Rocky Reach Fish Forum

Wednesday, 3 September 2014
1:00 – 4:00 p.m.
Chelan PUD Second Floor Conference Room
Wenatchee, WA

Meeting called by Steve Hemstrom — Chairperson, Tracy Hillman
Notes taken by Heidi Kunz

Attending Representatives:

Hemstrom, Steve	Chelan PUD	(509) 661-4281	steven.hemstrom@chelanpud.org
Irle, Pat (phone)	Ecology	(509) 454-7864	Pirl461@ecy.wa.gov
Kerec, Matt (phone)	Alcoa	(412) 553-4361	Matthew.kerec@alcoa.com
Lewis, Steve	USFWS	(509) 665-3508 x14	Stephen_lewis@fws.gov
Rose, Bob (phone)	YN	(509) 865-5121	rosb@yakamafish-nsn.gov
Verhey, Patrick	WDFW	(509) 754-4624	patrick.verhey@dfw.wa.gov

Attending Participants:

Hillman, Tracy	BioAnalysts	(208) 321-0363	tracy.hillman@bioanalysts.net
Jackson, Chad (phone)	WDFW	(509) 754-4624 x250	Chad.jackson@dfw.wa.gov
Keller, Lance	Chelan PUD	(509) 661-4299	lance.keller@chelanpud.org
Kunz, Heidi	Chelan PUD	(509) 661-4758	Heidi.kunz@chelanpud.org
Nelle, RD	USFWS	(509) 548-7573	Rd_nelle@fws.gov
Rainey, Steve (Phone)	Consultant	(503) 260-6990	wsteverainey@aol.com

Meeting Minutes

I. Welcome and Introductions

Tracy Hillman welcomed everyone to the Rocky Reach Fish Forum (RRFF) meeting.

II. Review of Agenda

The agenda was approved with two changes: (1) switch the order of the Pacific Lamprey and White Sturgeon discussions and (2) move the "vote on stocking approach for 2015" to the last item under White Sturgeon.

III. Review and Approval of Meeting Minutes

Draft notes from the 6 August meeting were reviewed. A request was made for additional time to review the draft notes. Members agreed to review and finalize the August draft notes during the October meeting.

Action Items:

- **All edits/comments on the draft August meeting minutes are due to Tracy Hillman by 4 September.**
- **Tracy Hillman will e-mail the draft August meeting minutes with edits along with the draft September meeting minutes to the RRFF for approval at the 1 October meeting.**

IV. White Sturgeon

Rearing Update

Bob Rose reported that everything is fine at Marion Drain. Pat Irle commented that an update on fish at Marion Drain may not be important for this group because juvenile sturgeon for the Rocky Reach Project Area are rearing at WDFW facilities. Bob responded that although this is true, if something happens at the WDFW facilities that reduces the survival of sturgeon there, fish at Marion Drain are available to supplement fish released into the project area. Chad Jackson reported that things are going well at both Chelan and Columbia Basin Hatcheries. Columbia Basin Hatchery has already completed their first culling and Chelan Hatchery is getting ready to do theirs. Columbia Basin Hatchery has collected the first round of fish health samples and Chelan Hatchery will do the same in the next week. Chad said that half-sibs are still represented and looking good.

Monitoring Update

Lance Keller reported that Blue Leaf Environmental and Columbia Research are currently carrying out the 2014 Monitoring and Indexing efforts on the juvenile white sturgeon population in Rocky Reach Pool. They have completed Session I of IV, which means 25% of the draft results are available. In the first session, there were 71 fish recaptured; 52 of those fish were from the 2013 release, 11 from the 2014 release, 7 from the 2011 release, and 1 from the 2012 release. The consultants will be out again this week using the same approach as last year (i.e., systematic sampling initially and then switching to sampling hot-spot areas during the last session). Lance also reported that he received the 2013 final report last week from Blue Leaf. He will forward the final report to Tracy Hillman, who will send it to the RRFF.

Action Item:

- **Lance Keller will send the 2013 final report from Blue Leaf Environmental to Tracy Hillman for**

distribution to the RRFF.

Phase 2 Sturgeon Conservation Program – UBC Sturgeon Model

Lance Keller reported that he is in the process of downloading the EcoPath/EcoSim model, which is free software on the internet (http://www.ecopath.org/). For security reasons, he has to work with the Chelan PUD IT Department to download the software. After installing the software, Lance intends to study and explore the capabilities of the model. This includes examining how researchers at the University of British Columbia (UBC) used the model for sturgeon. Chad Jackson requested that Lance Keller report his findings on the EcoSim model at the next meeting and discuss at that point when the Sturgeon Subcommittee should be reconvened to address future stocking efforts and population abundance targets. Lance stated that the EcoSim model could potentially identify carrying capacities for the project area.

Action Items:

- **Lance Keller will talk to UBC on how they tailored the EcoSim model to fit white sturgeon management.**
- **Tracy Hillman will work with Chad Jackson on writing a primer on bioenergetics modeling.**

Decision: Vote on stocking approach for 2015

Chad Jackson reported that when the White Sturgeon Subcommittee met on 28 April 2014, they agreed that the first thing they needed to do was to identify a recovery or population abundance target and use that to build a long-term stocking program. Because it may take one to two years to get a long-term plan approved, a stocking plan that everybody can agree to is needed for 2015 and possibly 2016. It was agreed at the subcommittee meeting that this plan would follow the current White Sturgeon Management Plan with a few extra guidelines. These guidelines were detailed in the report from Chad Jackson on "Results from the White Sturgeon Subcommittee Meeting on 28 April 2014" (see May meeting notes). The RRFF did not officially approve the original proposal at that time and Chad asked that the RRFF review a revised proposal prepared by WDFW titled, "Revised Proposal on the Number of Juvenile White Sturgeon to Release in 2015" (see Attachment 1). Chad asked that voting members of the RRFF review the revised proposal and submit their votes by Wednesday, 17 September. This will give members two weeks to study the proposal. Chad also noted that the Yakama Nation and WDFW will meet on 4 September to discuss sturgeon management.

Pat Irle thanked Chad Jackson for preparing the notes on the subcommittee meeting. She wanted to note that she was at the meeting, but arrived after the discussion on the number of fish to release in 2015. Pat noted that conservation and genetics are both important, and that both lean toward using larvae. She questioned why the number of 6,500 is being used (at this time for this project) and how that number was determined. She also questioned the basis for using brood stock versus larvae. Chad Jackson stated that in his opinion, although these are conservation programs, it does not necessarily

require that they should be using larval fish. Managers are trying to use the best product possible. He stated that the 6,500 release number is used in two of the three PUD White Sturgeon Management Plans. He said the 6,500 number was based on information from the plans that a minimum of six females and six males should be collected and spawned in a full or partial factorial mating. Until a long-term plan can be approved, a release number needs to be given to the hatcheries in order to provide a juvenile rearing target to stock in 2015. Chad also stated that there are no larval fish currently available at the Wells Hatchery that can be redirected to other PUD programs.

Pat Irle stated that she had written the 401 certifications for all three projects (Chad had not been present at any of these), and that the 6,500 number was an arbitrary number for the Rocky Reach Project Area.[1] She also said that the experts stated that if the goal of the program is to produce hatchery fish for harvest, broodstock collection is fine (see Attachment 2; Responses from the White Sturgeon Experts). However, if the goal is conservation, larvae should be used. Chad Jackson stated that the 6,500 number was based on the best science available at the time and that brood stock has been available for use for conservation programs, but if larval fish are going to be used, then they will need to be collected on a larger scale. Tracy Hillman stated that Pat Irle's comments should be an important part of the discussion for the Phase 2 Sturgeon Conservation Program. Lance Keller said that they are still collecting data that will be used to make decisions for the Phase 2 Sturgeon Conservation Program and using larvae is still a consideration. Steve Hemstrom reminded the Forum that a year of data collection was lost in 2012. He also stated that it is in the Settlement Agreement that Chelan PUD will stock 0 to 6,500 fish based on monitoring results.

Steve Lewis questioned whether there should be more clarification in the revised proposal about the stocking number and how it was determined. Discussion took place about the wording of the introductory language for the revised proposal. Steve Hemstrom suggested adding a paragraph to the proposal providing a brief history about how the proposal was developed. Chad Jackson commented that this is a one-year agreement for 2015, and that a long-term agreement should be developed soon.

Action Items:

- **Tracy Hillman will e-mail Chad Jackson a reminder to add an introduction to the revised proposal.**
- **Tracy Hillman will distribute the revised proposal to the group for their review. The RRFF will submit their vote on the revised proposal by Wednesday, 17 September.**
- **Tracy Hillman will send the white sturgeon expert panel documents and the February white sturgeon workshop notes to the RRFF.**

[1] During the November meeting, some members recalled that the 6,500 number was informed by modeling efforts conducted for the Priest Rapids Project Area and therefore was not entirely arbitrary.

V. Pacific Lamprey

Rocky Reach Project Effects (No Net Impact)

Steve Hemstrom reported that Chelan PUD is discussing NNI internally. Chelan PUD is discussing the concept of NNI and alternative ways to achieve NNI.

Pacific Lamprey at Tumwater Dam

Steve Lewis discussed the link of Tumwater Dam to Rocky Reach Dam. Steve Rainey then described his tour of Tumwater Dam and discussed the memo he sent to Steve Lewis (see Attachment 3). RD Nelle stated that a Chelan PUD report from 1981 documented lamprey upstream of Tumwater Dam. Thus, there is no question that lamprey did occur upstream from the dam. In response to a question from Patrick Verhey, Steve Rainey reported that velocities at the entrance to the fishway are within the range of typical fishway entrance velocities. Patrick Verhey asked if the location of diffuser grating within the fishway would lend itself to applying plating for lamprey attachment when lamprey experience the upper limits of their swimming abilities. Steve Rainey stated that if a more comprehensive study is done, then it would be beneficial to include looking at this issue in more detail. Patrick Verhey commented that if adult lamprey have a route through the trap by bypassing the steep pass structure that they currently useit would not be a good idea to make modifications that would prevent them from using that path. Enhancing such a route, if it exists, should be considered.

RD Nelle commented that there are juvenile lamprey within a kilometer downstream of Tumwater Dam, so it is known that adults are spawning near Tumwater Dam. Steve Rainey stated that he did not necessarily recommend making modifications or additions to Tumwater Dam, but that any decisions should be based on observing lamprey passage behavior at Tumwater. RD Nelle stated that the last time adult lamprey were documented passing through Tumwater Dam was November 1998. Patrick Verhey commented that a lamprey passage device should be placed where the lamprey would naturally want to pass and all locations should be considered including the trap. Steve Rainey stated that a lamprey passage device adjacent to the downstream entrance may be a good location. RD Nelle commented that is important to observe where the lamprey want to go as opposed to where we think they want to go. He stated that the lamprey could possibly have been passing through an ice/trash sluiceway that was in place in the late 1980s instead of the ladder.

Discussion took place about whether the lamprey would pass the structure at night if there was no trapping. Steve Rainey expected that if some modifications were made to the fishway, lamprey could pass at night. He stated that the fishway was modified in the late 1980s and that perhaps the old fishway was easier for them to pass. RD Nelle stated that it is unknown if the disappearance of the lamprey after the late 1980s is due to the modifications of the fishway or the change in operations of the facility. Steve Rainey commented on the importance of observing upstream migrating lamprey to assess behavior below and within the fishway. This could be done by either transporting them from

another location or by studying another location that is similar in order to determine the best location for a lamprey passage device at Tumwater Dam.

Steve Hemstrom asked that Steve Rainey incorporate comments from the group into his memo in order to correct inaccuracies. RD Nelle asked about the possibility of touring the fishway at a time when it is dewatered. Chelan PUD will check to see when the fishway will be dewatered and if a tour could be scheduled. Discussion took place about submitting comments to Steve Rainey on his memo. In order to correct inaccuracies in Steve Rainey's report, Steve Hemstrom stated that Tumwater Dam does not focus on trapping bull trout; bull trout capture is incidental. Also, the Dryden canal does not have screens that impinge juvenile lamprey. Juvenile lamprey are rescued out of the canal when it is dewatered. Steve Hemstrom will elaborate on these issues in his comments to Steve Rainey. Tracy Hillman will append Steve Rainey's memo to the September Meeting Minutes, but he will mark the report as a draft.

Action Items:

- **Steve Hemstrom will check on dewatering of Tumwater Dam and identify a good date for a tour this winter.**
- **Steve Hemstrom will check to see if Tumwater Dam had an auxiliary water supply pathway to the forebay.**
- **Comments on Steve Rainey's memo need to be submitted to him by Friday, 12 September. Reviewers should send a courtesy copy of their comments to Steve Lewis.**

Regional Implementation Planning Process

RD Nelle reported that all meetings have been held except for the Methow and Okanogan River basins. Those meetings had to be rescheduled because of the fires. Patrick Verhey reported that he attended a Conservation Team meeting last week in Portland. He said the meeting was well attended and participants were eager to discuss lamprey conservation. He reported that the intent of the meeting was to develop a conservation team, discuss a chair or co-chair for the group (possibly someone from the USFWS and someone from a tribal entity), and how the conservation team would interact with the Pacific lamprey technical workgroup to make decisions.

Wanapum Response: Rock Island Lamprey Passage Structures

Lance Keller noted that Tracy Hillman distributed the September Interim Fish Passage Plan (IFPP), which summarizes the September activities of the implementation of the IFPP at Rock Island Dam in response to Wanapum Dam issues. Lance Keller reported that flows are decreasing, which caused powerhouse 1 to be shut down for most of August. They are now seeing instances where the 51.5 foot of head, which is the maximum amount of head under which powerhouse 2 units can be operated, are exceeded. In that instance, powerhouse 2 shuts down as well and 100% of the water is spilled. When this happens, Chelan PUD provides spill past Rock Island per the IFPP that is outside the fish spill season that ended on

24 August at Rocky Reach and Rock Island dams.

Lance Keller reported that Chelan PUD is starting to rely on the denil operations for a greater majority of the day as they continue to see river fluctuations. Daily fish counts confirm that fish are passing when the denils are in place. In one instance, the left-bank denil was operated continuously for five days and salmon and lamprey counts were logged throughout that time period. Fishway attendants have also observed lamprey using the lamprey passage system (LPS) attached to the denil. Lance stated that the lamprey are most likely choosing to use either the LPS system or the denils based on the elevation of the tailrace, but it is unknown if they are using both. To date, there have been 2,065 lamprey counted at the Rock Island windows.

Pat Irle stated that she had not seen any reports of exceedances of total dissolved gas and wanted to know what numbers Chelan PUD was recording. Lance Keller reported that Chelan PUD is currently seeing 103.1% at Rock Island. Lance Keller suggested that Marcie Steinmetz would be the best contact for those data.

Lance Keller noted that the Rock Island IFPP monthly reports are distributed to FERC, the Habitat Conservation Plan coordinating committee, and the RRFF. Lance said that Chelan has submitted data monthly and that the Biological Assessment would be compiled after the Wanapum Response is complete. Lance reported that the denils were engineered to work at a tailrace elevation of 38 KCFS at Rock Island and that BPA has guaranteed a minimum of 45 kcfs (kcfs = thousand cubic feet per second) through October. The denils were observed at 45 kcfs during a low flow test. They were inspected and it was determined that they are staying in place, operating the way they should be, and they have not shifted at all. The denils will not be removed until Chelan PUD is certain that they will not need to be used again and that passage can be provided via the normal entrance routes. RD Nelle expressed interest in observing the denils in operation during low flows and Lance Keller said that he could arrange a tour.

Grant PUD Adult Trap and Haul: 2014 Rocky Reach Tagging and Detections Update

Steve Hemstrom reported that as part of the Wanapum Response, Grant PUD has been trapping adult Pacific lamprey at both Wanapum and Priest Rapids dams and transporting them to two different locations upstream of Rock Island Dam. The fish hauled to Kirby Billingsley Hydro Park (KBHP) are untagged and released into the river. As of 28 August, the total number of transported fish to KBHP and released there is 1,259 lamprey. An additional 198 fish have been hauled to the Rocky Reach Bypass sampling facility. Of those, 191 have been tagged with half duplex 32 mm PIT tags and released. Of the 191 total tagged fish that have been released at Confluence Park, 78 have been detected at the top of the Rocky Reach fishway. Not all of the data have been collected or processed. There were five different tagging dates for the 191 fish: 31 July, 5 August, 14 August, 22 August, and 27 August. Preliminary information looks like the fish are making it quickly to Rocky Reach Dam and going fairly quickly through the project. A full summary report is not available at this time.

Patrick Verhey reported, per Mike Clement's update at the PRFF meeting earlier this morning, that trapping will continue through 15 September and then Grant PUD will reevaluate the need for continued trap-and-haul. The number of traps may be reduced at that point, but trapping may continue through the end of the month with fewer traps. Steve Hemstrom stated that the operation to move fish upstream has gone well, and this effort will give Chelan PUD good data to evaluate the Rocky Reach fishway, including timeframes, the total number of fish, and what the fish are doing. Steve Hemstrom reported that they have used all of their tags and confirmed that all addition fish will be released at KBHP. Steve Hemstrom was unable to get additional 32 mm PIT tags. RD Nelle will look into getting more tags for Steve Hemstrom.

Modeling Lamprey/Sturgeon Interactions

Tracy Hillman reminded the Forum of his Action Item from last month, which is to prepare a primer on bioenergetics modeling. He indicated that he and Chad Jackson should have it available for the Forum by October.

Action Item:

- **Tracy Hillman will work with Chad Jackson on writing a primer on bioenergetics modeling.**

VI. Bull Trout

Bull Trout and Tumwater Dam

Steve Lewis reported that the Habitat Conservation Plan Hatchery Committee meeting had a good discussion in terms of whose take is whose if there is overlap in different types of actions at one particular facility such as Tumwater. Steve Lewis stated that agencies cannot borrow incidental take from each other. Steve said he is still working on the Section 6 Permit. He asked to keep this issue on future agendas.

Action Item:

- **Tracy Hillman will keep the Bull Trout Tumwater Dam issue on the agenda for future discussion.**

VII. 25-Mile Creek

Tracy Hillman reported that Jason Lundgren, Cascade Columbia Fisheries Enhancement Group (CCFEG), is still working with Chelan County and they are trying to find a good time to talk to the RRFF. The RRFF can decide to invite them to a RRFF meeting, or request that they submit a proposal before asking for a meeting with the RRFF.

VIII. Next Steps

The next regular meeting of the RRFF will be Wednesday, 1 October 2014 from 1:00 to 4:00 p.m. in the Chelan PUD Second Floor Conference Room.

Attachment 1

Revised Proposal on the number of Juvenile White Sturgeon to Release in 2015

2015 White Sturgeon Stocking Agreement (Rocky Reach Project Area):

I. **Chelan PUD currently has 40 half-sibling families available for stocking.**
II. **Based off available half-sibling families in the hatchery, the RRFF agrees (through unanimous vote) to stock 6,500 age-1 juvenile white sturgeon into the Rocky Reach Project Area in 2015 provided:**
    i. **≥18 half-sibling families are available at the time of release.**
    ii. **Half-sibling equalization is reflected in the release to the greatest extent possible.**
III. **If <18 half-sibling families are available at the time of release, a reduced and pro-rated release strategy will be employed.**
    i. **For example: If 10 half-sibling families are available then the 2015 release would be 3,610 age-1 juvenile white sturgeon (6,500/18 half-sibling families = 361 fish/half-sibling family; 361 fish/half-sibling family X 10 half-sibling families = 3,610 stocking rate)**
IV. **This white sturgeon stocking agreement only affects release year 2015 and does not have any bearing on future releases.**

Attachment 2

Responses from Sturgeon Experts

Jim Powell, Ph.D.
Chief Executive Officer
Center for Aquatic Heath Sciences

To assure the integrity of the process, it is proper that I not participate in the Expert Review. While qualified, my prior participation in the preparation of the document could be viewed as a conflict.

As one of many contributors to the construction of the PR WSMP, it was my understanding that the WSMP constituted a recovery plan where hatchery augmentation was meant to bolster existing populations while the issues surrounding juvenile recruitment were identified and addressed. In the ranking of Waples and Drake (2004; below) the WSRP was addressing an increase in the rate of sturgeon recovery while addressing the factors that contributed to the decline. Although the emphasis in the WSRP is on augmentation, it was not my belief that it strayed from Conservation Benefits as a motivation for recovering the population. The interpretation from brief wording in the plan regarding future harvest potential places the emphasis of the WSRP on Societal Benefits for fisheries augmentation. To support the former position, conservation genetic practices were written into the plan to embrace a motivation that is conservation based. The harvest perspective ignores the need for a broad-based breeding strategy, instead focussing on biomass production.

Conservation Benefits Items:

1. Contingency against catastrophic loss of natural population
2. Reduce immediate (short-term) risk of extinction
3. Increase rate of recovery
4. Maintain natural population while factors contributing to decline are addressed
5. Reseed vacant habitat
6. Science/experimental contributions to hatchery and/or conservation science

Societal Benefits Items:

1. Legal mandate compliance
2. Fishery augmentation
3. Ecosystem Restoration

4. Public relations/education

In my outside view, the issue is to decide the future of the 'recovery' effort. Is this a Conservation initiative aimed at sturgeon recovery or a Societal initiative based on future harvest?

This is up to the co-managers and the people of WA state to decide.

Waples, R.S. and J. Drake. 2004. Risk-benefit considerations for marine stock enhancement: a Pacific salmon perspective. In K. M. Leber, ed. Stock Enhancement and Sea Ranching: Developments, Pitfalls and Opportunities, pp. 206–306. Blackwell, Oxford.

Scott Blankenship, Ph.D.
Applied Geneticist
Cramer Fish Sciences

General Comments:

I have no conflict of interest. I am working on a white sturgeon project for the USFWS to develop a new population monitoring tool based on genetics metrics, but this is currently in an experimental state and the test population is comprised of hatchery individuals housed in California.

It does not surprise me that there has been deliberation, without resolution, over several months regarding proposed stocking numbers for juvenile White Sturgeon. The problem statement presents two conflicting objectives, with one proposal intending to produce future harvest opportunities and the second proposal intending to supplement the existing population(s) using conservation genetic principles. The project goals, perceived or realized benefits, and tolerance of risk differ depending on the overarching intent of the program(s). The forums will need to resolve the primary intent of the program(s) or the decision-making process will remain unproductive, as supporting a fishery and conserving the genetic diversity of a population segment have conflicting priorities.

The program objectives state that carrying capacity will be determined and supplementation performance will be judged relative to estimated capacity of each reservoir. Yet, there doesn't appear to be a task associated with investigating what might be limiting White Sturgeon populations that currently reside in each reservoir. As a result, the indefinite use of artificial propagation appears to be envisioned, which poses significant challenges (from a genetics perspective) given each reservoir population is isolated (disconnected). A parallel process that identifies limiting factors seems warranted.

Specific Comments:

Proposal #1: 6,500 release

Proposal #2: 4,332 release

1. Based on your understanding of the problem statement, current situation, and proposed releases, what are the pros and cons of each proposal?

Pros and cons depend on the overarching program intent, they are not absolute. The central question is whether these groups are going to be managed based on census size or effective size. If the purpose of the program(s) is to provide a fishery, then reservoirs can be managed based on census size (i.e., the number of fish present). On the other hand, if the genetic trait diversity present in these isolated reservoir groups is a priority, then the effective population size is the metric by which to gauge program performance.

2. Given the status of the white sturgeon populations within the project areas and the goals and objectives of the WSMPs, which proposal do you support and why?

If the primary intent is to establish fisheries in the reservoirs, both proposals have quite similar outcomes from a long-term population genetics perspectives, in that they will essentially replace existing populations with a lower diversity hatchery derived group. Therefore, the proposal that commands the greatest support among all interested parties could be adopted.

If the primary intent is to increase population numbers while not reducing the genetic trait diversity within the groups isolated in each reservoir, then I support neither proposal. Both proposals (as I understand them) will reduce the effective population size below what is likely present now, and subsequently reduce trait diversity maintained within the isolated reservoir groups. Further, each proposal (as I understand them) may result in populations with effective sizes in a range where inbreeding is likely to occur. While the fitness loss expected due to inbreeding is unknown for these White Sturgeon reservoir groups, wild populations in general do not tolerate inbreeding well. For example, an increase in the inbreeding coefficient (i.e., F) from zero to 0.05 is expected to reduce fitness by 26% (Frankham et al. 2014). Given the White Sturgeon groups under consideration are not ESA-listed and are disconnected from the extant larger White Sturgeon gene pool, short-term tolerance of inbreeding is not warranted in order to boost population numbers.

3. Would you recommend a different release number or an alternate stocking rate (fish/area, fish/maternal group, etc.)? If so, why?

If the intent is to create a fishery, I would not recommend an alternative stocking strategy.

If the intent is to increase population numbers while not reducing the genetic trait diversity, I would recommend an alternative stocking strategy, because both proposals (as I understand

them) would reduce trait diversity from what is currently present. Alternative stocking scenarios are difficult to evaluate given imprecise biological measures and time constraints for this critique. Yet, I have roughed out some numbers given the modeling parameters already used to develop the current stocking proposals, namely a 10% annual mortality rate, a 30 y.o. age-of-maturity, and a 1:1 sex ratio.

This document states that White Sturgeon population sizes are N<300, N=551, and N=134, for Rocky Reach, Wanapum, and Priest Rapids reservoirs, respectively. If 6,500 juveniles are stocked in Rocky Reach reservoir for five consecutive years (years 1-5), then stopped, it is expected that 1,016 hatchery propagated adults would be present in the reservoir at year 35. Further, if no mortally occurs within the ~300 adults originally present, then the hatchery program will have a contribution rate of 339% (i.e., 1,016/300). If the original ~300 adults suffer mortality over the 35 years, then the hatchery contribution rate would obviously be higher. Using the same logic for the other reservoirs, a 5,000 juvenile and 1,500 juvenile stocking rate will result in 781 and 234 hatchery propagated adults present at year 35 in Wanapum and Priest Rapids reservoirs, respectively. Subsequent hatchery contribution rates would be 142% (i.e., 781/551) and 175% (i.e., 234/134), respectively.

Where this information exercise gets complicated is merging effective size information into the demographic information above. First, let's talk about the reservoir groups. While the effective sizes (N_e) are unknown, a rule-of-thumb is that N_e is ~25% of N, resulting in estimated N_e of 75, 138, and 33 for Rocky Reach, Wanapum, and Priest Rapids reservoirs, respectively. Now, let's talk about the hatchery group. Assuming the individuals in 2013 were all unrelated from each other (with inbreeding coefficients F = 0), the unequal sex ratios will create a hatchery N_e=9.6. Rounding up to 10 to make it easy, let's further assume that for each year (i.e., 5 in this scenario), that the same approximate number of unrelated (and unique) breeders are used for broodstock. This will result in a hatchery population specific N_e =50 (i.e., 10 x 5). Finally, let's talk about the Ryman-Laikre effect, which is genetics theory that relates expected total N_e given a hatchery contribution rate. Given a hatchery N_e =50 and N_e of 75, 138, and 33 for Rocky Reach, Wanapum, and Priest Rapids reservoirs, respectively, contribution rates that do not diminish total N_e can be estimated. The Ryman-Laikre model estimates that total N_e begins to diminish at contribution rates of 0.3 (i.e., 30%), 0.4, and 0.6 for Rocky Reach, Wanapum, and Priest Rapids, respectively (Figure 2). In other words, in order to not lower N_e below current levels, there can be up to 100, 220, and 80 hatchery adults present at year 35 within Rocky Reach, Wanapum, and Priest Rapids, respectively. Note, if the hatchery N_e is lower than assume, contribution rate would need to be lowered to achieve same result.

The same demographic parameters from above can be used to estimate a juvenile stocking rate

that would result in the specified number of hatchery adults being present in each reservoir at year 35. Stocking 700 juveniles per year for 5 consecutive years in Rocky Reach reservoir is estimated to produce ~100 adults at year 35. Similar calculations estimate that stocking 1,500 and 500 juveniles per year will result in ~220 and ~80 adults in Wanapum and Priest Rapids reservoirs, respectively. If higher stocking rates are desired, then a hatchery population with greater diversity must be used.

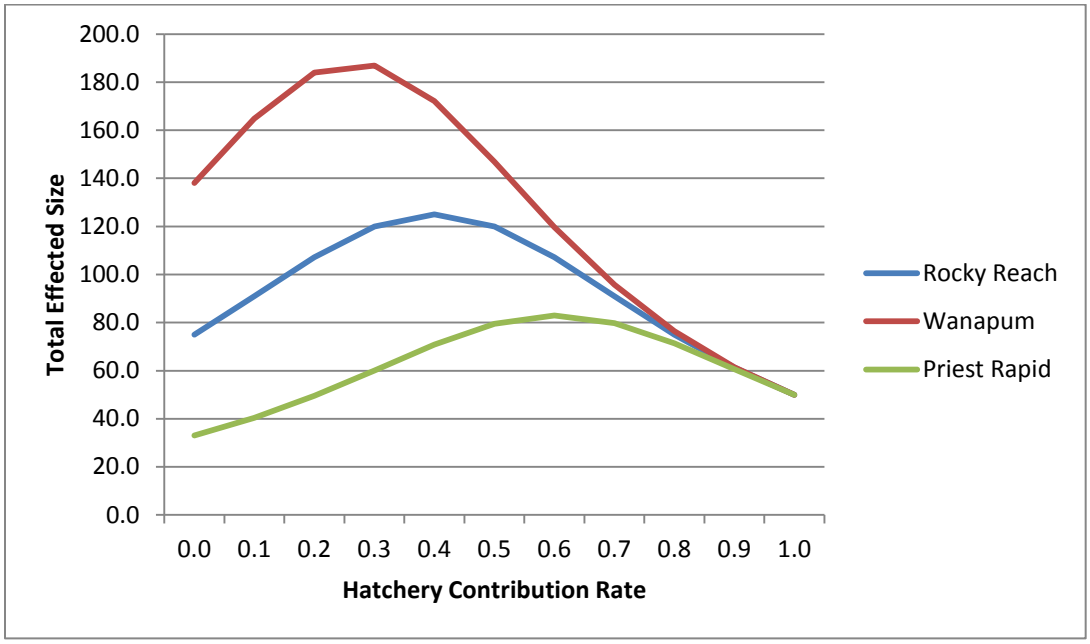

Figure 2. Ryman-laikre models for reservoirs discussed. At zero hatchery contribution, total effective size is that estimated for reservoir groups. At 100% hatchery contribution, total effective size is that estimated for hatchery (N_e = 50).

4. A lot has been said about the potential genetic risks (future genetic bottlenecks) associated with releasing 6,500 juveniles in 2014 based on 12 of the 18 crosses. Given the releases of juveniles into the project areas to date and the potential for entrainment, can you advise the Forums on what you believe would be an acceptable level of risk?

As I understand the programs, there are three genetic risk categories posed by these stocking programs: 1) Reduction of within population genetic diversity; 2) Reduced effective population size; and 3) Domestication selection. There are many strategies for mitigating domestication selection, but this issue is best handled within HGMPs, so I will not deal with that issue here. From a conservation genetics perspective, a minimum threshold for effective size (N_e) that is tolerated in intensively managed populations is N_e=50. At this population size, a majority of

trait diversity is expected to be retained over about a 100 year period, although I would expect variation around rate of genetic diversity loss to occur given the complex genetic architecture of White Sturgeon and long generation time. Yet, recent review of empirical evidence suggests that N_e=100 may be a more appropriate threshold for retention of trait diversity in the short-term (i.e., ~5 generations) (Frankham et al. 2014). I would recommend the forums adopt a criteria that reservoir populations must remain above N_e=50 and should remain above N_e=100 over the duration of supplementation evaluation in order to mitigate the risk of fitness loss due to inbreeding. Conservation genetics principles manage to effective size, not census size.

5. If the potential risks become manifest, what is the likelihood that they can be reversed, and if so, how would that be accomplished? Are there examples where this has been achieved?

Effective size functions as a harmonic mean (i.e., 1/Ne). As a result of this property, N_e can decrease quite rapidly (on the order of years). Effective size recovers as a function of the mutation rate, which is on the order of 10s to 100s of thousands of years. Further, the quantitative diversity (i.e., traits) lost within each population would be unknown. Therefore, the best action is to not reduce N_e, as is tends to ratchet lower in finite populations, leaving a smaller gene pool of available trait diversity. The only practical means to increase effective size on a "management" timeframe is to use migration to introduce diversity back into isolated populations. In other words, genetic diversity must be brought in from elsewhere to increase effective size. I am not aware of published documents specific to White Sturgeon regarding donor stock characteristics, but for other listed species (e.g., bull trout) and minimum N_e=500 is recommended in order to be considered as a donor source. I would generally agree with this recommendation.

6. Given the goals and objectives of the two WSMPs, the potential for entrainment, and the low numbers of white sturgeon in the project areas, do you have recommendations for future stocking efforts (e.g., guidance on numbers to release per maternal family or half-sibling family; total numbers to release; age and size at release; use of broodstock, wild larvae, or both; etc.)?

Answered within question #3 above.

Literature Cited:

Frankham, R., C.J.A. Bradshaw, and B.W. Brook. 2014. Genetics in conservation management: Revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. Biological Conservation 170: 56–63.

Andrea Schreier, Ph.D.
Project Scientist, Department of Animal Science
University of California, Davis

1. Based on your understanding of the problem statement, current situation, and proposed releases, what are the pros and cons of each proposal?

The first proposal would increase population size more rapidly assuming that carrying capacity has not been/will not be reached. The first proposal also may allow carrying capacity to be studied sooner. It's not clear to me how the second proposal was developed. I understand the importance of equalizing family sizes to maximize N_e by reducing variance in individual reproductive success (I support that!), but I don't understand why the number to stock from each family can't be derived from the 6,500 release goal. 6,500/12 half sib families = total number of juveniles to stock from each family. The principle of equalizing family size has more to do with increasing genetic diversity preservation and maximizing N_e rather than constraining release sizes.

It would be easier to evaluate pros and cons if survival rate was known. If survival is low, then stocking 2,168 fish may not make much difference.

2. Given the status of the white sturgeon populations within the project areas and the goals and objectives of the WSMPs, which proposal do you support and why?

I honestly don't think there is much difference between the proposals from a genetic perspective. If you equalized family sizes in both strategies, the difference in number of juveniles released per family is <200. I don't know enough about the habitat in the project areas to provide an opinion about how a larger stocking number may affect population dynamics. At this point, there doesn't seem to be enough information to evaluate that.

3. Would you recommend a different release number or an alternate stocking rate (fish/area, fish/maternal group, etc.)? If so, why?

I would recommend using as many wild broodstock as possible each year to maximize the number of maternal groups. (Better yet, use wild captured larvae!) That advice isn't exactly relevant to the two proposals but as a geneticist I recommend focusing more on representing as many parents as possible rather than worrying about differences in release sizes when the total number of fish to be released is so small (relative to many other hatchery programs).

4. A lot has been said about the potential genetic risks (future genetic bottlenecks) associated with releasing 6,500 juveniles in 2014 based on 12 of the 18 crosses. Given the releases of juveniles into the project areas to date and the potential for entrainment, can you advise the Forums on what you believe would be an acceptable

level of risk?

Operating a hatchery program is going to introduce genetic risks. Releasing 4332 fish or 6500 fish will reduce the N_e of the wild population (Ryman Laikre) and potentially introduce maladaptive alleles. The choice to operate a supplementation program (vs not supplementing) is going to have a much greater effect on the wild population than the effect of stocking 6500 or 4332 juveniles. It is a good idea to equalize family sizes, a feature of both proposals. With the mating design available, this is the best way to reduce negative effects on N_e.

If you want to further minimize risk, use wild spawned larvae (excess from UCR program?) as they will represent genetic contributions of a greater number of adults and will be less likely to suffer negative effects from hatchery spawning (spontaneous autopolyploidy, hatchery selection operating at very early life stages).

5. If the potential risks become manifest, what is the likelihood that they can be reversed, and if so, how would that be accomplished? Are there examples where this has been achieved?

If genetic diversity loss and/or reduction in N_e do occur, these can be ameliorated by introducing more genetic diversity. This may be accomplished by translocating adults from adjacent reaches or increasing the number of crosses used in supplementation. I am not sure the proposal for selective harvest mentioned above will be successful. What would be the method of selection? How could an angler discern whether a fish belonged to an overrepresented family or not?

Another point is that we don't know how much inbreeding is going to cause inbreeding depression in polyploid sturgeon. Obviously we want to prioritize maximizing genetic diversity conservation in supplementation programs but we can't predict exactly how genetic diversity loss of various magnitudes will affect the wild population.

6. Given the goals and objectives of the two WSMPs, the potential for entrainment, and the low numbers of white sturgeon in the project areas, do you have recommendations for future stocking efforts (e.g., guidance on numbers to release per maternal family or half-sibling family; total numbers to release; age and size at release; use of broodstock, wild larvae, or both; etc.)?

My #1 recommendation would be to supplement with wild larvae from a geographically proximate reach exhibiting consistent recruitment. Using wild larvae preserves natural mating behavior, reduces the incidence of spontaneous autopolyploidy (which may be occurring in this program if standard artificial spawning techniques are used), and increases the number of wild parents represented. If captive spawning must be used, wild broodstock from the same or adjacent reaches are preferable. Continuing to equalize family sizes is important. I would avoid

getting excess larvae from captive broodstock because programs with a small number of broodstock are more likely to be inbred (adults are close relatives) which greatly increases the chance of inbreeding depression in wild population. Wild broodstock are likely unrelated given the relative recentness of habitat fragmentation in the Columbia. I would also continue avoiding use of broodstock from below Bonneville and expand this to include adjacent reaches in the Lower Columbia (Bonneville Reservoir, The Dalles, John Day). Patterns of population structure in the Columbia suggest that white sturgeon occupying the Lower Columbia may not have interbred often with white sturgeon further up in the system.

In terms of age and size at release, reducing length of time in the hatchery is best (reducing length of time individuals exposed to unnatural selection pressures) but this also needs to be weighed with survival rate at various life stages. It is obviously not advantageous to stock juveniles at very small sizes to avoid unnatural selection pressure if survival of small juveniles in the wild is low.

Dr. Schreier offered the following addition information based on a question from the Forums:

During the workshop, participants had a question regarding Dr. Shreier's response to question #6. In her response she stated, "I would also continue avoiding use of broodstock from below Bonneville and expand this to include adjacent reaches in the Lower Columbia (Bonneville Reservoir, The Dalles, John Day)." The Forums asked if she was recommending that we should not collect broodstock (or wild larvae) from the lower Columbia (downstream from John Day Dam)? If so, why?

Dr. Schreier responded, "Population structure in the Columbia-Snake system is rather complex, so your question is a good one. There appears to be one population associated with the downstream-most end of the Columbia and one associated with the Middle Snake. Everything in between seems to be admixed, with the influence of the Middle Snake group decreasing as you sample fish downstream. This is likely a reflection of net downstream gene flow (sturgeon entrain downstream through dams but can't be back upstream, except at The Dalles). That being said, it's probably better to get broodstock or larvae from the Middle or Upper Columbia as these are most similar to the project area. The fish in Dalles and John Day are a somewhat more similar to that Lower Columbia population than to the Mid Columbia. If there is no viable option in the Mid or Upper Columbia, Dalles and John Day would be better options than the Columbia River estuary. I wish we had better genetic markers so I could give you a more clear answer, but we are stuck with interpreting dominant microsatellite data for now."

Mr. Ken Lepla
Senior Biologist
Idaho Power Company

Given the low numbers of white sturgeon [WS] in the project areas, supplementation to rebuild WS abundance certainly appears warranted, and likely the only alternative that can meet Plan goals. That being said, it appears the primary concern (as well as most of the questions) is specific to population genetics and suspect best addressed by fish geneticists. Unfortunately I am not one and therefore my response is more along lines of some general thoughts. My suggestion to the Fish Forums is to rely on the guidance provided by genetic experts regarding what are appropriate mating schemes, release numbers, stocking rates, etc. and the acceptable levels of risk. I do not have the expertise to provide recommendations. However, because of uncertainty and potential for risk it would seem prudent to be proactive and implement strategies that maintain as much genetic diversity as possible (or managing those actions that decrease diversity) rather than later try to deal with reversing potential negative effects that could manifest.

Given WS abundance in the Project areas are small; it also seems beneficial to consider multiple sources for diversity. As you noted and a population structure analysis of white sturgeon by Schreier et al. 2013 shows, several downstream reaches in the Columbia, with much larger abundances of WS, were genetically similar to the Project areas. Perhaps brood stock or wild larvae (or both) from these reaches can be incorporated periodically in supplementation strategies, as a means to ensure high levels of diversity in the Project areas, as well as reduce downstream concerns about hatchery introgression from entrainment. The Colville Tribe has demonstrated the benefits of collecting naturally-produced larvae (see Jason McLellan). This novel approach potentially could minimize a lot of the genetic concerns within reach as well as downstream export.

Again, thanks for considering my input, but strongly feel the Fish Forums should seek the advice of fish geneticists for guidance to these questions.

The following comments from Dr. McAdam and Dr. Anders were provided after the workshop.

Steve McAdam, Ph.D.
Senior Biologist
University of British Columbia, Fisheries Center

My apologies, but I just don't have the time to give you a proper answer.

I did briefly look over some of the material when I first got your e-mail. I do agree that the concern you are trying to address is important, but given the difference between two scenarios the consequences of choosing one scenario over the other for a single year might be small (at least for an individual year). The possibility of mitigating any 'error' by selective harvest in future is also an important consideration. Other important considerations I can think of are the extant genetic condition of the population, the low number of breeders (not unique to your situation by any means), expected survival rates, other hatchery effects (release numbers is likely only one of many considerations), future harvest levels....all of these would have affect your decision. While I didn't review your information thoroughly enough to see what information was provided on those points, they would certainly be things I would consider over the long term as release numbers continue to be evaluated.

Paul Anders, Ph.D.
Fisheries Scientist
Cramer Fish Sciences

There are so many issues, conditions, and uncertainties involved here that require careful presentation and discussion, and I don't want to over-simplify and be misinterpreted. I had intended to provide additional information, but am only able to provide a short summary today re the above subject.

Re the above subject, I agree with Andrea's assessment of the 2 release number options (6,500 vs. 4,332): "I honestly don't think there is much difference between the proposals from a genetic perspective".

Thus, in the short-term (and assuming that this hatchery program will be operating annually for at least the better part of a sturgeon generation?), I could support either proposal. However, I would initially suggest the larger release strategy during initial program years specifically to reduce the time required to produce the needed empirical post-release survival estimates. This

recommendation addresses a specific short-term goal, with no intention of downplaying the importance of any other demographic and genetic goals needed for the program, which the collaborating entities and outside reviewers have spoken to.

This recommendation assumes that: 1) the benefits of quickly establishing relevant post-release survival rates up front will exceed the genetic risks of these actions in the short term, or if not, risks can be compensated for over the life of the program; and 2) use of empirical survival rates from the populations of interest ASAP can reduce future risks that could occur without having those estimates. This recommendation does not suggest that the 6,500 fish release number should be maintained. Rather, survival rates should then be used to adjust future release strategies, along with efforts to maximize genetic benefit (e.g. measured as Ne, genetic contribution/diversity) and minimize genetic risks (inbreeding estimates), to be tracked annually but relevant at the generational time-scale, the time-scale at which many genetic risk/population persistence or viability models operate.

That said, the issue of equalization of family size at release is relevant here. This issue is less controversial when family sizes are not limiting or when they have relatively similar abundances. However, differences in pre-release abundance across families in the hatchery invariably occur. Then debate ensues about whether you should equalize family release numbers down to the smallest family size, which in extreme but not unusual cases can be too low to provide any benefit the population. Thus, an agreed-upon policy regarding equalization of family size at release with adequate resolution is needed if it doesn't already exist.

There are many more issues involved here. However, I am not currently able to address them with the detail they deserve, not due to of any conflicts of interest.. just due to conflicts of time....

Attachment 3

Memo from Steve Rainey to Steve Lewis on His Site Visit to Tumwater and 3-Mile Dams

Steve Rainey Fish Passage Consulting
1928 SE 12th Ave.
Camas, WA 98607
503-260-6990

July 15, 2014

To: Steve Lewis, FWS-Wenatchee

Subject: Site Visits to Tumwater and 3-Mile Dams Re Lamprey Passage Devices (LPD)

Hi Steve, I took a lot of notes at both sites, so am presenting impressions below. Please bear with me, as there may be some inaccuracies.

I visited the above sites on July 10 – 11, 2014. Purpose was to assess lamprey passage issues at Tumwater Dam, and to learn more about the LPD that has been in place at 3-Mile Dam since 2011.

Tumwater Fishway

Steve Lewis (FWS), Steve Hemstreet (Chelan PUD), Thad XX (PUD-biologist), and Jerry (PUD-Operations) were there for the site visit. As I had not been to Tumwater in years, I spent a short amount of time re-affirming different features relating to operation of fishway in/out of trapping operational mode, as they pertain to lamprey passage.

Fishway Trapping Operation

Washington Dept of Fish and Wildlife (WDFW) has been blocking/trapping the Tumwater ladder since 1994, and forcing fish to ascend the steeppass ladder where biologists can either trap them or return them to the river upstream of the dam. This trapping operation is consistent with the PUD HCP, and targets salmonid passage, but does not cater to lamprey passage.

Target species include:

- Spring chinook

- Steelhead
- Bull trout

Functional trapping needs include:

- Collect Hatchery salmon brood stock
- Minimize straying of hatchery adult returns
- Only pass wild salmon, bull trout (50 – 100 per year), and steelhead upstream of Tumwater
- Study reproductive success of wild vs hatchery salmon/steelhead

Adverse Lamprey and Sockeye Impacts from Salmonid Trapping Program

- Lamprey blockage (if lamprey are indeed indigenous to the river upstream of Tumwater)…many lamprey apparently overwinter before ascending tributaries, so would potentially be present earlier in the spring during continuous trapping operations. WDFW has not seen lamprey ascend the steeppass ladder from the trapping pool to the sampling facilities, nor have they seen lamprey at the fishway.
- Sockeye passage delay is 25 days with trap operating, but only a few minutes if it is not
- Sockeye delay has been assessed from PIT detectors at weirs 15 and 18, but not from 18 into the vee-trap, and up the steeppass. There is little delay from weir 15 to 18, but probably significant delay from 18 to the sampling facilities.

Lamprey passage is potentially impacted by forcing them to pass the steeppass, which is likely a complete barrier. By mid-July, targeted spring chinook and steelhead (many of which overwinter after entering the Columbia the previous year) have mostly passed. As sockeye numbers in the tailrace increase during mid-July, WDFW reduces trapping hours per day from 24 down to 16. There may still be some bull trout passing by this date.

My understanding is that FWS wants to assess placement of a LPD in the Tumwater ladder, to provide passage concurrent with adult salmonid trapping operations.

Lamprey Passage Uncertainties

Historic lamprey passage above Tumwater is apparently assumed, partly on the basis of the PUD's Steve Hayes' remembrance of seeing some amocetes upstream of the dam in the past. The key question is whether lamprey still move upstream to the dam, or whether that portion of the run has been extirpated. PUD data suggests that approximately 75% of the Rock Island lamprey count passes above Rocky Reach. Thus, at least some of the remaining 25% must be migrating up the Wenatchee.

There was also reference to a large number of amocetes on the Dryden Canal fish screens. However, distinction of whether that includes primarily Western Brook Lamprey, or targeted Pacific Lamprey, was not specified.

Also, an important question is whether a LPD should be placed in the Tumwater ladder if more is not known relative to the overall lamprey distribution and numbers in the Wenatchee River. Questions include:

- Did/do lamprey ascend the river above Leavenworth (where gradient is steeper and passage more challenging even for salmonids)?
- Do lamprey enter the Tumwater fishway? (A Didson camera could be used to detect lamprey presence immediately upstream of the fishway entrance)
- Is installation of a LPD in the fishway part of a more protracted and well-funded restoration program to increase numbers upstream of Tumwater (such as on the Umatilla River – see below)??
- Are observed lamprey in the Wenatchee at different sites Pacific Lamprey, or another lamprey species?

Considerations Relative to Installing an LPD at Tumwater

- To design an effective LPD, lamprey delay and accumulation locations should be identified for ramps into tailwater
- From work on the Umatilla at 3-Mile Dam (the initial tributary LPD), Lamprey seek upstream terminus locations, as do salmonids. That should dictate where the LPD "entrance" would be if one is implemented at Tumwater.
- The perceived upstream terminus within the ladder is at the upstream weir in the ladder (pool 18), where diffusers block further upstream movement of salmonids, but allow some ladder flow continues to pass. Other flow into pool #18 is from the adult holding pool through the vee-trap
- Logical location for a ramp to extend to the water surface would be this most upstream pool, in the southwest corner. It has the least turbulence for this pool, and could be where lamprey would accumulate. Confirmation that lamprey are accumulating at that point is considered an important pre-requisite to LPD implementation
- A 60-degree ramp could be provided into the selected holding zone, and could extend above walkway grating and original training wall (about a 9 ft lift at the flow of about 4200 cfs on this day). A transition to a 5-degree ramp could then lead ascending lamprey to a collection box, where fyke could be placed to assure against fallback. Lamprey could then be trapped, and either routed back to forebay (which is well upstream of the dam crest) or transported. The horizontal distance from Pool 18 to the river is only about 10 ft, and the drop is close to 9 ft at this flow.
- An LPD at the Tumwater ladder would be based on designs at Bonneville, and 3-Mile Dam

3-Mile Dam LPD

I met with Aaron Jackson on the morning of July 11. The Umatilla Tribe implemented a lamprey

restoration initiative over ten years ago. It included release of lamprey from Bonneville upstream of 3-Mile Dam on the Umatilla River, in favorable spawning habitat. The LPD was installed in about 2010 at the right fishway, immediately outside of the upstream fishway entrance. Lamprey passage was about 5 – 10 fish from 1998 to 2010. Counts increased to 129 in 2010, dropped to 104 in 2011, then increased to 325 in 2012 and are at 425 so far this year. Most of the fish overwinter, then pass in the spring. As it takes 4-6 years for juveniles to leave fresh water, and they spend 1-3 years in the ocean, the recent increases to 3-Mile could be attributed to the releases upstream of the dam.

The LPD has two 20" wide, 60 degree collection ramps that extend from a rest box down to tailwater (Figure 1). Location of each ramp entry to tailwater is on both sides of the fishway entrance. A single covered 45 degree 20" wide ramp then extends up from the rest box and over the dam crest (Figure 2).

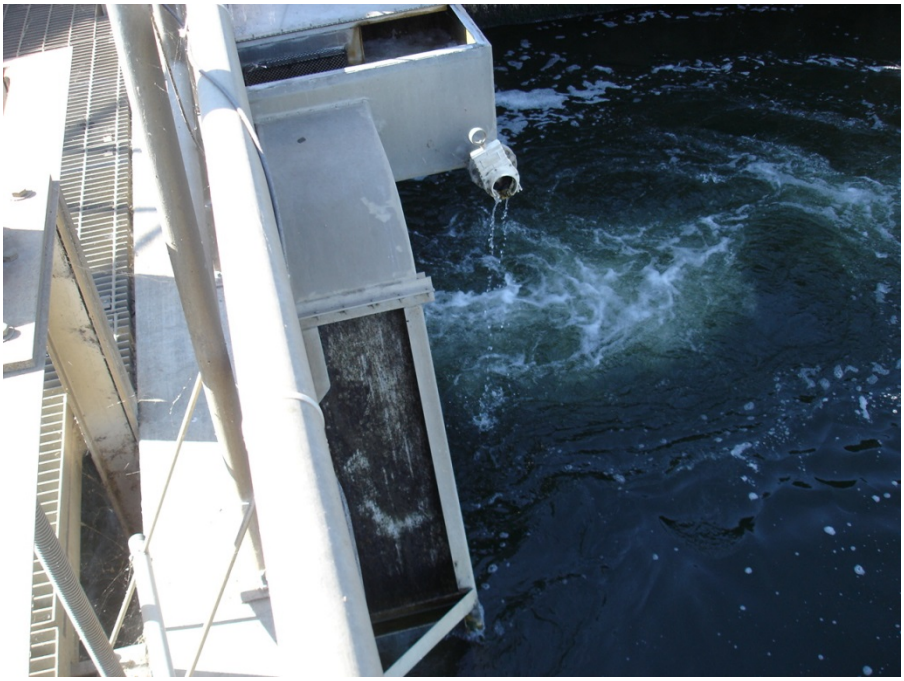

Figure 1

Figure 2

The 45 degree ramp then transitions and flattens to an easily accessible nearly flat ramp and lamprey must enter a transition to a 8” wide flume (Figure 3).

Figure 3

At this site, there is an experimental counter, then a half-duplex PIT detector, and an upwell box with a fyke (Figure 4) that supplies flow to the flume. Fish then pass thru a pipe to forebay (Figure 5)

Figure 4

Figure 5

Pump flow to the upwell is about 150 gpm, and the facility was fabricated in the NMFS Pasco screen shop, for about $60K - $80K.

Similar but smaller LPD's are installed at Feed Canal fishway and the Dillon Diversion.

Concluding Comments:

1. The tribes have seen success in restoring Pacific Lamprey upstream of 3-Mile Dam on the Umatilla River. They have been working on restoration for over ten years, and have committed appropriate resources to this effort.
2. Similar success on the Wenatchee will likely require a similar long-term investment of resources.
3. A trip to meet with Aaron Jackson, starting at 3-Mile and visiting Feed Canal and Dillion LPD's would be an important step in using the Umatilla lamprey passage efforts as a model for the Wenatchee.
4. Some lamprey behavioral observations in the 3-Mile Dam tailwater were important in siting the LPD.
5. I recommend a Didson camera be used to see if Pacific Lamprey are entering the Tumwater fishway. If they are not, and if there are no plans to reintroduce them upstream of the dam, installation of a LPD in the fishway may not lead to restoration upstream of the site.