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CHANGES IN GAS BUBBLE DISEASE SIGNS FOR MIGRATING JUVENILE SALMONIDS EXPERIMENTALLY EXPOSED TO SUPERSATURATED GASSES, 1997

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CHANGES IN GAS BUBBLE DISEASE SIGNS OF MIGRATING JUVENILE SALMONIDS EXPERIMENTALLY EXPOSED TO SUPERSATURATED GASSES, 1997

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EXECUTIVE SUMMARY

This study was designed to answer the question of whether gas bubble disease (GBD) signs change as a result of the hydrostatic conditions juvenile salmonids encounter when they enter the turbine intake of hydroelectric projects during their downstream migration. An answer to this question would substantiate the effectiveness of the present monitoring of juvenile salmonids for GBD signs and would provide needed information for river managers.

The study began in 1996 at Little Goose Dam using hatchery steelhead. However, results were not as conclusive as we had hoped due to the length of time between release in the forebay and recapture at the juvenile facility. This year there were insufficient numbers of test fish available in the Snake River, so the study was conducted at John Day Dam using juvenile coho salmon. Because there are insufficient numbers of passive integrated transponder (PIT) tag recorders in the lower Columbia River to provide data for survival estimates, these analyses could not be conducted at this site.

Coho salmon were chosen for the 1997 study to minimize impacts on stocks listed under the Endangered Species Act and because they are approximately the size of juvenile chinook salmon. Thus, the objective of the 1997 study was to determine whether juvenile coho salmon with laboratory-induced signs of GBD retain the same prevalence and severity of signs of GBD following passage through a turbine intake at John Day Dam.

Juvenile coho salmon were collected from the smolt monitoring facility at John Day Dam and by gatewell dipnetting. The only fish not used in the study were those that were severely injured or appeared to be near death at the time of collection. No other sorting of test fish occurred. Test fish were first PIT tagged to provide a unique identification number which was used to compare pre-release and recapture examination records. Circular tanks (1,114-L

capacity) were used to hold the test fish while they were exposed to supersaturated gas conditions (average 114.6%).

After 48 hours exposure time, test fish were examined and the severity of external emphysema was classified by index units. Index units were based on the size of emboli and the percent of total body area affected by emphysema. Prevalence of GBD signs ranged from 21 to 86%, averaging 64%. Computer records were made for each fish prior to release, and signs of GBD were videotaped. National Marine Fisheries Service (NMFS) staff designed a canister to release test fish in front of Turbine Gatewell 8B at the top of the turbine intake ceiling (elevation 61 m m.s.l.). Dipnetting was conducted in Gatewell 8B to recapture test fish, which were separated from the dip-net catch based on the presence of recent PIT-tag scars.

Elapsed time from release to recapture ranged from 20 to 70 minutes for the first recapture effort and from 110 minutes to 3 hours for the second recapture effort. Recaptured fish were re-examined using the same technique as the pre-release exam. After re-exam, all test fish and all other fish collected in the dipnetting effort were allowed to recover from the anesthesia and were then released into the juvenile bypass conduit.

We were able to recapture a total of 372 (49%) released fish. Recaptured fish did not exhibit a statistically significant change in GBD-sign severity (2.9 to 2.8 index units). Prevalence of GBD signs also did not change. At release, 64% of test fish had signs compared to 65% at recapture. Forebay dissolved gas levels averaged 122.5% of saturation during the test period, according to Fish Passage Center weekly reports.

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INTRODUCTION

Since the mid-1960s, a well-documented increase in total dissolved gas (TDG) levels has occurred with increased spill at Snake and Columbia River dams. Exposure to higher spill levels causes gas bubble disease (GBD) and ensuing increased mortality in migrating juvenile salmonids (*Oncorhynchus* spp.). From 1966 to 1975, estimates of mortality in juvenile salmonids from the Snake River ranged from 40 to 95%, and a major proportion of that mortality during high flow years was attributed to GBD (Ebel et al. 1975).

In the last several years, higher spring flows, a reduced hydraulic capacity at some Snake River dams (caused by unit outages for repair or research), and efforts to achieve flood control elevations levations at storage reservoirs have required increased levels of spill. This has increased the TDG to levels approaching 140% of saturation, well above the present state limit allowing TDG levels up to 120%, and has prompted concern that juvenile migrants might suffer increased mortality from GBD. Because of this concern, the Gas Bubble Trauma Monitoring Program was initiated in 1994 as part of the Fish Passage Center's Smolt Monitoring Program. Under the new program, a percentage of smolts monitored for physical condition are also monitored for GBD.

Two important questions remain regarding the effectiveness of this biological monitoring: 1) Do signs of GBD change as a result of changing hydrostatic pressures experienced by juvenile salmonids during their passage through turbine intakes, gatewells, and bypass conduits of dams? and 2) Do physical detriments from GBD cause a decrease in survival resulting from direct or indirect effects, such as predation, during migration through reservoirs?

The suggestion that signs of GBD in juvenile salmon disappeared because of high hydrostatic pressures encountered during entry to the bypass systems at Columbia and Snake

River dams was made by Dr. Larry Fidler in a letter to R. Ted Bottiger of the Northwest Power Planning Council, Portland, Oregon (November 23, 1994). The Inspection Team of the Gas Bubble Disease Technical Work Group (GBDTWG 1995), and later the National Marine Fisheries Service (NMFS) Panel on Gas Bubble Disease (1996), documented their concerns that estimates of GBD prevalence made at mainstem dams may not represent prevalence in run-of-the-river juvenile salmonids. As a result of this potential flaw in the monitoring program, empirical evidence was sought to support or refute the premise of GBD-sign loss.

Results of laboratory investigation by Montgomery (1995) documented rapid reabsorption of gas emboli in the gills and lateral lines of juvenile chinook salmon following pressurization. However, for emphysema within fin tissues, which constitute the signs used as the primary index of GBD at smolt sampling sites on the river, changes were much less pronounced. Additionally, the loss of signs reported for test fish in laboratory conditions does not necessarily represent effects on smolts migrating through the hydropower system. Durations of exposure to high pressure at the dam are unknown and may vary considerably in association with differences in behavioral response to the variable water currents and traveling screens encountered by smolts during passage through the turbine intakes.

To address these concerns, we studied the impacts of experimentally induced GBD signs on juvenile steelhead (*O. mykiss*) migrating through the Snake River in 1996. The two main objectives of this study were 1) to determine whether juvenile steelhead with experimentally induced signs of GBD retain the same prevalence of signs following passage through juvenile fish bypass systems, and 2) to determine whether survival rates through the lower Snake River are different for juvenile salmonids with experimentally induced signs of GBD.

In 1997, the study site was moved to John Day Dam because of lack of available test fish in the Snake River system. As a consequence of this move, we were unable to conduct the survival objective during 1997 because there were an insufficient number of PIT-tag detectors downstream from the site to provide the data necessary for estimates of survival. The 1997 study was conducted using coho salmon (*O. kisutch*), to minimize impacts on stocks listed under the Endangered Species Act and because coho salmon more closely approximate the size of yearling chinook salmon (*O. tshawytscha*) than do the steelhead used in 1996.

METHODS

From 9 May to 31 May, 12 replicate tests were conducted at John Day Dam using run-of-the-river coho salmon. Fish were marked with passive integrated transponder (PIT) tags and then exposed to supersaturated dissolved gas. Prior to the occurrence of substantial mortality, and when a large proportion of test fish showed signs of GBD, test fish were individually examined and GBD signs recorded. Groups were then released into the forebay of John Day Dam directly in front of the turbine intake (Fig. 1).

Releases were made with a canister (Absolon and Brege In. prep.), which was lowered on guides down the face of the pier nose at the dam to a depth of approximately 20 m. The canister was held just above the turbine intake at elevation 61 m m.s.l. (201 ft), and fish were allowed to acclimate to this depth before release. The turbine unit remained running during the release and subsequent recapture.

Immediately following release, fish were recovered by dipnetting (Swan et al. 1979) the bulkhead gatewell slot directly behind the release site. Test fish were identified by the presence of a recent PIT-tag scar and examined for signs of GBD. Unmarked coho salmon were diverted into a tank for use in the next replicate. All other juvenile salmonids and recaptured coho salmon were diverted to a separate holding tank to recover from the anesthesia and were then released into the juvenile bypass system.

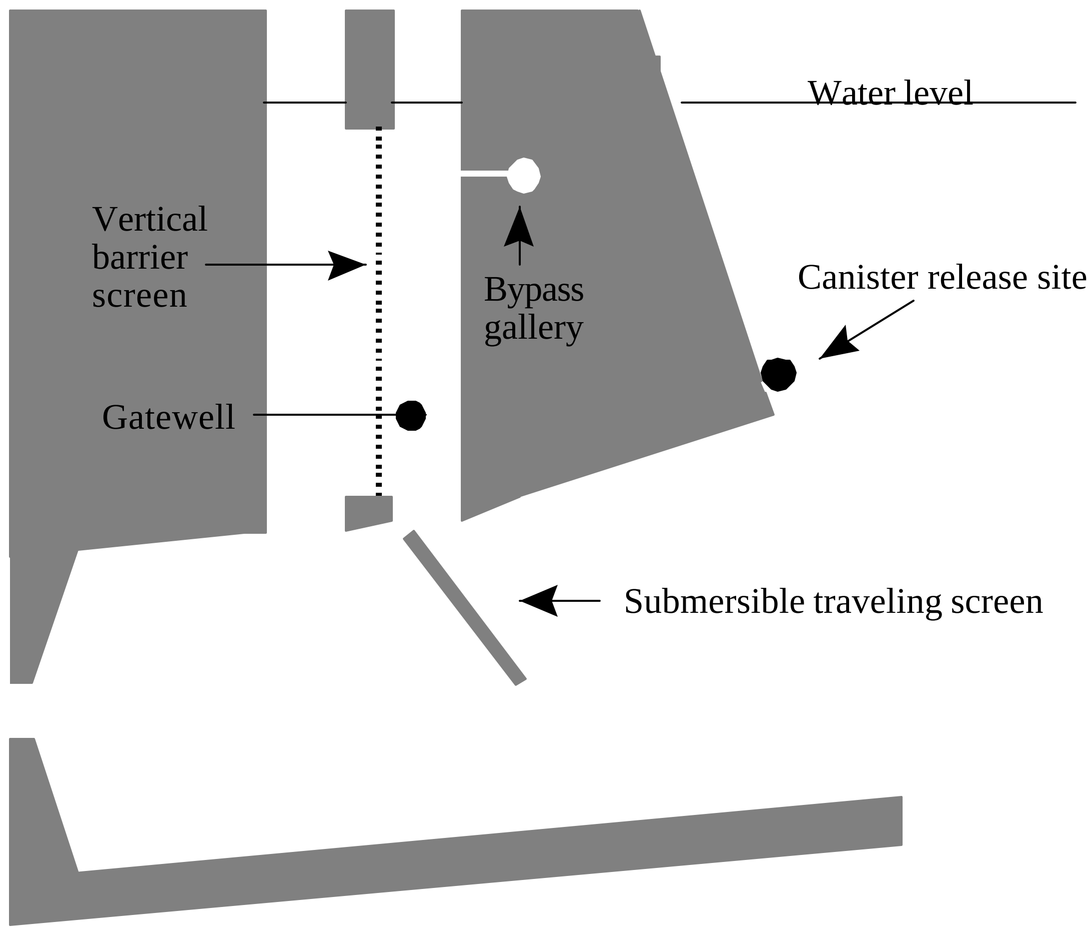

Figure 1. Cross section of John Day Dam showing major bypass system components and canister release site.

Test and Release Protocols

Coho salmon for this study were obtained from both our dipnetting effort to recapture test fish and from fish taken from the John Day Dam airlift pump (Brege et al. 1990) as samples for the NMFS Smolt Monitoring Program. For each test replicate, fish were anesthetized, PIT tagged, and placed in a 0.46-m-deep 1,100-L circular tank. Water was supplied at 15 L/minute by a 480-V submersible pump located in an adjacent gatewell. A second 480-V submersible pump was used to supply water to the fish-handling building. The circular tank was divided into quarters, with fish evenly divided between sections of the tank and with no more than 50 fish held in any section. Replicates of less than 50 fish were held in one tank section. For the 12 replicates, water temperature ranged from 11 to 15EC.

Dissolved gas levels required manipulation for these tests. To lower TDG levels, water was filtered through plastic packing aggregate Jaeger Rings.[1] To increase total dissolved gas levels, compressed atmospheric air was introduced through gas-permeable, hollow fiber membranes at a pressure of 2.5-3.0 kg/cm^2. Inflow water was passed over the hollow membranes and through 3-4 m of 1.9-cm-diameter hose to the holding tank. Average total dissolved gas levels ranged from 113.3 to 115.5% of saturation for the 12 replicates. Total dissolved gas levels were monitored hourly while fish were held in supersaturated conditions.

Fish were held for about 44 hours in supersaturated gas conditions and then examined for signs of GBD. After holding, test fish were anesthetized, then placed in a bath of circulating

[1] Jaeger Rings are a commercial product; reference here is not an endorsement by National Marine Fisheries Service.

anesthetic while they were visually examined at 5- to 20-power magnification. To keep levels of stress to a minimum, all fish were removed from one quarter of a tank for examination before fish were netted from the next quarter.

Visual exams were conducted for subcutaneous emphysema and emboli in all fins, the opercula, head, and eyes. We abandoned assessments of emboli in the lateral line due to the length of time required for exams. Also, examinations for emboli in the gill filaments were not conducted because the necessity for sacrificing fish precluded a before and after evaluation.

During examinations of individual fish, we indexed the severity of emphysema for each fin, eye, and operculum by estimating the surface area covered in 5% increments and the size of the largest emboli in 1-mm increments. Severity of signs was recorded, all signs of GBD were videotaped, and computer records (time of observation, PIT-tag number, affected body area, severity, and general comments on fish condition) were developed for each fish.

Releases were made using the same 240-L, cylindrical aluminum canister that was used at Little Goose Dam in 1996. However, in 1997 we bolted the canister to a specially made frame and lowered it with a crane to a depth of 20 m on the pier nose adjacent to Gatewell Slot 8B. Fish were held at elevation 61 m m.s.l. (201 ft) for 5 minutes before release. A plastic dome at the top of the canister trapped air so that fish could gulp air to equilibrate to neutral density at depth before release.

By running the canister down the pier nose to a position at the top of the turbine intake ceiling outside of the trashrack, we were able to obtain a consistent release position. Also, by having the release canister fixed to the pier nose, the turbine unit could remain in operation while each release was made. In contrast, during releases in 1996 at Little Goose Dam, the turbine was shut down because the trashrack rake was needed to attach the canister. With the turbine in operation we were able to recapture a higher percentage of fish than we did in 1996.

Fish collected by dipnetting were transferred to a tank where they were immediately sorted to identify recaptured coho salmon. Recaptured test fish were identified by the presence of a recent PIT-tag scar and examined for signs of GBD as soon as they were located in the dip-net catch. The first two replicates were additionally marked with an elastomer visual implant (VI) tag. After the first two replicates, we determined that the PIT-tag scar was easier to see than the VI tag, and therefore, the additional handling necessary to VI-tag the fish was avoided by using only the PIT tag.

Estimates of GBD-sign Changes

For data analysis, the increments used to index the severity of subcutaneous emphysema were combined, so that the percentage of fins or body area affected was recorded in 20% rather than 5% increments (i.e., 1-20% = 1, 21-40% = 2, etc.). Index units for the size of the largest emboli remained in 1-mm increments, the same as used for visual exams (i.e., 1 mm = 1, 2 mm = 2, 3 mm = 3, etc.). The sum of the index number for each affected area was the rank for an individual fish, and rankings at release and recovery were compared for each fish. Videotapes were used to validate the accuracy of the rankings during data analyses.

RESULTS

Twelve test replicates were completed in which a total of 759 fish were released and a total of 372 fish were recaptured (49%, Table 1). Time between release and recapture dipnetting effort ranged from 20 to 70 minutes and averaged 50 minutes from time of release to the first recapture effort. Fifty-eight percent of recaptured fish were collected in this initial effort. A second recapture effort was conducted in which time between release and recovery ranged from 110 minutes to 180 minutes and averaged 139 minutes. There was no difference between changes in GBD signs of fish recaptured in the first recapture effort and those recaptured in the second series of dip-net recaptures; thus the results were pooled for data analysis.

Changes in Prevalence of GBD Signs

Prevalence of GBD signs changed very little between release into the forebay and recapture in the gatewell. Mean prevalence of GBD signs was 64% at release and 65% at recapture. Also, the range of GBD-sign prevalence among replicates was similar: prevalence of signs ranged from 21 to 86% at release and from 24 to 88% at recapture.

Changes in Severity of GBD Signs

Of the 12 replicates, 5 showed a decrease in severity of external GBD signs and 7 had an increase following release into the forebay and recapture in a gatewell. The increases observed in GBD signs were generally small, ranging from 0.1 to 0.9 index units, and only two replicates had increases greater than 0.3 index units. Replicates showing a decrease in signs had a comparatively larger change, ranging from 0.4 to 2.1 index units.

Table 1. Prevalence and severity of external signs of gas bubble disease among juvenile coho salmon in tests at John Day Dam, 1997.

Julian date	Rep.	Forebay TDG % sat.	Release: Fish no.	Release: Preval. %	Release: Severity index Mean	Release: Severity index SD	Recovery: Fish no.	Recovery: Preval. %	Recovery: Severity index Decrease	Recovery: Severity index Same	Recovery: Severity index Increase	Recovery: Severity index Mean	Recovery: Severity index SD	Severity change mean
129	1	119	102	21	0.6	1.3	62	24	10	39	13	0.8	1.4	0.2
130	2	120	71	46	1.7	2.1	41	54	5	28	8	2.0	2.4	0.3
132	3	124	74	58	2.1	2.2	29	62	3	22	4	2.4	2.4	0.3
133	4	123	28	86	4.7	3.7	19	79	10	8	1	3.6	3.3	-1.1
134	5	124	22	82	4.5	3.3	10	60	3	7	0	2.4	2.8	-2.1
136	6	124	36	75	4.1	4.2	15	60	8	5	2	2.1	2.2	-2.0
140	7	125	46	80	4.0	3.6	21	81	6	8	7	4.9	4.2	0.9
142	8	124	78	71	3.4	3.7	45	78	15	18	12	4.0	3.4	0.6
143	9	126	134	80	3.6	2.8	62	77	27	25	10	3.2	2.9	-0.4
149	10	127	27	81	4.7	4.1	13	77	5	8	0	4.3	4.6	-0.4
150	11	127	80	76	3.4	2.9	39	79	15	16	8	3.5	2.7	0.1
151	12	126	61	62	2.8	2.9	16	88	7	8	1	2.9	2.2	0.1
Combined			759	64	2.9	3.1	372	65	114	192	66	2.8	3.0	-0.1

Of the 241 fish recaptured that displayed GBD signs at release, 47% showed a decrease, 36% showed no change, and 17% showed an increase in severity of signs. Seventy percent either did not change or changed 1 index unit or less, and average severity of signs decreased 0.6 index units, from 4.6 to 4.0 index units. Fish that showed a decrease in GBD signs had a mean index of 5.6 at release and 3.5 at recapture, while fish that exhibited an increase in GBD signs had a mean of 3.5 at release and 6.0 at recapture. Of fish that did not exhibit external GBD signs at release, 19% had signs at recapture. Collapsed and/or ruptured bubbles were not seen on any individuals.

DISCUSSION

The focus of the experiment was to determine if there were significant changes in GBD signs related to passage through the turbine intake, where high hydrostatic pressures might decrease existing GBD signs. Thus, to minimize passage time, juvenile coho salmon were released in the evening during peak migration and at a location adjacent to the turbine intake. Because releases at John Day Dam in 1997 were made with the turbine operating, a higher percentage of fish were recaptured and we were able to recapture fish much faster than was possible at Little Goose Dam in 1996 (Monk et al. 1997a).

Prevalence and severity of GBD signs among juvenile coho salmon decreased following passage through the turbine entrance and into the gatewells at John Day Dam, but the changes were not statistically significant. This decrease was due to the effect of a few fish with a high severity of GBD signs at release whose signs decreased by several index units at recapture. For the majority of fish, GBD signs changed little, if at all, and this was not unexpected. We often observed experimentally induced GBD signs in test fish that were more severe than those most commonly seen on juvenile salmonids examined from the river. Gas bubble disease signs that developed between release and recapture were generally minor.

CONCLUSIONS AND RECOMMENDATIONS

Changes (both increases and decreases) in GBD signs were observed in some test fish exposed to supersaturated gas conditions. Because we observed both increased and decreased prevalence and severity of GBD signs, and because most fish spent the majority of time between release and recapture in the gatewell (Monk 1997b), we believe that changes observed in test fish were due primarily to the depth maintained by fish before recapture. Collapsed and/or ruptured bubbles were not seen.

Because we were unable to evaluate effects on the survival of fish challenged with supersaturated gasses this year, future studies will be required if survival information is needed. However, these studies will depend upon both the availability of appropriate-size fish in the lower Snake River and upon sufficient PIT-tag detection in the lower Columbia River. However, NMFS has estimated survival for the general migrant population passing dams on the Snake and Columbia Rivers in recent years with high flows and spill and found that survivals were relatively high (Smith et al. 1998).

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