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# Observations of Fish Behavior Recorded by a DIDSON Sonar Concurrent with Blasting Events During Renovation of the Lyle Falls Fish Ladder

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## EXECUTIVE SUMMARY

A Dual-Frequency Identification Sonar (DIDSON) sonar was deployed to record fish behavior within the trap of the Lyle Falls Fish Ladder during periods when rock blasting events occurred – events associated with renovation/construction activities. The DIDSON was operated intermittently over the period from April 16 to May 6, 2010. During operation, it was programmed to record sequential 1-hour files. Records from the construction contractor indicated that 11 blasting events occurred during times when DIDSON files were recorded. “Echograms” were processed from the original DIDSON video files which contained these 11 events. The precise moment of each blast was noted in the associated echogram and DIDSON file, and fish behavior for the 5 minutes preceding and following each event was qualitatively assessed. During the period of recordings, there was a near constant presence of small fish, most likely hatchery released coho smolts, which schooled in a position 1-3 m in front of the sonar, oriented into the direction of water flow. In 7 of the 11 files, there was a sudden scattering of these fish concurrent with the explosion. In 2 cases the scattering was barely noticeable, and in 2 instances no disturbance of the fish was apparent. In the 9 cases where a disturbance in behavior occurred, the fish generally re-established their position in front of the sonar within 10-20 seconds. While the explosions associated with the rock blasting events were indeed of an alarming nature to the fish in the Lyle Falls trap, the perturbation to their behavior was short-lived.

## INTRODUCTION

Beginning in March 2010, a construction company on contract with the Yakama Nation (YN) began renovation activities on the Lyle Falls Fishway, rkm 3.5 on the Klickitat River (Figure 1). Scheduled to finish in 2011, the renovation work will create a state-of-the art adult fish collection facility, bringing the ladder into compliance with federal fish passage criteria. The new facility will incorporate modern monitoring capabilities, reduce fallback of adult fish over Lyle Falls, and provide better fish attraction flows and a safer working environment (YN 2008). However, construction activities in the vicinity of the ladder include excavation of over 18,000 cubic yards of material, much of it rock which was/will be loosened by dynamite blasting. Concern was expressed relative to the disturbance these explosions might have on fish behavior – in particular, will the explosions delay upstream adult migration, and/or will they negatively affect harvestability of the fish (there is a significant tribal fishery immediately below the Lyle Falls ladder)?

What was needed to help answer these questions was a means to observe behavior of fish in proximity to the ladder, to assess the magnitude of any disturbance caused by the explosions. Use of optical cameras for this purpose was impractical due to their limited range of operation and dependence on lighting. In contrast, a Dual-Frequency Identification Sonar (DIDSON™; Sound Metrics Corporation, Seattle, Washington, www.soundmetrics.com) has a greater range and can operate irrespective of light conditions and turbidity. A DIDSON is a multi-beam underwater acoustic video camera. It repetitively emits sets of sound beams and uses its

unique patented lens to resolve the reflections (echos) of objects passing through the water column within its field of view into a two-dimensional video image. Placed in a body of water and oriented to transmit horizontally through the water column, it produces a top-down ("bird's-eye") view of the conically-shaped ensonified field - 28° horizontally and 14° vertically. The vertical field of view can be expanded to 28° with use of a spreader lens. The standard model of the DIDSON (DIDSON-S) operated at its high frequency (1.8 MHz), emits an array of 96 beams and has a functional range up to 10-12 m (see "Introduction to DIDSON" slide presentation, http://www.soundmetrics.com/INFORMATION/information.html).

We examined the possibility of placing a DIDSON at a location in the open river near the ladder where adult fish might be holding, but discarded the idea due to the high amount of turbulence (reflections from entrained air bubbles greatly reduces resolution of DIDSON images). However, placing a DIDSON within the trap of the fish ladder appeared to be a reasonable alternative. There is little turbulence within the trap, and fish, both large and small, are often present. We report here on DIDSON-based observations of fish behavior in the Lyle Falls fish trap concurrent with 11 different blast events that occurred in April-May 2010 as part of the fish ladder renovation activities.

## METHODS

### DIDSON Installation and Operation

On April 16, 2010, we installed a DIDSON-S (equipped with a spreader lens) within the adult trap in the Lyle Falls fish ladder. The sonar was programmed with a 0.5 m Start Length, a 5 m Window Length, and set to record at 15 frames per second. The sonar was mounted in a downstream corner of the trap on an "H-frame" stand, with the sonar lens approximately 0.8 m above the bottom and directed across towards the opposite upstream corner (Figure 2). The resulting field of view encompassed approximately a third of the water column near the bottom of the trap. The DIDSON was linked to a field computer and a 500 GB external hard drive, both of which were kept in a locked metal job site storage box placed in the vicinity of the trap (Figure 2). While operating, the DIDSON recorded sequential 1-hour files directly to the external hard drive. Power was supplied to the DIDSON and computer with two pairs of 12 v batteries, placed in an adjacent storage box, linked in series to provide the 24 volts DC output required by the sonar. The computer was supplied with 12 volts DC with use of a 24 v to 12 v converter; the hard drive was powered from the computer through the USB cable. The batteries were replaced, one pair at a time, with freshly recharged batteries every couple days of operation. The DIDSON was operated during the following periods within three consecutive work weeks: 4/18 (9 AM) to 4/23 (6 PM), 4/26 (10 AM) to 4/30 (11 AM), and 5/4 (10 AM) to5/6 (2 AM).


Figure 1. - Location of Yakama Nation facilities associated with the Klickitat River Anadromous Fisheries Project.

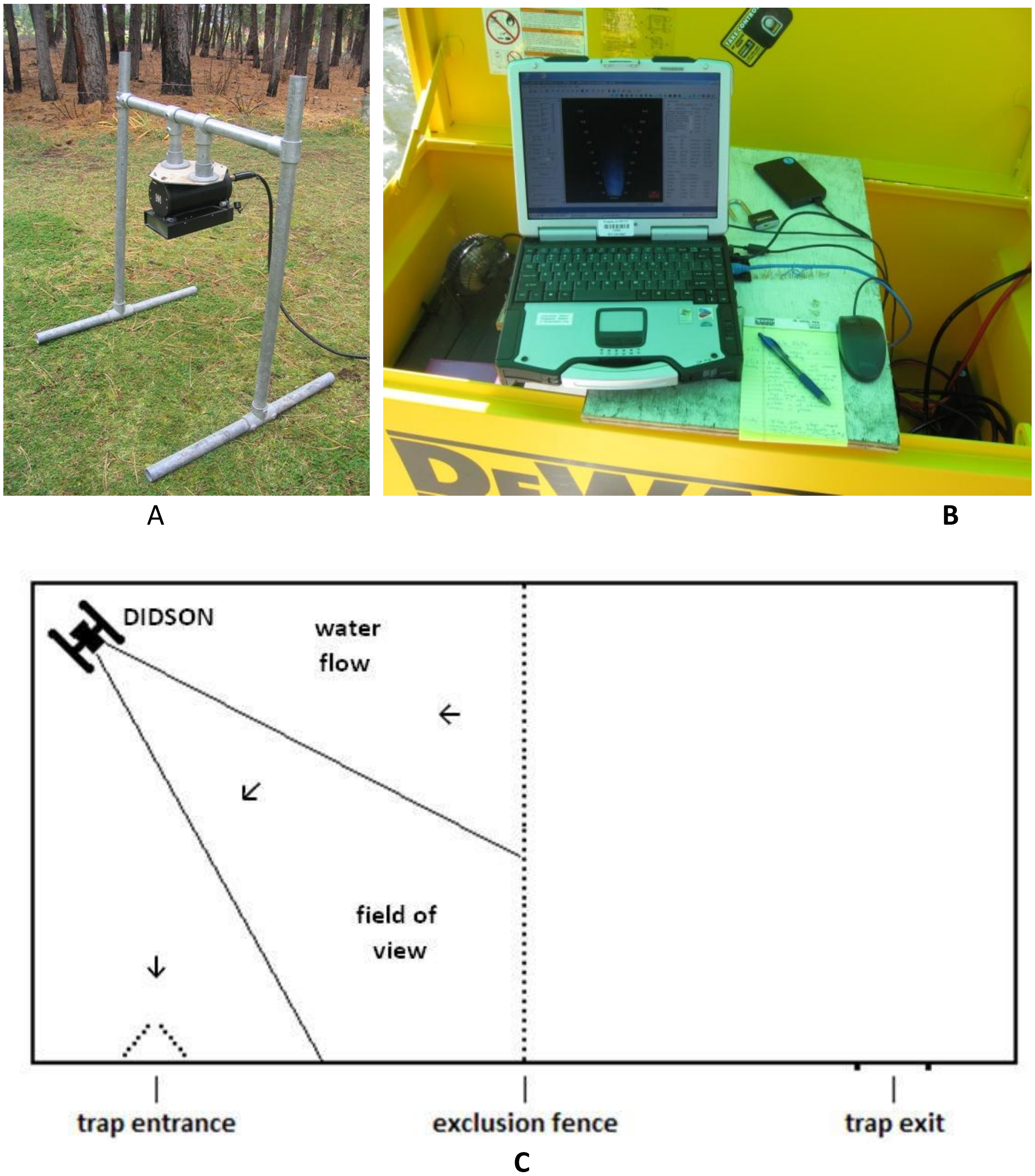



Figure 2. - A) DIDSON on stand. B) Field computer and external hard drive. C) Schematic - top view - of placement of DIDSON within the Lyle Falls Ladder fish trap.

Review of DIDSON Recordings

Subsequent to operation of the DIDSON, the contractor provided us with a copy of the blasting schedule, which contained the time and associated data for each blast event. During the periods when the DIDSON was in operation, 11 blast events occurred – two on April 21, one on April 22, one on April 23, three on May 4, and four on May 5. The DIDSON files corresponding to these events were selected, and "echograms" processed for each. An echogram provides a

time-distance graphical representation of objects moving within the field of view of the DIDSON that create a reflection of a size and intensity that is greater than minimum values selected by the operator. As opposed to replaying a raw DIDSON video recording, scrolling though its echogram presents a much more rapid means to review fish movement events (see: http://www.soundmetrics.com/NEWS/PUBLICATIONS/SpecialFeatures.pdf).

In most of the echogram and DIDSON files a “flash” was noted, apparently created by the shock wave from the explosions. In the echograms the flash was visible as an intense vertical line (Figure 3), and in the DIDSON files by a distinct fan shaped pattern within two to five successive frames (Figure 4). Presence of this flash was used to identify the precise moment of each blast event. The echograms and the raw DIDSON recordings were then reviewed for a 5 minute period preceding and following each event. A qualified assessment was made relative to the behavior of the fish prior to the explosion, and to the intensity of the behavioral disturbance following each blast event and to the rapidity with which normal behavior was re-established.

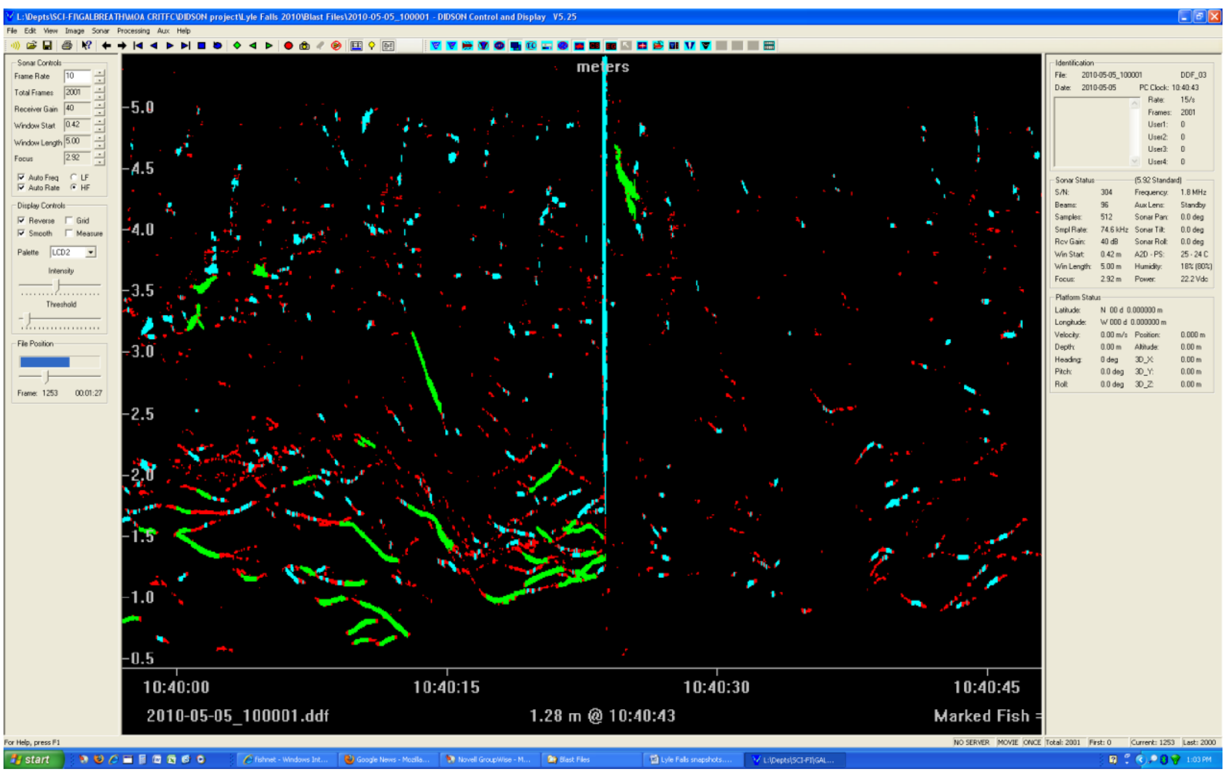
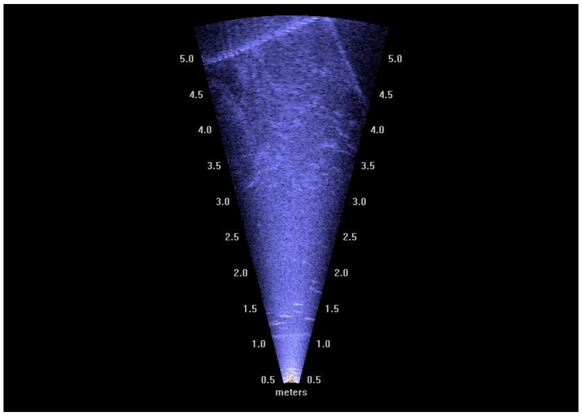
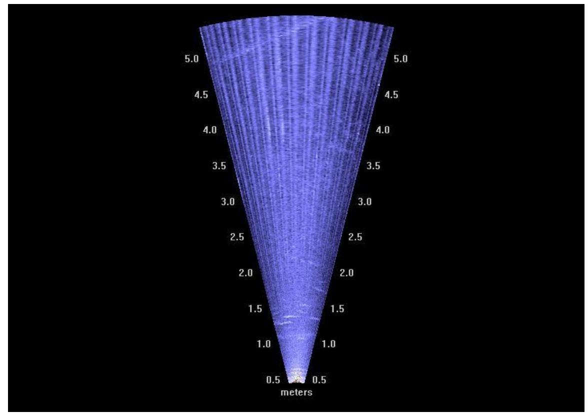


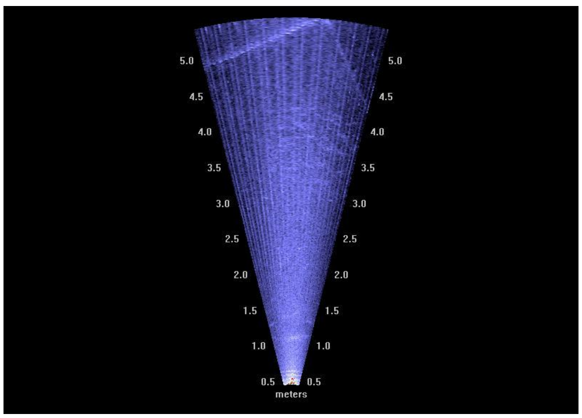

Figure 3 – Echogram for Blast Event #9 (5/5/2010) showing the “flash” (vertical line) produced by an explosion at time 10:40:25. Note the large number of “tracks” at 1-2 m range prior to the explosion (created by fish schooling in front of the sonar), and their near absence following the explosion.



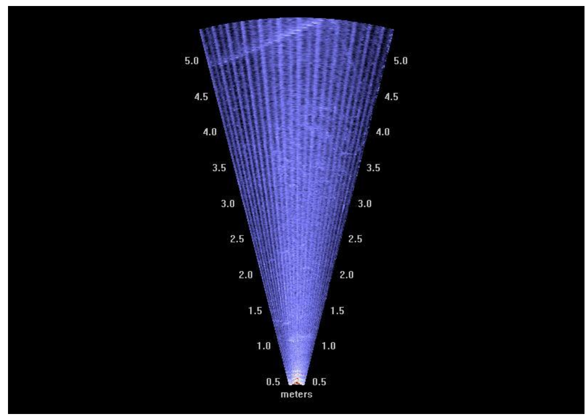

Frame 999



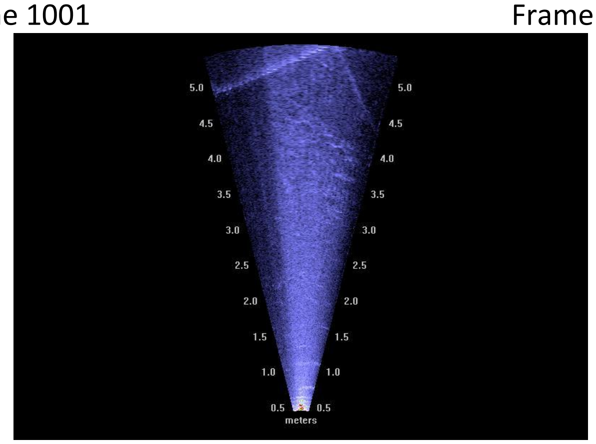

Frame 1000




Frame 1001




Frame 1002




Frame 1003

Figure 4 – Sequence of frames in the DIDSON file for Blast Event #9 (5/5/2010) showing fan-shaped "flash" produced by an explosion – in this example, for three successive frames - 1000 to 1002.

**RESULTS and DISCUSSION**

In 8 the 11 DIDSON files associated with blast events, a "flash" was produced by the shock wave of the explosion. Creation of this flash was fortuitous as there was a several minute difference between the time as recorded in the DIDSON file and the time indicated on the Blasting Schedule provided by the contractor (the difference being approximately 6:27 min in the April files, and 7:20 min in the May files). Without the flash, identifying the exact time of the explosion would have been much less certain. Time of the explosion in the 3 files where a flash was not present was estimated using the time lag between the computer clock and the blast schedule time for other blast events on the same day which did create a flash.

Prior to the blast events, a number of small (approximately 10-20 cm length) fish could be observed within the field of view of the DIDSON. We suspect that these fish were hatchery origin coho smolts, as several releases of coho juveniles had taken place in the weeks just preceding operation of the DIDSON. These fish were slowly milling at a distance of 1-3 m in front of the sonar. They were generally facing into the current, which was flowing more or less perpendicular from left to right across the field of view of the sonar. Larger fish (adult salmon or steelhead) were also present, though less systematically and their behavior was more erratic, making it difficult to establish a baseline "normal" behavior pattern, to which behavior subsequent to an explosion might be compared.

In 9 of the 11 files, the small fish scattered immediately following the explosion. After the initial scattering, the fish were seen swimming quickly back and forth in different directions across the field of view. In 7 of these files, the scattering was very sudden and distinct. In the other 2 cases the scattering was less dramatic - the fish swam away, but less quickly. In 2 cases, no disturbance to the behavior of the fish was apparent. In the 9 cases where a disturbance did occur, the fish generally re-established their position in front of the sonar within 10-20 seconds and resumed the same slow milling/schooling behavior observed prior to the blast (Table 1).

The Blast Schedule data provided by the contractor included various measures recorded for each blast event by a seismograph operated on site. One of these metrics is peak particle velocity (PPV), measured in longitudinal, transverse and vertical direction, the individual values for which were combined into a summary measure of "Resultant PPV". The Resultant PPV provides a relative measure of the intensity of the shock wave produced by the explosion, as it travels through the rock. This measure of intensity we found provided a rough positive correlation with the number of successive frames in the DIDSON file which exhibited the fan-shaped flash pattern (Figure 5). Of note, this correlation is confounded to an unknown extent by the fact that the explosions occurred at different distances from the trap, which we were unable to calculate with the data provided. Also, the magnitude of the Resultant PPV measure and the number of frames per file with a fan-shaped flash pattern both showed a rough positive correlation to the differences the reaction of the fish to different blast events. In particular, the two blast events where no disturbance to behavior was observed (No. 7 and 10) corresponded to the events with the lowest Resultant PPV values and where no flash was visible in the DIDSON files.

In summary, the shock waves created by the explosions were generally perceived by the fish, causing the small fish within the trap to suddenly scatter and to swim frantically back and forth. In some cases, however, the reaction appeared to be less dramatic, apparently in response to a shock wave that was less intense. In all cases, the perturbation to behavior of the fish was relatively short-lived, with the fish resuming their slow schooling/milling behavior within 10-20 seconds.

Table 1 – Summary data for each of the eleven blast events and associated observations of fish behavior.

| Blast Event No. | Date | Time Blast | Time DIDSON | Time diff. | Note | Flash visible # frames | Resultant PPV* (in/s) |
|---|---|---|---|---|---|---|---|
| 1 | 4/21/2010 | 11:04:27 | 10:58:01 | 6:27 | flash; fish scattered but returned to normal within approx. 15-20 seconds | 2 | 1.710 |
| 2 | 4/21/2010 | 13:21:52 | 13:15:26 | 6:27 | no flash; fish scattered (avoiding large fish?) but returned to normal within approx. 15-20 seconds | 0 | 1.285 |
| 3 | 4/22/2010 | 13:51:39 | 13:45:08 | 6:31 | flash; few fish in view; fish scattered but returned to normal within approx. 15-20 seconds | 2 | 1.854 |
| 4 | 4/23/2010 | 10:24:39 | 10:18:12 | 6:27 | flash; few fish in view; fish scattered but returned to normal within approx. 30-40 seconds | 2 | 1.748 |
| 5 | 5/4/2010 | 11:30:08 | 11:22:51 | 7:17 | flash; fish scattered but returned to normal within approx. 10-15 seconds | 3 | 3.785 |
| 6 | 5/4/2010 | 13:27:55 | 13:20:38 | 7:17 | flash; few fish in view; fish scattered but returned to normal within approx. 15-20 seconds | 5 | 2.890 |
| 7 | 5/4/2010 | 15:26:54 | 15:19:32 | 7:22 | no flash nor any sudden scattering observed | 0 | 0.923 |
| 8 | 5/5/2010 | 8:50:56 | 8:43:35 | 7:19 | flash, but minimal scattering, returned to noraml within approx. 10 seconds | 2 | 1.213 |
| 9 | 5/5/2010 | 10:47:45 | 10:40:25 | 7:20 | flash; few fish in view; fish scattered but returned to normal within approx. 20-30 seconds | 3 | 2.820 |
| 10 | 5/5/2010 | 13:34:06 | 13:26:45 | 7:19 | no flash, and no scattering behavior observed | 0 | 0.578 |
| 11 | 5/5/2010 | 15:44:51 | 15:37:29 | 7:22 | flash, but scattering hardly noticeable, returned to normal within approx. 10-15 seconds | 4 | 2.125 |

* Peak Particle Velocity

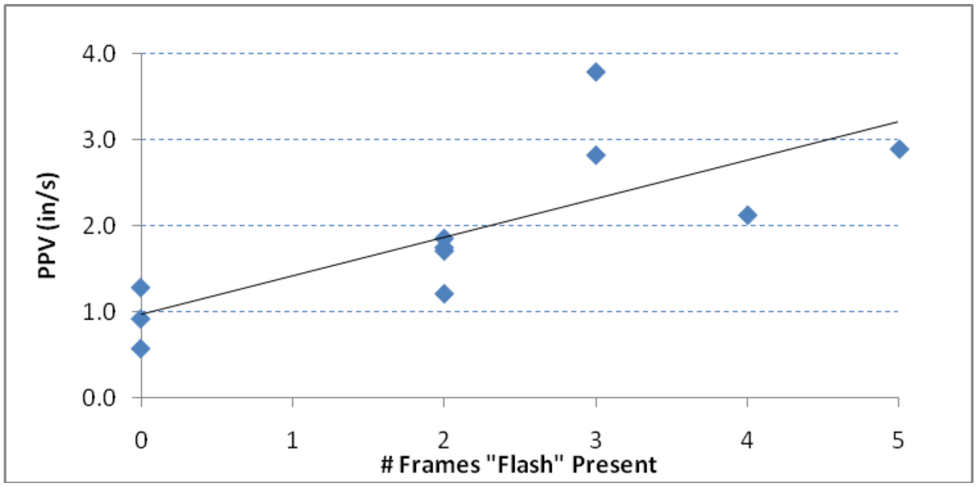



Figure 5. – Correlation between the successive number of frames that a "flash" was present and the Peak Particle Acceleration (PPV) - a measures of the intensity of the associated explosion.

**REFERENCES**

YN (Confederated Tribes and Bands of the Yakama Nation). 2008. Klickitat River Anadromous Fisheries Master Plan. Prepared in cooperation with Washington Department of Fish and Wildlife. Yakama/Klickitat Fisheries Project. Toppenish, Washington. (http://www.efw.bpa.gov/IntegratedFWP/KlickitatPlan110804web.pdf)