or not an action to improve anadromous fish passage (i.e., voluntary spill that allows TDGS = 120%) has adverse effects on biological diversity and resident fish species (FWP, page 13, Basin wide Provisions section A. 2. 5th & 9th bullets). It is conceivable that this research will determine that allowing TDGS > 110% is detrimental to some aquatic animals, such as Pacific lamprey, which the FWP lists specifically as needing to be restored (FWP, page 16, Biological Objectives, section 2, Objectives of Biological Performance, 1st bullet). The objectives and assumptions of the FWP are based on the natural, dynamic interactions of diverse species and healthy habitats within which they can persist. By examining the impacts of water management decisions on several aquatic animals, we will determine whether or not levels of gas supersaturation up to 120% alter the dynamic balance.

(3) ISRP: paragraph 2, 7th sentence: "...(can) this project be incorporated into the existing 199602100...or vise versa..."

If both projects are funded, this seems reasonable. Also, please see our response to ISRP review of project 199602100 and the comments from Bill Maslen, BPA COTR in section 7, below.

(4) ISRP: paragraph 3, factor (1). "...all three species tend to be bottom oriented and deep water species, and most TDG effects are in the upper two meters..."

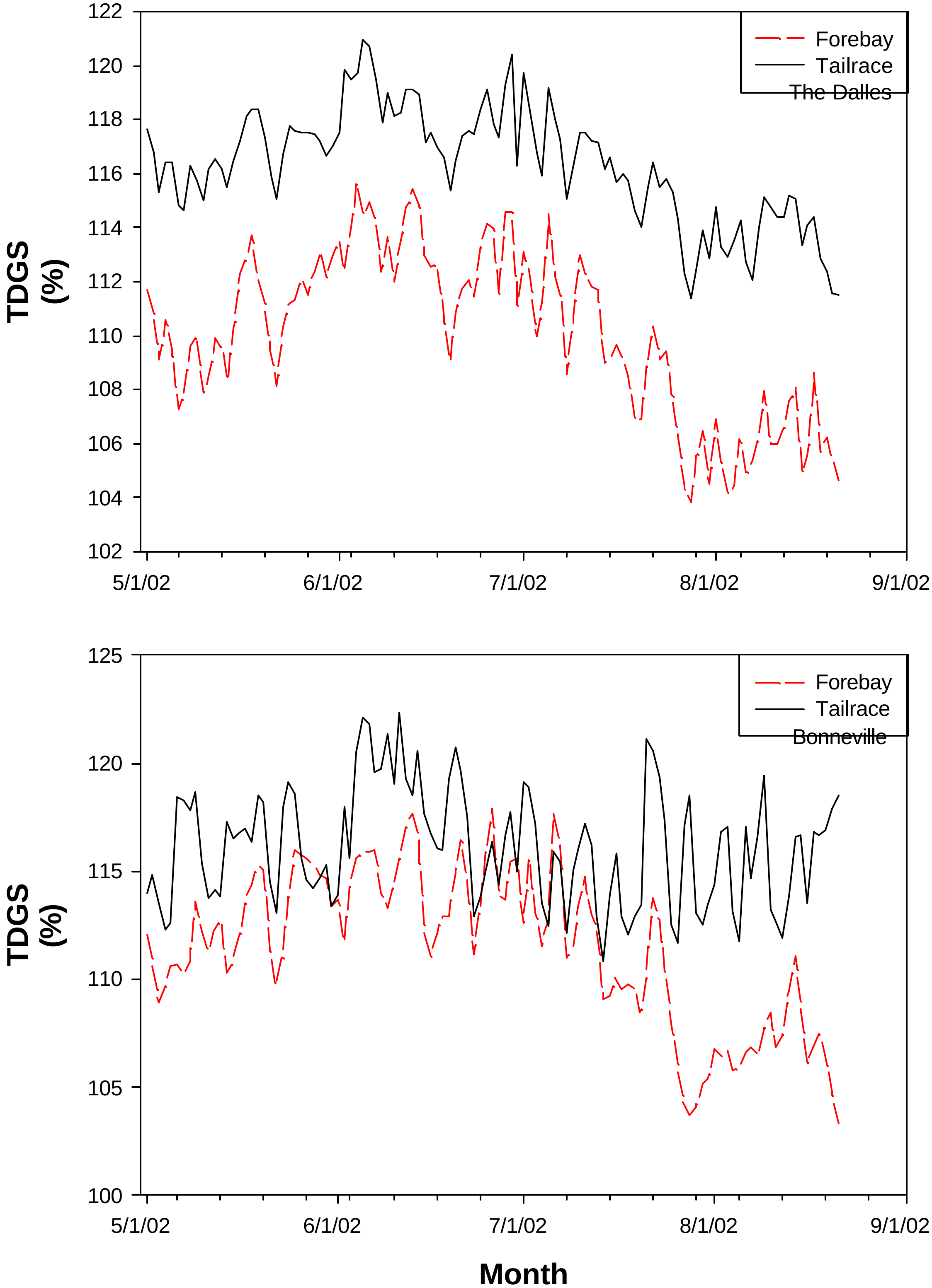
While this is true generally, there are documented times when they are at the surface: Pacific lamprey are in relatively shallow water when they go upstream past dams; white sturgeon are at the surface during the feeding frenzy when American shad immigrate; in a recent spill test at Libby Dam, bull trout captured down stream had signs of gas bubble disease. The real problem, however, is that the regulatory agencies do not have sufficient information to determine whether or not there is reason for concern.

(5) ISRP: paragraph 3, factor (2); paragraph 4 last 2 sentences; also paragraph 7. "the levels of TDG are generally not excessive at either The Dalles or Bonneville."

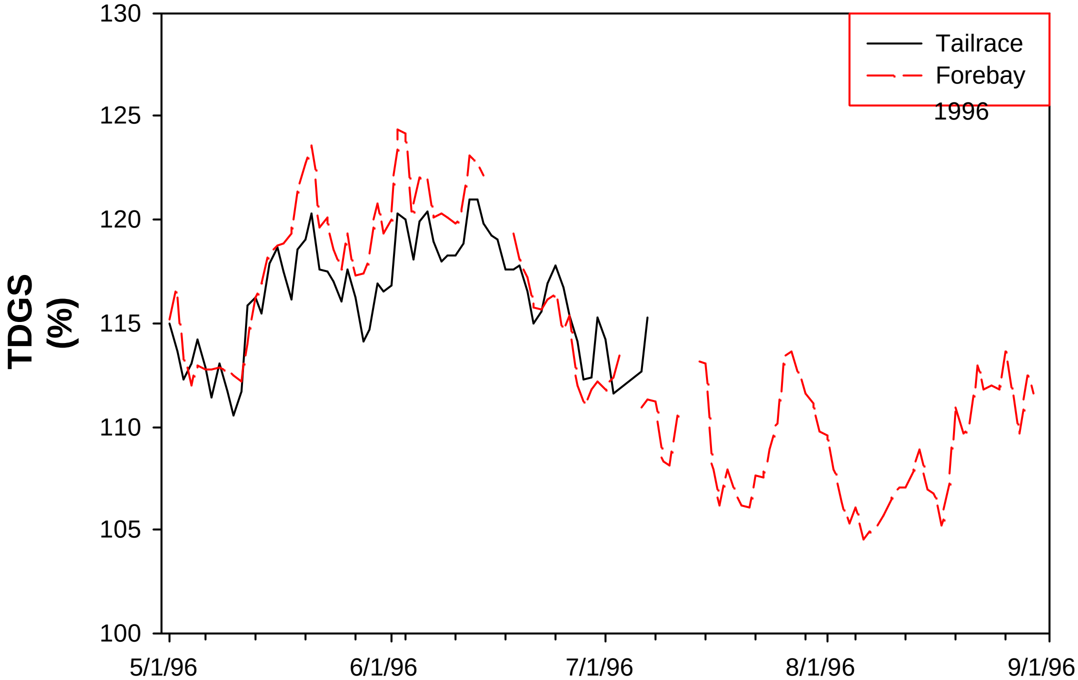
Based on the state wavier for the voluntary spill program, TDG must not exceed 120%. Again, it is at this level that the state water quality agencies need information. In laboratory studies we have (and will) expose animals to TDG > 120%, but this is to define the higher limits of responses (i.e., a positive control).

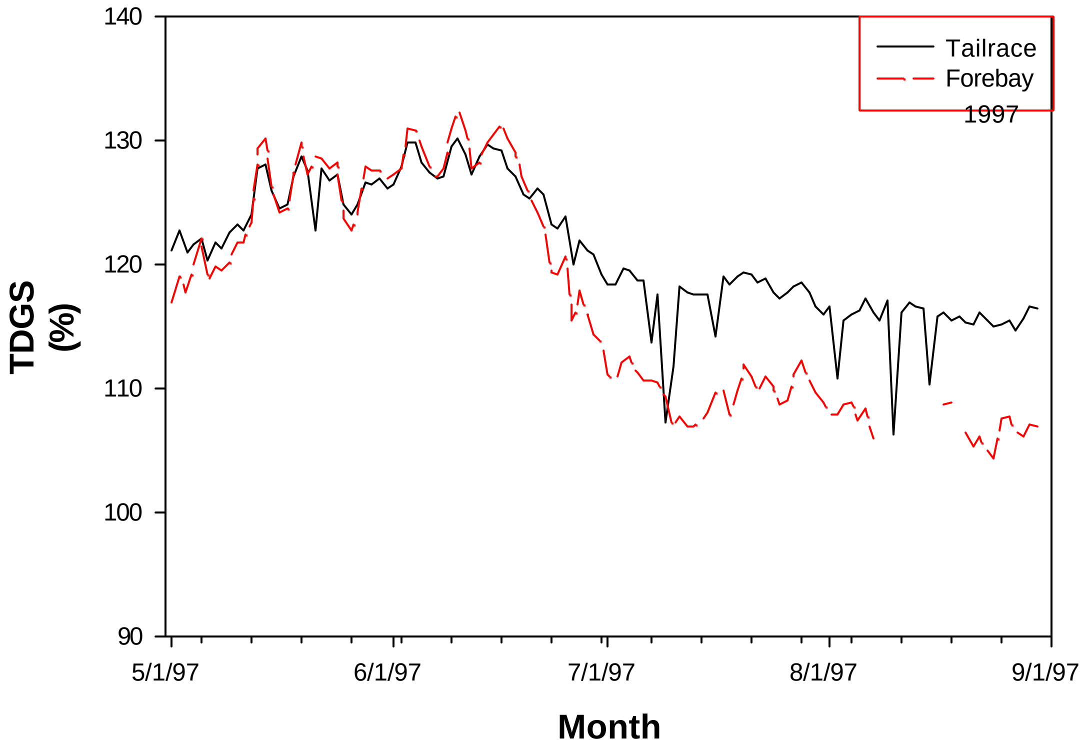
As is illustrated in the three graphs below, TDG below The Dalles Dam can exceed 120% and the Bonneville Dam forebay can exceed 115% under low flow (i.e., controlled spill); so, conditions in the Bonneville Pool can be adequate for our experiments. Under high flow conditions (i.e., 1997), TDG can exceed 135% in the tailraces and 125% in the forebays of both dams. We have learned from our work below Grand Coulee, however, that past performance is no guarantee of future TDG.

2002 TDGS for The Dalles and Bonneville Dams in a Low Flow Year

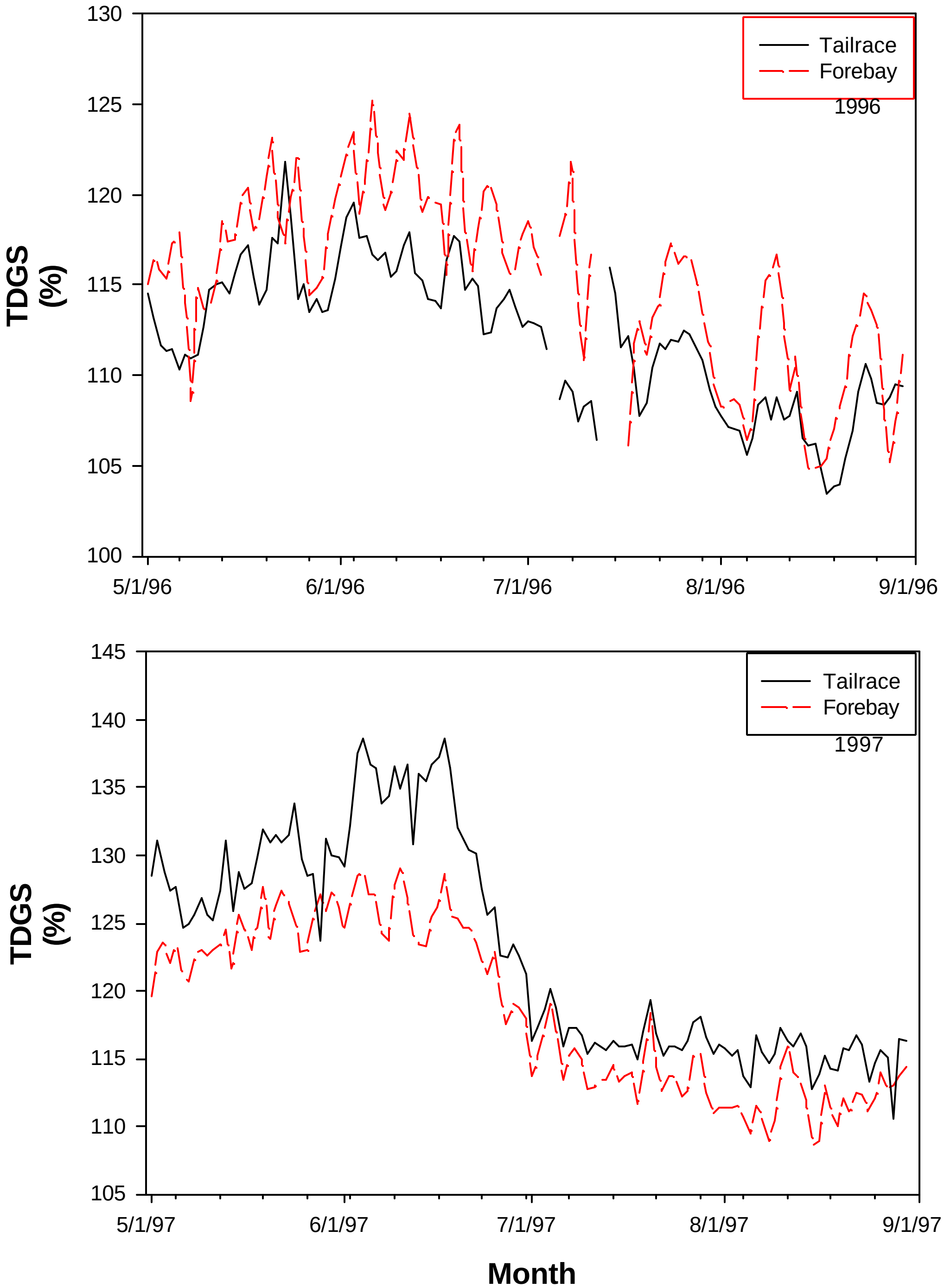


1996 & 1997 TDGS levels from the Tailrace and Forebay of the Dalles Dam





TDGS levels for April-August, 1996 & 1997 at Bonneville Dam



(6) ISRP: paragraph 3, factor (2); paragraph 4; also paragraph 7. Suggestions re: doing bull trout studies at Cabinet Gorge and lamprey studies at Willamette Falls.

We would have no problem conducting studies at these locations. We will also consider working in the Tucannon River, where the US Fish & Wildlife Service is capturing and tagging bull trout. A limiting factor is the areas of interest of BPA. Please consider the following email from Bill Maslen, BPA COTR (**Bold & underline** added for emphasis):

"Maslen, Bill - KEWR-4" <wcmaslen@bpa.gov>	To:"'Alec G Maule'" <alec_maule@usgs.gov>
08/06/02 07:17 AM	cc:
	Subject: RE: ISRP review of 199602100

Alec:
Thanks for the message and opportunity to comment.

I agree with you that the issues raised by ISRP on 199602100 are policy (and administrative). I also agree with the ISRP about the need for programmatic review of the overall monitoring program. Your project is not a stand-alone, but rather support for the GBD component of the monitoring program. As such, it seems the ISRP comments are really more relevant to those projects, not yours. Further, response to these policy questions are appropriate from managers and regulatory agencies, not project sponsors.

The priority for the new proposal (#35013) is also dependent on these same policy questions, particularly in terms of any management implications that might arise of GBD monitoring of non-salmonids species. **Further, some changes suggested by ISRP as being "more justified" would result in focus that is outside of BPA's responsibility (e.g., monitoring for effects of spill at Cabinet Gorge and at Willamette Falls).** With regard to combining projects, we would not do so if the total cost would go up. I believe there are other means to achieve efficiencies or better integration without the burden of increased cost. As you are aware, achieving increased cost efficiencies is a high priority to BPA and the region.

Bill

(7) ISRP: paragraph 5. "Some of the objectives do not spell out sample sizes or sampling schedules." "...proposal does not specify a sampling protocol that would be used to conduct field studies to determine if Pacific lampreys in the wild are impacted by TDG." "...how many adult salmon...at what TDG levels..."

Before conducting a full-scale field evaluation of TDG effects on lampreys, we believe it would be prudent to complete our proposed laboratory studies. Many characteristics of lampreys make it difficult to predict how they'll respond to excessive levels of TDG. For example, the arrangement and irrigation of the gills in lampreys is quite different than that of teleost fishes. Also, the lack of a gas bladder, a poorly developed lateral line system, and a single dorsal aorta with a cephalic circle in the region of the first gill pouch precludes using a teleost model to predict the effects of TDG on lampreys. In reality, we don't even know what TDG levels might be considered "high" for lampreys. Because we may find that lampreys deal quite well with high levels of TDG, conduct of the laboratory work may reduce the need for a large field study and lead to cost savings.

Thus, at this time, it would be premature to provide a detailed protocol for any field sampling we might do. Most likely, however, our proposed fieldwork would involve procedures similar to those already in use for the juvenile salmonid GBT monitoring program. Lampreys would be captured at Bonneville Dam (or other sites) using traps during the time of their upstream migration, from about May through August. Fish would be anesthetized and examined for signs of GBT. We will attempt to monitor trends in GBT signs and assign some level of severity to them. Again, before we can start this work, the laboratory research must be completed since we don't know how lampreys will manifest signs of GBT nor how such signs might relate to survival or performance.

Regarding adult salmon, researchers at the University of Idaho have implanted archival depth and temperature tags into Snake River adult spring chinook salmon collected at Bonneville Dam (http://www.ets.uidaho.edu/coop/download.htm). The data from these tags describes the depth and temperature history of these fish as they migrate from Bonneville Dam to their home hatchery. We propose to combine these data with the TDGS monitoring data collected in the forebays and tailraces of the dams to establish exposure scenarios that we will duplicate in the laboratory experiments. Again, since we are primarily interested in TDGS created under voluntary spill, most of these exposures will be at TDGS $\leq$ 120% and will vary based on tag data describing depth and time. Sample sizes will equal 12 adult salmon per treatment. Based on power analyses of our earlier work on adult salmon reproductive success (Gale et al. 2001; in review), with a = 0.05, sample sizes of 12 will detect a 100 egg difference in relative fecundity, a 0.7 mm difference in egg diameter, and a 0.04 g difference in egg mass with 90% power. All of these differences represent about 10% of mean values from control fish.

(8) ISRP: paragraph 6. "If (sturgeon) larvae are exposed to TDG, are the impacts likely to be significant to limiting the population below Bonneville? Recruitment is occurring. What mitigation would be possible..."

One of the objectives of this project is to provide information on the vertical distribution of white sturgeon larvae in the water column. We propose conducting this work downstream from Bonneville Dam simply because there is a high probability of encountering sturgeon larvae in this reach. The research is intended to provide insight as to why recruitment failures may be occurring in other areas of the Columbia Basin, particularly in the upper reaches of the Columbia including Canadian waters where gas levels are high and sturgeon recruitment is negligible. While there appears to be substantial recruitment of white sturgeon to the fisheries downstream from Bonneville Dam and the TDG levels below Bonneville do reach and exceed 120% (see figures above), it is possible that the numbers of eggs spawned could be so great in this reach that a substantial proportion of larvae could be lost to gas bubble trauma and recruitment would still be high. This may not be the case in other areas of the Columbia River basin where numbers of spawning fish are very low and dissolved gas levels are quite high. If this work shows that minimal numbers of white sturgeon larvae rise to depths that could cause gas bubble trauma, no mitigation (beyond existing standards) would be called for. However, if the work shows that substantial numbers may rise to depths that could cause harm when TDG levels are high, mitigation in areas typified by high TDG levels may be necessary to allow populations to rebound through natural production.

There is not much data available on the vertical distribution of sturgeon larvae. We have captured them in surface nets and nets fished on the bottom, but the sampling was not done in a manner that allowed comparisons. The NMFS did a bit of sampling downstream from Bonneville Dam that showed that the majority of white sturgeon embryos traveled downstream near the bottom. In a Russian study, Veshchev (1981) sampled in the lower, middle, and surface 3 m layers for *Acipenser guldenstadti* and *A. stellatus*. At two sites, approximately 67% of the embryos were caught in bottom sets, 28-30% in middle sets, and 3-4% in surface sets. However, even if the distribution is skewed and most of the larvae are found along the bottom, the question to ask is, do all larvae eventually end up at the surface or do the majority remain near the substrate? If, through mixing by turbulence, every larva eventually gets pushed near the surface (even though only a small percentage is there at any given time) then potentially every larva could be exposed to high gas levels. Our work in the laboratory showed that it doesn't take a very long exposure for sturgeon larvae to show signs of gas bubble trauma.

The objective of this proposal is to advise the water quality agencies as to effects of the current water management strategy on aquatic animals. If there are effects at 110% ≤ TDG ≥ 120%, then current mitigation efforts to reach the 110% standard will continue.

Veshchev, P.V. 1981. Effect of dredging operations in the Volga River on migration of sturgeon larvae. Journal of Ichthyology, 21(5):108-112.

(9) ISRP: paragraph 9: "The response should include a review of Earl Dawley's resident fish and benthic organism studies."

Ryan et al. (2000) provided the most extensive study of effects of TDGS on non-salmonid fishes to date. Sampling from the Snake and lower Columbia rivers from 1994 through 1997, they examined almost 40,000 non-salmonid fishes (27 species) and 5,500 benthic invertebrates. They also conducted 151 4-d, in-river netpen holding experiments with fish collected from the river. Unfortunately they encounter very few fish of the species we will consider in this project; they examined 5 lamprey, 1 sturgeon, but no bull trout. Of the almost 5,500 benthic invertebrates sampled from water less than 0.6 m deep only 7 (all cladocera) had any sign of BGD. It would have been informative if Ryan et al. (2000) had reported water level fluctuations to determine the range of hydrostatic compensation available to these benthic invertebrates.

Similar to our recent work in Lake Rufus Woods, Ryan et al. (2000) reported that there was a 30-fold difference in the prevalence of signs of GBD in the most frequently examined fish. Signs of GBD were most frequent when TDGS was greater than 120% and increased as TDGS increased. In 1996, when TDGS exceeded 120% for much of April through June, Ryan et al. (2000) examined 1,227 Catastomidae larva below

Bonneville Dam. Of these larva, 14.3% had signs of GBD, as compared to 5.1% of the 1,116 larger fish examined. This information is in agreement with other studies that have shown that small fish are more sensitive to GBD than are large fish. Furthermore, based on the distribution of sucker species in the Columbia River, these larva should all be largescale or bridgelip suckers—which may support our preliminary analyses of unpublished field studies in Lake Rufus Woods and lab studies. It appears that largescale suckers and bridgelip suckers are more susceptible to GBD than are longnose suckers; and that this sensitivity may be expressed by reducing survival of individuals during early development (e.g., larvae, fry or young juveniles) resulting in missing year classes of these sucker species during years of high TDGS.

Ryan et al. (2000) developed several models to predict (1) prevalence of GBD in field samples based on an exposure index that characterizes the TDGS during a 7-d period, and (2) % mortality based on prevalence of GBD in netpen experiments. The former model was very predictive with $R^2 = 0.79$ when all species were combined ($n > 13,000$). The mortality model, however, was of much less value as the $R^2 = 0.049$. Moreover, Ryan et al. (2000) indicate that species-specific modeling was unsuccessful. As we reported for shallow tank lab experiments with salmonids (Hans et al. 1999, Mesa et al. 2000) and in our unpublished data on similar lab experiments with non-salmonid fish, Ryan et al. (2000) reported high variability in mortality and severity of signs in netpen studies. It appears that the combination of differences in exposure history, species-specific sensitivity and individual sensitivity will continue to make predictive models elusive.

Hans, K.M., M.G. Mesa, and A.G. Maule. 1999. Rate of disappearance of gas bubble trauma signs in juvenile salmonids. Journal of Aquatic Animal Health 11:383-390.

Mesa, M. G., L. K. Weiland, and A. G. Maule. 2000. Progression and severity of gas bubble trauma in juvenile salmonids. Transactions American Fisheries Society. 129: 174-185.

Ryan, B. A., E. M. Dawley, and R.A. Nelson. 2000. Modeling the effects of supersaturated dissolved gas on resident aquatic biota in the main-stem Snake and Columbia rivers. North American Journal of Fisheries Management 20: 192-204.