PRFF, RRFF, and ASWG
Pacific Lamprey Subgroup Meeting
Conference Call

Wednesday, 6 August 2025
9:00 a.m. – 2:30 p.m.

FINAL MINUTES

Meeting Attendees

Mike Clement, Grant PUD
Chris Mott, Grant PUD
Ryan Harnish, PNNL
Mariah Mayfield, Douglas PUD
Andrew Gingerich, Douglas PUD
Lance Keller, Chelan PUD
Corey Wright, LGL/Blue Leaf
Pete McHugh, CRITFC
James Barron, WDFW
Laura Heironimus, WDFW
Michael Lucid, USFWS
Melissa Peterson, Ecology
Sannon Adams, YN
Aaron Jackson, CTUIR
Kyle Tidwell, USACE
Tracy Hillman, Chair
Ralph Lampman, YN
Joseph LeMoine, Grant PUD
Bob Mueller, PNNL
Chas Kyger, Douglas PUD
Bill Towey, Chelan PUD
Scott Hopkins, Chelan PUD
Tod Sween, Nez Perce
Grace Adams, PLCI Coordinator
Laurie Porter, CRITFC
Monica Blanchard, WDFW
Todd Miller, WDFW
Jason McLellan, CRCT
Ann Grote, USFWS
Tom Lorz, CRITFC
Larissa Rohrbach, PRCC Chair

Action Items:

- Tracy Hillman will share the draft meeting notes and recommendations from the Pacific Lamprey Subgroup meeting with the chairs of the PRFF, RRFF, and ASWG. **Complete**
- Jason McLellan said he will share a paper with the groups that looks at predation and its effect on survival studies. **Complete**

- Ryan Harnish will estimate sample sizes for a study involving a combined ViRDCt/ViPRe study. **Ongoing**

I. Welcome and Agenda Review

Tracy Hillman welcomed everyone to the meeting and reviewed the agenda. He explained that the purpose of the meeting is to examine the most recent information on estimation of survival of juvenile Pacific Lamprey migrating through hydroelectric projects. In addition, the Subgroup will review "key questions" associated with a valid juvenile Pacific Lamprey survival study and identify possible recommendations for the Priest Rapids Fish Forum (PRFF), Rocky Reach Fish Forum (RRFF), and Aquatic Settlement Work Group (ASWG).

II. PNNL Summary of Research Results and Responses to Questions

Tracy Hillman introduced Ryan Harnish from the Pacific Northwest National Laboratory (PNNL) and noted that Ryan received a list of questions from the PRFF, RRFF, and ASWG (see Attachment 1) regarding how to conduct valid juvenile Pacific Lamprey survival studies. The questions focused on route selection, performance of hatchery versus wild juvenile lamprey, source fish, release location, precision and survival, tag detection and residency, tag availability, modeling approaches, scale of study, and run timing and environmental conditions. Tracy noted that Ryan and his team have been conducting juvenile lamprey survival studies in the Snake and Columbia rivers since 2022.

Ryan Harnish thanked the groups for inviting him to the discussion and gave a presentation in which he responded to questions regarding valid juvenile Pacific Lamprey survival studies (see Attachment 2). The following notes capture highlights from discussions associated with each question.

Route Selection

<u>Question</u>: What routes through dams are juvenile lamprey most likely to take?

> Ryan presented a table that showed the route selection of juvenile lamprey at all of the dams they have evaluated (Lower Granite, Lower Monumental, McNary, and John Day dams) through 2024. He showed the percentage of tagged fish that passed through the powerhouse, conventional spill, and spillway weir at each dam during day and night. Generally, passage was about a 1:1 split between the powerhouse and spillway, meaning that tagged juveniles are equally likely to pass through the powerhouse and spillway. Percentages through the powerhouse ranged from 39-59%. He added that spillway weirs were used about 7-16% of the time, with most of the passage at the spillway weir occurring at night. Similarly, most of the passage through the conventional spill occurred at night. In contrast, most of the passage through the powerhouse occurred during the day.
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> Laurie Porter asked whether the differences between day and night were related to spill operations. Ryan responded that spill operations appeared to affect passage route. For example, at John Day Dam, operations switched between lower performance standard spill during the day and the higher gas cap spill at night. This affected the passage routes of juveniles passing through the powerhouse at John Day Dam. Spill operations also appeared to affect the depth at which juveniles migrated. There was no difference in spill operations at McNary Dam during day and night and therefore little difference in passage routes of juveniles. Ralph Lampman asked whether the spillway weirs were set up similarly at all the dams evaluated in this study. Bob Mueller responded that they are similar based on the depth at which they draw water; however, flows through the spillway can vary depending on operations. Ryan added that the spillway weirs are located in the first spill bay closest to the powerhouse.

Question: How does migration vary by time of day and water depth?

Ryan presented figures showing the depth at which juveniles approached and passed through the powerhouse and spillway at each project during day and night. At all projects, fish that passed through the powerhouse migrated at deeper depths than those that migrated through the spillway. In addition, juveniles that migrated during the day were generally deeper in the water column than fish migrating at night. He added that this is opposite of what is seen with salmonid smolts. Smolts tend to migrate deeper during the night than they do during the daytime.

Question: Is there a relationship between flow distribution and passage route?

Ryan presented figures showing the relationship between spill proportion and powerhouse passage probability for each project. In general, as spill proportion increased, powerhouse passage probability decreased (i.e., negative association). This was true regardless of which project was evaluated. Ryan noted that the "across-channel" distribution of fish affected passage route. That is, at Lower Granite Dam for example, fish located on the spillway side of the channel had a lower probability of passing through the powerhouse than fish distributed on the powerhouse side of the channel. That was consistent across the different projects evaluated.

Ann Grote asked whether there was an evaluation of water velocities, swim speeds, and whether the juveniles can move laterally within the forebays. Ryan responded that it appears the fish can move laterally within the forebays, but it is related to river flow. For example, at higher flows, juveniles basically are entrained in the flow and go through the dam based on their location in the forebay. At lower flows, the fish appear to be able to move laterally within the forebay. For example, at Lower Granite Dam, juvenile approaching the powerhouse on the powerhouse side of the river had a 50% chance of passing through the powerhouse at lower flows, while the percentage was much higher (~100%) at higher flows.

Question: How do flows, flow fluctuations, and water temperatures affect passage routes?

Ryan presented figures showing the relationship between flows and powerhouse passage probability, and forebay temperatures and powerhouse passage probability. At Lower Granite Dam, powerhouse passage probability increased with outflow, but the relationship was affected by which side of the reservoir the fish approached the dam. At Lower Monumental, McNary, and John Day dams, powerhouse passage probability generally decreased with flow; however, the decrease in passage probability at McNary and John Day dams was small over the range of flows. In general, at all dams, powerhouse passage probability increased with forebay temperature.

Ralph Lampman asked whether the proportion of flow going through the powerhouse and spillways affected passage routes. Ryan responded that it appears to be dam specific and depends on gas cap, time of day (i.e., day or night), and cross-channel distribution. In general, the proportion of juveniles passing through the spillway and powerhouse is close to 1:1 when flow is equally split.

Question: How do flows, flow fluctuations, and water temperatures affect survival?

Ryan said they have not conducted any in-depth analyses that would address this question; however, they have examined relationships between river kilometers and survival probability for groups that are released at different times. Fish released in May and June (higher flow conditions) had a higher survival rate than fish released in April (low flow conditions). Flow conditions in 2024 were very low and survival of tagged juveniles from McNary Dam to Crow Butte was about 12%. Survival to John Day Dam was about 3%. Ryan noted that during these low flow conditions, they are not sure the fish are actively migrating. The juveniles may be holding until there are higher flows. Thus, the survival estimates may be biased low during low flow conditions.

Laurie Porter asked whether survival rates were affected by temperatures. Ryan said he does not believe temperature had a large effect on the survival rates. For example, the low survival rates of the April release group occurred when temperatures were cold. Andrew Gingerich asked for information on the life of the tags and whether that could affect the survival rates observed in juveniles migrating during lower flow conditions. Ryan indicated that he would address that question later in the presentation.

Question: What role does proximity to the thalweg and flow fluctuations play in route selection?

Ryan presented figures that showed the proportion of juveniles detected across the forebay of each dam. The figures reveal the cross-channel distribution of fish about 2 km upstream from the dams. Ryan was not sure of the location of the thalweg but noted that fish tended to move in the Snake River closer to the Washington (north) shore. At McNary Dam, the fish tended to be distributed closer to the Oregon (south) shore. There was no apparent skew in the distribution data at John Day Dam. Ryan also pointed out that there is not much fluctuation in flows at the federal projects.

Question: What information is available on the type of screen infrastructure across Mid-C projects and is it currently “lamprey friendly?”

Ryan said he does not have information on the screens on Mid-C projects but noted that Lower Granite and McNary dams have extended-length bar screens (ESBS). Lower Monumental and John Day dams have submersible traveling screens (STS). Bob Mueller indicated that based on lab studies, STS are more fish friendly than ESBS. Ryan said juvenile survival rates at Lower Granite and McNary dams (with ESBS) were 0.8058 and 0.7295, respectively. Juvenile survivals at Lower Monumental and John Day dams (with STS) were 0.7924 and 0.5910, respectively. Interestingly, survival at John Day Dam at night was relatively high (0.7063). Ryan clarified that the survival estimates at these projects are not a direct result of the screens. It is unknown how many juveniles were killed on the screens.

Lance Keller asked what proportion of the turbine intakes are screened at the federal projects. Bob Mueller responded that he was not sure but speculated that about the upper third of the intakes are screened.

Performance of Hatchery versus Wild Juvenile Lamprey

Question: Are there differences in behavior between hatchery- and natural-origin juveniles?

Ryan said they tagged hatchery-origin juveniles in 2023 and 2024 and included those fish with the run-of-river (ROR) release groups. This allowed them to compare the residence and egress times of the different origins. In 2023, the median residence times for hatchery and ROR fish at Lower Granite Dam were 1.6 and 2.7 hours, respectively. The median egress times were 0.4 and 0.6 hours for the respective origins. At Lower Monumental Dam, the median residence times for hatchery and ROR fish were 1.0 and 1.1 hours, respectively, while the median egress times were 0.4 and 0.4 hours for the respective origins. In 2024, the hatchery-origin fish tended to travel a bit more quickly than ROR fish; however, by later in the migration period, ROR fish traveled more quickly than did hatchery-origin fish. The change in migration rates may be related to the loss of hatchery-origin fish as they migrated downstream.

Laurie Porter asked whether it is safe to say the hatchery-origin fish are an adequate substitute or surrogate for ROR fish. Ryan said he believes so. He added that the routes that hatchery-origin fish take through the projects are similar to ROR juveniles. Ryan added that survival of hatchery-origin juveniles was related to their length and weight. Hatchery-origin juveniles generally had lower weights than ROR fish of the same length. Ann Grote asked about the number of hatchery-origin fish used in the studies. Ryan indicated that for the 2024 hatchery-origin versus ROR juvenile survival comparisons from release to McNary Dam and McNary Dam to John Day Dam, the sample sizes were 116 hatchery-origin juveniles and 118 ROR juveniles. Ralph Lampman asked whether there is a relationship between the size of ROR fish and their survival. Ryan responded that they have not identified a relationship between the size of ROR fish and their survival.

Release Location

Question: How far upstream from a dam should juvenile lamprey be released to maximize detection and survival?

Ryan noted that in 2022, they released juvenile lamprey at Blyton Landing, which is 20 km upstream of Lower Granite Dam. The juvenile lamprey survival rate was 0.884 from the release site to the dam. As pointed out earlier, the survival rate for the April release group was low (0.697), while the survival rate for the May/June release groups was 0.921. In 2023, the survival rate from Blyton Landing to Lower Granite Dam was 0.907. In 2024, the survival rate of juvenile lamprey from Port Kelly to McNary Dam was 0.735 (distance of 34 km), while the survival rate from Arlington to John Day Dam was 0.454 (distance of 39 km). Ryan said they typically release the fish about 20 km upstream of the dam. This is needed to make sure the fish recover from handling and tagging effects and behave and redistribute themselves as ROR fish before they encounter the dam.

Ralph Lampman asked whether there were any differences in the time of day that the tagged fish were released that could explain the results. Bob Mueller said the 2022 and 2023 releases were made at dusk. The 2024 releases were made during the late afternoon. Ann Grote asked whether the tagged fish were released at the boat launch, or were they released across the width of the channel. Bob Mueller said they released the fish at five equally spaced locations across the width of the channel. Ralph Lampman asked whether they evaluated the effects of the five release locations on juvenile survival. Ryan said they did not evaluate the effects of release location across the channel on survival rates. Andrew Gingerich asked whether the tagged fish released are the "study" fish, or do they have to make it to some array closer to the dam to be considered "study" fish (i.e., virtual release). Ryan said the purpose of the study is to estimate dam passage survival; therefore, the virtual releases represent the "study" fish. That is, of all the tagged released, only the tagged fish detected before they reach the dam are included in the study. Ryan added that there was a group of juvenile lamprey released at Arlington in 2024 that had some fungus and that group suffered higher mortality rates than other groups.

Precision and Survival

Question: What is the relationship between sample size (i.e., number of juveniles tagged) and precision of route-specific survival rates?

Ryan presented a figure that showed the relationship between virtual release size and precision of the survival estimate (90% or 95% CI). For this analysis, Ryan assumed the use of the ViRDCt (virtual release/dead-fish correction) model, D_1 = 100 (number of dead fish released), S_D = 0.75 (dam passage survival estimate), λ = 0.7 (joint probability of survival and detection to the next downstream array), φ = 0.3 (dead fish detection rate), and p = 0.98 (tailrace array detection probability). As shown in the figure, as sample size increases, precision increases up to about 120 fish in the virtual release group. After that, increasing sample size does little to increase precision. Ryan added that the dam passage survival estimate also affects precision. To demonstrate this, Ryan presented a figure showing the relationship between dam survival and precision. The relationship shows that as dam passage survival increases, precision improves. Dead fish detection rate has little effect on precision unless detection rates are high (>75%). Ryan noted that tailrace detection probability is the last factor that affects precision. Here, the goal is to achieve >75% detection probability, which they have found to be easy to achieve (they have achieved 99%). Ryan added that the number of dead fish released does not have a large effect on precision.

Laurie Porter asked whether there is enough information available to identify an appropriate sample size of juvenile lamprey to conduct a valid, statistical survival study. Ryan responded that it depends on the assumptions and the scale of the study. The work completed at the Snake and Columbia River projects provides useful information and would certainly provide a starting point for estimating sample sizes. Sample size will also depend on what level of precision is needed in the survival estimate and whether route specific information is required. Ann Grote asked whether they are identifying any of the dead fish released as part of the study. Ryan said they detect a relatively high proportion of the dead fish released (20-40%). He added that John Day Dam was the exception. There, they detected around 2% of the dead fish.

Question: What level of precision can be expected in survival estimates?

Ryan said that based on virtual release group sizes of 178 to 312 juveniles, survival rates ranged from 0.714 to 0.911. Standard errors associated with those survival estimates ranged from 0.029 to 0.059 (3-6%).

Question: Pros and cons of so many different release groups? Why Feb to June? Are there advantages to combine?

Ryan presented some graphs showing the changes in flows and temperatures over time at Lower Granite and Lower Monumental dams. He also showed the number of juveniles observed at the dams. He said in most years, juveniles move through the system in May through mid-June, but there have been some years when some juveniles move through the system in late summer or early fall. He added that there is variability in when the fish move and it is difficult to predict when they will move. It can also be difficult to collect a sufficient number of fish for the survival studies; therefore, you may have to collect fish from several different locations and hold them before tagging and release. Ryan showed figures demonstrating the different "pulses" of juveniles observed at the Lower Granite Dam juvenile fish facility. For example, in one year (2022), there was a pulse of juveniles in late March and another pulse in late May. Interestingly, in that same year, there was a pulse of juveniles in October. In 2023, most of the juveniles passed Lower Granite Dam in mid to late April with another smaller pulse in early May. He said this is why their studies have been conducted over a relatively extended period of time.

Aaron Jackson noted that based on his trapping studies in tributaries in the Umatilla River basin, juvenile lamprey tend to move out of the systems during freshets. Some of these events occur between October through March and therefore these fish would not be included in mainstem survival studies. Aaron believes that a large component of the fish are moving at times when survival studies would not occur. Ryan agreed and said that is why they tried to capture juveniles as early as possible (e.g., beginning in February).

Question: Regarding reservoir survival studies, is there any value to paired releases?

Ryan showed a table identifying the survivals for different reaches for survey years 2022 and 2023. For example, the survival per kilometer of tagged juveniles from Central Ferry to Little Goose Dam forebay (reservoir reach) was 0.9975 in 2022 and 0.9989 in 2023. The survival per kilometer of juveniles from Ice Harbor pool to Ice Harbor forebay was 0.9936 in 2023. This estimate may be underestimated because of premature battery failure of one release group. Ryan reminded the group that the objective of the survival studies in the Snake and lower Columbia rivers was to estimate survival at the dam, not through the project area, which includes both survival in the reservoir and through the dam. He added that if the objective is to evaluate project survival (i.e., upstream end of reservoir to the tailrace), then a paired release may be most appropriate.

Tag Detection and Residency

Question: How many juveniles reside in the reservoir without migrating through the dam? What proportion of tagged migrants delay their migration through the reservoir?

Ryan noted that they do not have a good estimate of the number of juveniles that reside for extended periods within the reservoir. He said the best they can do is look at the joint probabilities of migration and survival. He added that the assumption is that juveniles are actively migrating but whether they complete migration through the study area before the battery of transmitter dies is not known with certainty. Tag-life corrections should help but these corrections do not correct survival estimates for a juvenile that passed the dam after its transmitter died. Ryan indicated that they tagged some fish with PIT tags and those fish were detected at downstream locations after the acoustic tag had died. Ryan stated that juveniles tagged in 2024 and released at Arlington migrated during low flows. It is likely that several of those fish did not migrate, or they migrated after the tag died. He commented that they observed very low migration rates of tagged larvae, but that was expected.

Question: Do the tags last long enough to track the slow migrants through the reservoir and dam? Are the tags capable of assessing unbiased project-scale (reservoir and dam) survival rates? Are there limitations such as battery life, reservoir length, and flow conditions?

Ryan noted that this is difficult to answer from their studies because the focus of their work was on dam passage. Thus, estimates through the reservoirs or longer reaches is based on the joint probability of migration and survival through the reach. Ryan presented figures showing results from their tag-life studies. In general, they found that tags lasted through about 20 days and then started to die from 20 to 40 days. The results were similar in 2022 and 2023 (up to 20 days), but after 20 days, most of the tags evaluated in 2023 died rapidly. Ryan also presented a figure showing the travel times of tagged juveniles from release at Blyton Landing (20 km upstream of Lower Granite Dam) to the mouth of the Snake River. The median travel times were less than 10 days; however, there were several tagged fish that migrated slowly (> 20 days). It is unclear whether some tagged fish migrated after the tag died. Travel time based on PIT tags indicated that juveniles generally migrate about 10-40 km per day. Ryan indicated that in their studies, most of the tagged juveniles migrating through the study area before the tags began to die. Lastly, Ryan stated that tag life was higher for the 2024 studies (25-30 days) compared to the previous years.

Andrew Gingerich noted that about 15% of the tagged fish were still moving through the study area after tag-life started decreasing. He asked how that was accounted for in the analysis. Ryan responded that the farther the fish travel, the less certain the survival estimates will be. This is because the tag dies before the fish arrive at the downstream interrogation location. Ryan added that in their study, about 95% of the tagged fish arrived at McNary Dam when about 95% of the tags were still active. Ryan also indicated that they have found variability in the life of tags from different batches, which adds an additional level of complexity to the analysis. Ideally, one would want about 50-100 tags per batch to evaluate tag longevity. Unfortunately, at this time, these acoustic tags are not mass produced and only a small number of tags are available to do both survival and tag-life studies. Therefore, they could only use 5-10 tags per batch in their tag-life studies. Andrew commented that it appears the tag may work best if the goal is to estimate survival through one dam or one project area (reservoir and dam). If the objective is to evaluate juvenile survival through multiple dams or project areas, this acoustic tag may not be appropriate. Ryan remarked that their evaluation of survival through both Lower Granite and Lower Monumental dams was appropriate given that the dams are about 45 km apart and the study was conducted during a high-flow year. This was not the case for evaluating survival from McNary to John Day dams, which is a distance of about 130 km. In this case, they included an additional tagged group that was released upstream from John Day Dam. Andrew commented that this is useful information. They want to make sure survival estimates are not biased low because some fish move slowly through the project areas and pass detection points after their tag has died. Ryan agreed.

<u>Question</u>: How does seasonality affect movement and survival within reservoirs? Are there optimal run timing windows or environmental conditions (e.g., flow, temperature) that reduce variability in migration and improve detection?

Ryan displayed figures showing the sample count of juvenile lamprey over time at Lower Granite and McNary dams. These figures demonstrate that run timing of juvenile lamprey is highly variable across years. In some years, most juveniles migrated in March, while in other years, most migrated in April and some migrated in August. Ryan said that run timing of juveniles is hard to predict in the Snake and lower Columbia rivers. He showed additional figures that suggested an association between flows and run timing. In general, juvenile run timing is associated with flows, with more juveniles migrating during higher flow periods.

Ann Grote asked whether the sample counts include both juveniles and larvae, or only juveniles. Ryan said the counts are juveniles only. Ralph Lampman asked whether juvenile survival was correlated with flows. Ryan said the April release group occurred during low flow and the survival estimates were low compared to groups released during higher flows. He added that the data suggest that juvenile survival is related to flow; however, they want to do multiyear analyses to determine the effects of flow, temperature, and other factors on survival. Bob Mueller added that higher flow is also associated with higher turbidity in the river and the higher turbidity may stimulate migration because turbid water reduces predation. Ralph Lampman asked whether there is a lag in the time when flow begins to increase and when the juveniles are observed in the project area, and whether there is some type of a "threshold flow" that seems to trigger movement. Ryan responded that they have not looked into that question.

<u>Question</u>: Juvenile lamprey can be expected to have a preference for benthic travel and will thus be more likely to be exposed to turbine intake structures, which is different than salmonids. Could this limit

the utility of using study arrays/deployments designed for salmonid passage studies? Could such arrays easily be added to create 3D arrays?

> Ryan displayed diagrams showing the deployment of hydrophones on the upstream face of Lower Granite, Lower Monumental, McNary, and John Day dams. Ryan stated that the ELAT (Eel-Lamprey Acoustic Tag) has a shorter detection range than the JSATS (Juvenile Salmon Acoustic Telemetry System tag) used for salmonids. As a result, they deployed hydrophones at shallower and deeper depths to capture signals from the ELATs. This helped them conduct 3D tracking of tagged fish as they approach the dam, and they were able to assign passage routes and calculate time of passage. Bob Mueller added that they can also achieve 3D tracking in the reservoir provided the arrays are spaced close together.
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> Lance Keller asked whether the lower detection range of ELATs was a result of lower power output or the ping rate. Ryan responded that it is related to power output. Ryan thought the detection range of the ELAT is about 100-150 m, which is about a 40% reduction in detection range compared to salmonid tags.

<u>Question</u>: If reservoir passage can be assumed to take multiple days due to diurnal movements, would additional sensor arrays be needed in the reservoir? What would be the spacing? At a minimum, I think reservoir arrays would need to be spaced close enough to enable detection and survival estimates of lamprey between reservoir points. Are there any battery life considerations needed in longer reservoirs?

> Ryan presented figure of the migration rates of juvenile lamprey in 2022 and 2023. In general, juvenile lamprey migration rate ranged from 10-40 km per day. Variation in travel rates is related to the length of the reservoirs and river flows.

Modelling Approaches

<u>Question</u>: What are the pros and cons of using the Virtual/Paired Release (ViPRe) Model and the Virtual Release/Dead-Fish Correction (ViRDCt) Model?

> Ryan indicated that on the positive side, the ViRDCt model requires substantially fewer tags/fish, releases, and arrays to achieve precise estimates of dam passage survival. In addition, the ViRDCt model allows for a more straightforward approach to estimating dam passage survival over shorter time periods (e.g., specific operations, etc.). On the negative side, the ViRDCt dead tagged fish releases must match the spatiotemporal distribution of virtual release group mortality. To address this, it helps to have some prior knowledge of timing/routes of mortality and requires frequent releases of dead tagged fish. Post-study random sampling can be used if spatiotemporal distributions differ. Ryan noted that a con for the ViPRe model is that $S_2 > S_3$ (survival of the R_2 release group to a second downstream detection array is greater than the survival of the R_3 release groups to a second downstream detection array).[1] assumption was violated in ~10% of FCRPS Biological Opinion studies. Thus, there were several instances where the precision requirement was not met with the virtual paired release model despite the large number of fish tagged.
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> Ralph Lampman asked why the ViRDCt model is a more straightforward approach to estimating dam passage survival over shorter time periods. Ryan responded that with the ViRDCt model, the virtual release group is designed to pass the dam during the period of interest, and the dead fish are released during that same time period. For the ViPRe model, there are issues with mixing of the R_2 and R_3 groups over time that could make the S_2 to S_3 ratio vary over time. Ralph

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[1] Note that S_2/S_3 = survival between the tailrace and the first tailwater array.

Lampman asked how many dead fish need to be released. Ryan said the recommendation is 200 dead juvenile lamprey. Because dead lamprey are difficult to find, they have used 50-100 dead lamprey in their studies. Tracy Hillman asked which model would be most appropriate if the goal is to estimate project-scale (reservoir and dam) survival. Ryan responded that the ViPRe model may be the best model for estimating project-scale survival.

Question: Why is the ViRDCt model the most appropriate model for a juvenile lamprey survival study?

Ryan said that if one is interested in evaluating dam passage only, then the ViRDCt model is the most cost-effective option. However, if one is interested in project-scale (reservoir and dam) survival, then the ViPRe model is an option.

Ralph Lampman asked whether it is possible to use two separate ViRDCt approaches, one for the reservoir and the other for the dam. This would include two different release locations. Ryan responded that the release group for estimating reservoir survival would need to be released upstream of the next project. This is needed to give the released fish time to recover from tagging and handling before they entered the reservoir as a virtual release. Lance Keller asked whether this additional approach would require additional tagged fish, additional arrays in the reservoir, and additional dead fish. Ryan said yes it would require additional tagged live and dead fish and would require an additional array at the upstream end of the reservoir. Ralph Lampman asked whether the ViPRe model could be used to estimate the reservoir survival rate and the ViRDCt model could be used to estimate dam passage survival. Ryan thought that would be possible and fish released for the ViPRe approach could be used as the virtual release for the ViRDCt approach. Ryan added that he would need to think about this approach. Lance Keller asked about how tagging and handling effects would be addressed with the ViPRe approach. Ryan stated that it would depend on the length of the reservoir. He thought releasing the fish about 20 km upstream from the project area would be appropriate. He said a project-scale evaluation will be more complex than a dam-passage evaluation.

Question: What are the assumptions of the ViRDCt model for lamprey movement or how would they be addressed if the juveniles are actively swimming or simply drifting?

Ryan said the ViRDCt model has no assumptions regarding how juvenile lamprey move or how they may be swimming in the water column. He added that evidence suggests that juvenile lamprey are not passively drifting, at least not in the forebay of the dams.

Question: Can the ViRDCt model be equally applied for use with 2D and 3D arrays?

Ryan noted that one of the assumptions of the ViRDCt model is that the virtual release is composed of fish known to have arrived alive and passed through the dam. 3D tracking makes sure this assumption is met. A 2D array cannot ensure compliance with this assumption. The ViRDCt dam passage survival estimates may be biased low if fish that do not approach the dam are included in the virtual release group. A forebay array can be deployed to detect fish moving upstream before encountering the dam.

Ralph Lampman asked whether a 2D array could still be used in a survival study. Ryan responded that it could be used but any survival estimate could be biased low; however, the bias may not be huge (it could be within the margin of error). Ann Grote asked what other information, besides loss in precision, would be missing if a 2D array is used? Ryan said route-specific information would be missing because of blind spots in the forebay. This would also affect time of passage estimates, which are needed to correlate passage with dam operations.

Question: How is the likelihood of not migrating handled? I assume this model assumes a tagged fish is a migrating fish or will migrate. What factors contribute to fish holding or staging behavior?

> Ryan said the ViRDCt model only estimates survival from the time of passage through the immediate (~1-2 km) tailrace. Therefore, a fish must be an active migrant to be included in the virtual release group and must be motivated to migrate ~1-2 km once they have passed the dam. He added that for some of the longer reaches, he cannot say for certain whether fish held/staged in the reservoir or reach, or they suffered mortality. He said they observed the lowest survival rates during low flow conditions. Under low-flow conditions, the fish may have held before actively migrating. If so, they may have migrated after the battery died and therefore were assumed to be dead even though they survived and migrated through the dam.

Run Timing and Environmental Conditions

Question: How long should tagged juvenile be held before releasing them into the study area?

> Ryan said they held the fish for 24-36 hours after tagging. He added that this is consistent with how long they hold tagged salmonids for survival studies. He did note that they have held fish much longer (up to a week) while they waited for additional juvenile lamprey to be collected for use in a survival study. Bob Mueller added that it is best not to hold fish too long (e.g., up to a week) when water temperatures are high (approach 20˚C). They have observed more fungus issues with fish held at warmer temperatures and the fungus can spread among the fish being held.
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> Ann Grote asked whether the sample size affects the amount of time the fish are held. Bob Mueller responded that, yes, it can take time to collect the appropriate number of fish to be tagged and released. They strive to tag and release 100 juveniles per sample group, but they have tagged and released about 40-50 juveniles to avoid holding the fish too long. Ralph Lampman asked whether there are any analyses on holding time and juvenile behavior. Ryan responded that they have someone looking into that but do not have any results at this time. He stated that they try to stick with holding the tagged fish no longer than 24-36 hours.

Question: What behaviors do we anticipate from juvenile lamprey released into the reservoir?

> Ryan indicated that they observed juveniles passing the dams during both daytime and nighttime. As such, he does not believe they "sucker" during the day and swim/drift mostly at night. He also noted that it does not appear the juveniles "sucker" for multiple days before migrating; however, this may occur during lower flows. Ryan presented figures that show travel time as a function of reach length (km). Responding to the question whether travel rates of 38-64 km per day can be assumed for juvenile lamprey, Ryan noted that those rates appear too high compared to what they have observed. He said rates of 10-40 km per day are more common based on their observations.

Ryan concluded by showing which questions he was unable to answer because they do not have information available to answer the questions or the analyses have not been completed. The questions he was unable to answer include:

- Is there a difference in survival rates and behavior of fish that are captured downstream of the project area and used in an upstream study area compared to those captured upstream from the study area?
- Do juveniles from mainstem habitat behave or survive differently than those from tributaries?

- Do wild juveniles from distant source populations behave differently than local ones?
- How do wild fish held in captivity compare to freshly collected wild fish?
- By using lamprey from upstream sources, can we reasonably assume that those study fish will be active migrants? Are there other indicators (e.g., physiological) that can indicate whether a fish is actively migrating?
- Do migration behavior and survival vary depending on where the tagged fish are released (e.g., differences in survival and behavior of fish released in the reservoir versus upstream of the reservoir)?
- Regarding reservoir survival, how do we determine a negative effect of the reservoir without a baseline for undammed riverine survival?
- Are suitable tags readily available for a juvenile lamprey tagging study?
- Should the study design consider releases to occur with the onset of nautical dusk when some studies have suggested lamprey will begin to make volitional movements?
- Stream flow influences on lamprey migration seems well established; higher flows correlate with increased lamprey movements. The General Study Design mentions flow conditions could be influenced by dam spill and that lamprey releases will be attempted to be timed with observed high flows. I suspect pulse influences could be moderated due to reservoir impoundments and might have a more limited influence as one approaches a dam. What is not mentioned is the influence routine (non-spill) operation of dams could have on flow. Dams variously impound and release water. While this influence is moderated by the small storage of each facility in the lake-like conditions of the reservoirs could be a more dominant signal? I think the multi-release date approach will help control for various phases of dam operation, but could be a confounding variable? Data on dam operation should be collected during the study period.

Jason McLellan asked how they account for predation. How do you know whether the behavior you are observing is actually the juvenile lamprey and not a predator that consumed a juvenile lamprey? Ryan responded that they look for upstream movement of the tagged fish. If they detect upstream movement, it is likely the juvenile lamprey was consumed by a predator and the predator is moving upstream. These detections are then removed from the database. Although they assume downstream movement reflects the juvenile and not a predator, they are not certain that is the case. It is possible that a predator that consumed a tagged juvenile is moving downstream. Ann Grote asked whether that assumption also applies to salmonid survival studies. Ryan said, yes. Jason McLellan said he will share a paper with the groups that looks at predation and its effect on survival studies.

Ralph Lampman asked about tag availability and whether the tag has been commercialized. Ryan indicated that Daniel Deng would need to respond to that question. Bob Mueller noted that the tag is in the process of being commercialized but does not know when the tag will be available. Ralph Lampman noted that ATS has a contract with PNNL to commercialize the tag but there is no information on when the tag will be available or the cost of the tag.[2] Mariah Mayfield asked whether a substantial number of

[2] Ralph received an email from ATS during the meeting indicating that tags should be available the end of this year (Dec) or early next year (Jan). The goal to have pricing mid-October, once ATS has a few internal production runs.

tags would be available once the tag is commercialized. Ralph Lampman said he did not know. He believes Daniel Deng would have that information.[3]

Ralph Lampman asked whether hatchery-origin juvenile lamprey need to meet a certain size or condition factor to be used in a survival study. Ryan responded that they have not looked into that question but believes it would be appropriate to match the size, weight, and condition of the hatchery-origin fish to the natural-origin (ROR) fish. Bob Mueller noted that they do have a minimum length for tagging but no targets for weight or condition factor. Tracy Hillman noted that Frick et al. recently published a paper that compares performance of artificially propagated and wild Pacific Lamprey juveniles and larvae.[4] In that report, they state "…behavioural difference could have important survival consequences for artificially propagated lamprey as they approach turbine intakes, bypass screens and irrigation diversion headgates." This does not appear to comport with Ryan's work but will need to be discussed within each of the groups.

III. Pacific Lamprey Survival Strategy

Ralph Lampman, Yakama Nation, reviewed the questions and comments he received on the draft report titled, "Juvenile Pacific Lamprey Passage Behavior and Survival at Upper Columbia River Hydroelectric Dams: General Study Design." Ralph walked through the comments and provided his responses to questions and comments. The report, which includes a list of questions/comments and his responses to the comments, was sent to the group before the meeting today. Ralph did note that there were questions regarding the spatial scope of a survival study (e.g., project scale or dam only). He recommended that the focus be on dam passage survival given that most of the work in the Snake and Columbia rivers has focused on dam passage survival and we can draw upon that information to design a valid survival study. He also noted the importance of estimating specific routes that juveniles use to pass dams. Ralph shared his color-coded table that shows the possible sources of juveniles to use in survival studies. He believes juveniles from any location could be used in a survival study (with priority given to juvenile lamprey upstream of the dam and closer to the source) but understands that members will want to discuss this. The color coding helps identify sources of fish that are close to dams (to clarify priority ranking). He added that the groups will need to discuss the precision needed in the survival estimates and believes the precision established in the Snake and Columbia River studies should be sufficient for studies in the upper Columbia. He also updated the estimated cost to conduct a survival study. Ralph indicated that he reached out to researchers at Michigan State University and USGS about evaluating juvenile migration readiness. Those researchers indicated that one could measure hormonal changes in gill function, but it would not be practical, and you could not do it on all fish.

IV. Key Questions and Recommendations

Tracy Hillman presented the key questions that need to be discussed within the Subgroup. He reminded those attending that we can only offer suggestions/recommendations to the Fish Forums and ASWG. The Subgroup is not a decision-making body. Tracy identified the following key questions:

1. What is the scope of the project (entire project area or dam only)?

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[3] ATS (Jamie Erickson) stated that ATS has produced over 50,000 acoustic tags in one season (over 30,000 last season). Currently, they have 3,500 ELATS on forecast. The key is to submit PO sooner than later (12 week lead-time)"

[4] Frick, K., M. L. Moser, T. Liedtke, L. Weiland, A.N. Maine, and A.D. Jackson. 2025. Performance comparisons for artificially propagated and wild Pacific Lamprey juveniles and larvae. Aquaculture, Fish and Fisheries 2025:5:e70070, https://onlinelibrary.wiley.com/doi/10.1002/aff2.70070

2. What survival model is most appropriate to use?
3. What is an acceptable precision level for the survival estimate?
4. What is the source of juvenile lamprey for a survival study?
5. How will the study deal with tag performance (i.e., tag life, biological effects, seasonality, etc.)?

What is the scope of the Project?

Tracy said it is important to note what each of the Pacific Lamprey Management Plans says about juvenile lamprey survival studies. Section 4.3.1 of the Priest Rapids Pacific Lamprey Management Plan states the following:

> *In a timely manner, but no later than 10 years following license issuance, identify and mitigate Project effects on juvenile Pacific lamprey with the intention of meeting juvenile lamprey passage criteria referred to in 4.3.2 below. Grant PUD is developing downstream passage measures for juvenile salmonids, which may also reduce or eliminate impacts to juvenile lamprey. This includes the Wanapum Future Unit Fish Bypass (WFUFB), which not only capitalizes on the behavioral responses of smolts related to hydraulic conditions in the Wanapum forebay, where the bulk surface flow is directed to the right side of the powerhouse, it also extends to a depth of 68 feet. Given the tendency for juvenile lamprey to swim low in the water column (Long 1968 as cited in Moursund et al. 2000), it is anticipated that the WFUFB will successfully pass juvenile lamprey. Fyke net capture data from Wells (Douglas PUD) and Rocky Reach (Chelan PUD) dams confirm that juvenile lamprey tend to pass via turbines in lower half of the water column (BioAnalysts 2000).*

And Section 4.3.2 states the following:

> *When the technology exists, Grant PUD will evaluate bypass, turbine, and spillway survival, and utilize this information to develop juvenile lamprey passage criteria. Criteria will include consideration of; 1) success achieved at other Columbia River Basin projects and, 2) Project-specific conditions. Grant PUD has avoided the use of turbine intake or deflector screens, which has shown to be a potential mortality factor for juvenile lamprey at Projects in the Columbia River basin. The turbine intakes at both Wanapum and Priest Rapids dams are not equipped with barrier or diversion type screens of any kind so harm to juvenile lamprey would be negligible. Specific activities associated with this objective include operation of the WFUFB, Priest Rapids Future Unit Bypass (in development), and Wanapum Advanced Turbines in accordance with the criteria for the Biological Opinion for the Priest Rapids Project and Priest Rapids Salmon and Steelhead Anadromous Settlement Agreement, as approved and/or amended by NMFS or Federal Energy Regulatory Commission.*

The Priest Rapids Pacific Lamprey Management Plan is not clear on the scope of a survival study. Section 4.3.1 seems to suggest the study should be conducted at the project scale; however, Section 4.3.2 focuses on route-specific survival. Mike Clement reported that Grant PUD's position is that a survival study would be at the dams only. This is based on language in Section 4.3.2 that specifically calls out evaluating bypass, turbine, and spillway survival, and utilize this information to develop juvenile lamprey passage criteria. Ralph noted that the language is not very clear given what is stated in Section 4.3.1. Laurie Porter commented in the chat that a survival study should include the reservoir (based on language in Section 4.3.1).

Section 4.2.3 of the Rocky Reach Pacific Lamprey Management Plan states the following:

> *Between years two and five of the New License, Chelan PUD shall continue to measure the type and magnitude of any ongoing Project impacts on the downstream passage of juvenile lamprey,*

using appropriate and reasonable methodologies. Specifically, these methodologies will address juvenile lamprey downstream migration timing and passage survival through the Project. Associated with these methods, Chelan PUD shall, in consultation with the RRFF, develop the means to provide sufficient numbers of juvenile lamprey for these evaluations. Chelan PUD, in consultation with the RRFF, may choose to contribute to other local or regional lamprey investigation programs in order to gain efficiencies in the development of methods for lamprey investigations at the Project. It is anticipated that the initiation and preliminary evaluations of any ongoing Project related impacts will be conducted within the first five years of the New License. The cost for this measure is estimated to be $700,000.

It is not clear in the Rocky Reach Pacific Lamprey Management Plan whether survival is measured at the project scale or just at the dam. Lance Keller agreed and said this is something the RRFF will need to discuss.

Section 4.2.4 in the Wells Pacific Lamprey Management Plan states the following:

Based upon the current state of the science regarding tag technology and methodologies for Pacific lamprey macrophthalmia (Section 2.3), coupled with the challenges of obtaining macrophthalmia in sufficient numbers within the Project to meet sample size requirements for a statistically rigorous study, a juvenile downstream passage and survival evaluation is not feasible at this time.

During the term of the new license, if tag technology and methodologies are developed and field tested and a sufficient source of macrophthalmia in or upstream of the Project are identified to ensure that a field study will yield statistically rigorous and unbiased results, Douglas, in consultation with the Aquatic SWG, shall implement a one-year juvenile Pacific lamprey downstream passage and survival study.

If statistically valid study results indicate that Project operations have a significant negative impact on the Pacific lamprey population above the Wells Dam, Douglas, in consultation with the Aquatic SWG, shall identify and implement scientifically rigorous and regionally accepted measures (e.g., translocation, artificial production or habitat enhancement), if any, or additional studies to address such impacts. If operational changes are needed to improve passage survival of juvenile lamprey migrants, then those changes need to be coordinate with the HCP Coordinating Committee.

Tracy said, as with the others, it is not clear whether a survival study at Wells Dam includes the entire project area or just the dam. Tracy also noted that there are differences among the three plans. The Wells Pacific Lamprey Management Plan makes it clear that only juveniles collected upstream from Wells Dam can be included in a survival study. The other two plans do not make that statement. Andrew Gingerich noted that the last paragraph makes it clear that there is a need to evaluate “project operations.” Because all “project operations” occur at the dam (e.g., opening and closing turbine and spillways), it appears the study would be confined to the dam and not the reservoir. This is something the ASWG will need to discuss. Andrew added that the ASWG will also need to discuss whether the behavior of juveniles collected in the tributaries would match ROR fish in the Columbia River. They also need to discuss tag life and migration rates.

Tracy Hillman remarked that Andrew brought up a good point that before we can address the other key questions, we will need to settle on the scope of the project. Once the scope of a survival study is decided unanimously, then issues about sample size, which model to use, tag life, migration behavior, residency, and other issues can more easily be resolved.

Mariah Mayfield noted that if we were able to measure reservoir survival, what would that survival estimate mean without some baseline estimate of juvenile survival in the absence of a reservoir? That is, what would be the natural mortality rate of juvenile lamprey in the project area in the absence of the reservoir? By focusing on dam passage survival, we can potentially address operations that would improve dam passage survival.

Ralph Lampman said he agrees that the respective groups will need to decide the scope of the studies and that decision will help inform the other key questions. He added that he believes the focus of the studies at this time should be dam passage. That said, he also believes there is value in conducting studies in the reservoirs to acquire baseline information. This could be accomplished by tracking tagged fish released at upstream projects that move through downstream reservoirs.

Tracy Hillman summarized the discussion and stated that the respective groups will need to identify the scale and scope of the juvenile lamprey studies. This information will be passed on to the respective groups.

What is the source of juvenile lamprey for a survival study?

Ralph Lampman indicated that juvenile lamprey behavior is much different than that of juvenile salmonids. Salmonids have distinct populations and ESU/DPS, while lamprey do not. Lamprey from different areas mix and do not have the same homing tendencies as salmonids. Therefore, using juvenile lamprey only collected upstream of the study area is not as critical as it would be for salmonid studies. For example, juvenile lamprey used in the Snake and Columbia River studies came from different locations and the results from those fish were reasonable. Ralph added that the color-coded table shows source locations close to project areas and using juveniles from locations close to the project area but downstream from the project area makes sense given the genetic makeup and behavior of juvenile lamprey.

Tracy Hillman said Ralph makes a good argument for using juveniles from different locations but noted that any deviation from what is in the approved management plans would need to be approved by the group. He added that in all groups, agreement requires consensus. Ralph asked Ryan whether he evaluated behavior of fish from different sources. Ryan responded that they have not, mainly because they do not have the data to evaluate this question. He added that the hatchery-origin fish from the Yakima River basin seemed to behave like ROR fish.

Mariah Mayfield reported that WDFW, who operates the smolt traps in the Methow River basin, collected over 1,600 juvenile lamprey in the traps. She said this may indicate that the adult translocation efforts are working. She also stated that flows during the last two years have been very low and WDFW was able to operate the traps for longer periods. She noted that few lamprey are captured in the Okanogan River basin. Ann Grote said that CTCR is collecting increasing numbers of ammocoetes but few to no juveniles.

Tracy Hillman asked whether anyone has been studying the efficacy of the juvenile lamprey trap. Bob Mueller responded that they have been conducting preliminary tests in the lab. He said those tests are mostly done and the large-scale collector appears to work very well. He noted that it is not a floating trap but rather a trap that is designed to work within a bypass system. It could also be placed on the riverbed to collect juvenile lamprey. They are still testing the trap and making minor refinements to the trap.

Ralph Lampman reminded the group that hatchery-origin fish are used in salmonid survival studies and questioned why hatchery-origin lamprey could not be used in a survival study. Lance Keller responded that in salmonid survival studies, they include ROR fish, which in this case includes both natural- and hatchery-origin salmonids. These fish are collected during their downstream migration, and those that meet the criteria for the study are included in the study regardless of their origin. In addition, the Habitat Conservation Plans do not call out the need to evaluate specific origins of salmonids. The PUDs are required to mitigate for unavoidable losses of both hatchery- and natural-origin salmonids. Therefore, it makes sense to include ROR fish consisting of both origins in the survival studies. Lance added that it is somewhat confusing in that we are told not to force the salmonid paradigm on lamprey (e.g., population characteristics, migration behavior, etc.), but then in other situations we are asked to use the salmonid paradigm. It is unclear when we should or should not use the salmonid paradigm.

Andrew Gingerich stated that Douglas PUD uses PIT tags rather than acoustic tags in their salmonid survival studies. This is because Douglas PUD is concerned about the effects of acoustic tags on salmonid behavior. A disadvantage of using PIT tags is that a larger sample size of fish is needed because detection probabilities are lower for PIT-tagged fish compared to acoustic tagged fish. Because of the large number of fish that need to be PIT tagged, the Wells Coordinating Committee agreed to use hatchery-origin fish for survival studies. This minimizes potential take on ESA-listed natural-origin salmonids and allows the fish to be tagged in the hatchery, addresses tagging and handling effects (wounds have time to fully heal), and does not require "turning-on" tags. Andrew concluded by stating the language in the Wells Pacific Lamprey Management Plan is very specific and the ASWG would need to agree unanimously to pivot from that language.

Ralph Lampman stated that although the Management Plans provide specific information, which was based on the best information available at the time, there is better information currently available that should be used when considering source fish. He said his color-coded table should be used when deciding on sources of fish for a survival study. Pete McHugh agreed with Ralph and believes the groups need to be flexible in their use of source fish, including the use of hatchery-origin fish. Ann Grote noted that once the Okanogan River basin begins producing juveniles, there may not be an issue with source fish. Between the Okanogan and Methow systems, there may be enough fish to conduct a valid survival study. Andrew Gingerich agreed and said it may be a moot point if there are adequate numbers of juvenile lamprey available upstream from Wells Dam. He is encouraged by the results from the translocation work. Ralph Lampman commented that we do not know from year to year what the juvenile numbers will be. They tend to vary widely from year to year, so we need a backup in case upstream sources are unable to produce a suitable sample size for a survival study in a given year.

Ralph Lampman questioned whether the source of fish for salmonid survival studies matters. That is, would there be a concern using salmonids collected from screw traps or locations downstream for studies at, say, Lower Granite Dam. Ryan responded that for their salmonid studies, they were able to collect all their fish from the fish facilities at the dams. Therefore, they did not use fish collected in screw traps. However, for Biological Opinion compliance studies, they have used fish collected from a downstream dam (e.g., John Day Dam) for testing survival through multiple dams (e.g., McNary Dam through Bonneville Dam). Lance Keller indicated that for Chelan PUD studies, all the fish (salmonids) were captured at the dam at which the studies occurred. Mike Clement stated that fish used for their survival studies at Wanapum and Priest Rapids dams were collected at the dams. The fish were collected from the gate wells at the dams. Ann Grote indicated that in studies in California, where they have few ROR fish to use to examine passage through water-management areas, they use hatchery-origin fish. She said when things are dire, you use whatever surrogates are available.

What survival model is most appropriate to use?

Ryan Harnish showed a diagram of the different design options for conducting a juvenile survival study. He said the paired design (ViPRe) can account for the handling and tagging mortality but may also address fish that do not migrate. He explained that the ratio of R_1 and R_2 may account for fish that do not migrate. He reasoned that this may be true provided that environmental conditions are similar between R_1 and R_2. This could be combined with the ViRDCt model, which would be used to estimate passage survival at the dam. He thinks this will work provided the battery in the tags do not die before the fish pass through the project area. Ralph asked Ryan what the sample size would need to be to conduct a combination ViPRe/ViRDCt study. Ryan responded that he will need to think about this question and get back to the groups with estimates of sample size. Mariah Mayfield indicated that she reached out to Dave Robichaud and asked him to calculate a sample size for estimating project-area survival. Mariah said that Dave estimated a sample size of about 1,600 juvenile lamprey, which is based on several assumptions and information from the Snake River studies. Ryan noted that the sample size may be larger if dead fish are included in the study. One would also need to consider the length of the reservoir in the project area. This affects battery life and may affect sample size. Mariah noted that Wells is about 35-miles long (56 km); Mike Clement indicated that Wanapum is about 58-miles long (93 km). Mariah added that the length for the Wells study would depend on where they release the fish (mouth of the Okanogan River or near Chief Joseph Dam). For context, Ryan said in 2023 they released tagged fish upstream from Lower Granite Dam to evaluate survival at Lower Monumental Dam, a distance of 126 km.

Tracy Hillman summarized the discussion by stating that a project-scale study would use the ViPRe model or combination of ViPRe/ViRDCt models, while a passage study at the dam would use the ViRDCt model.

What is an acceptable precision level for the survival estimate?

Tracy Hillman indicated that the studies in the Snake and Columbia rivers achieved precision estimates of 2.9-5.9%. These estimates were based on the ViRDCt model, which measures juvenile lamprey passage survival rates at the dams. Ryan added that the precision estimates were based on virtual release group sizes of 178-312 juveniles. Ralph Lampman asked whether the 178-312 was the number released. Ryan said, no. The number released was in the 200s-400s (not counting the dead fish). Of those released, 178-312 were detected at the array in the forebay and were used in the survival calculation. Tracy Hillman said the respective groups will need to identify what level of precision they need in a survival study, which may vary depending on whether a project area or dam only study is conducted.

How will the study deal with tag performance (i.e., tag life, biological effects, seasonality, etc.)?

Reflecting back on Ryan's presentation, Tracy Hillman stated that we observed figures showing the relationship between tag life and travel time, and between travel time and river flows. In general, Ryan's data showed that tags began dying after about 20 days. Given that PIT-tagged lamprey migrated 10-40 km per day (migration rate was in part related to river flows), it is likely the acoustic tags would last long enough to conduct a survival study at the dam and perhaps also at the scale of the project area during higher-flow years. However, Ryan also pointed out that tag performance varied across batches of tags. Therefore, it would be necessary to evaluate tag life. In addition, the forums and ASWG would need to evaluate how to deal with predation effects and baseline conditions (survival rates in the absence of a reservoir). The respective groups will also need to evaluate the time periods for conducting the studies, because, as Aaron Jackson pointed out, we may be missing a large percentage of fish that migrate outside the "typical" window when the survival studies are conducted. Lastly, the respective groups will need to determine how many tags will be needed to conduct a valid study and whether those tags would be available. As Ryan noted earlier, there are a lot of factors to consider before a study can be conducted.

Ralph Lampman commented that a survival study should be ready regardless of whether the fish arrive early or late during the migration period. This was the approach used in the Snake and Columbia rivers. He added that it is difficult to predict when the fish will arrive; therefore, being ready to take advantage of the fish when they are available will be important. Ralph also noted that the fish cannot be held too long or they will develop fungus, which can affect their survival rate.

Ann Grote asked how PNNL deals with battery drain before the fish are tagged and released. Ryan responded that they store their acoustic tags in a freezer, which slows the drain on the batteries. This extends the shelf-life of the tag. Although they have not conducted an extensive evaluation of battery drain, they were able to store tags for up to 8 months with no apparent effect on the life of the tag.

Tracy Hillman said he will draft the notes from the meeting and share them with the respective groups for review and discussion. He thanked everyone for joining and participating in the Subgroup meeting and believes the information shared will be useful to the respective groups as they discuss juvenile lamprey survival studies. Tracy said he believes the first issue the respective groups will need to address is the spatial scale of the study. Once that is determined and agreed upon, the rest of the key questions should be straightforward. Tracy thanked Ryan Harnish and Bob Mueller for joining the meeting and responding to the questions from the groups. Ralph Lampman agreed and thanked everyone for joining the meeting. Ralph said he was happy with the discussions and how far we have come in the last few years.

V. Adjourn

With no additional business to discuss, Tracy Hillman adjourned the Pacific Lamprey Subgroup meeting at 2:30 pm.

Attachment 1

List of Questions Presented to PNNL before the Meeting Regarding Juvenile Lamprey Survival Studies

Route Selection

- What routes through dams are juvenile lamprey most likely to take during downstream migration (i.e., is there a relationship between flow distribution at a dam and the route juvenile lamprey take)?
  - See page 2, 25, and 26.
- What are the route-specific survival rates of juvenile lamprey as they pass through dams?
  - See page 27, 28.
- How do flows, flow fluctuations, and water temperatures affect passage routes and survival?
  - See page 26, 27.
- How does migration vary by time of day and water column depth?
  - See page 25.
- What role does proximity to the thalweg and flow fluctuations play in route selection?
  - See page 27.
- [Kirk Truscott, CTCR]: Agree that Project and dam passage route survival for juvenile lamprey are data gaps that need to be assessed in order to formulate operations/ structural adaptations and/or mitigation measures to address project-level impacts to juvenile lamprey (if needed).
  - No questions identified.
- [Kirk Truscott, CTCR]: Piggy-backing on hydrophone arrays used for anadromous fish juvenile survival studies makes sense; however, I'm not sure of how well the projects will be "wired" for passage-route assessments. I'm pretty sure that neither Wanapum nor PRD will be wired for passage-route survival assessments in the juvenile salmonid studies beginning in 2026.
  - No questions identified.
- [Stuart Fety, USFWS]: It is my understanding that screens designed to divert juvenile salmonids from turbine intakes and other infrastructure can result in impingement of lamprey. I understand screen orientation (vertical, horizontal, etc), approach velocity, screen type (bar, mesh) and screen spacing can all influence rates of impingement vs. rates of passage for lamprey. What information is available on the type of screen infrastructure across the Mid-Columbia projects and is it currently “lamprey friendly”? Perhaps the

addition of cameras at anticipated passage points could be considered to monitor potential screen impingement and entrainment rates.

– See page 28.

Performance of Hatchery versus Wild Juvenile Lamprey

- Are there differences in behavior, route selection, and survival rates between hatchery- and natural-origin juveniles?
  – See page 28, 29.
- Do hatchery-origin juvenile lamprey use the same passage routes as natural-origin juvenile lamprey?
  – See page 28, 29.

Source Fish

- Is there a difference in survival rates and behavior of fish that are captured downstream of the project area and used in an upstream study area compared to those captured upstream from the study area?
  – See page 11 (unable to answer now, but see page 29, 30).
- Do juveniles from mainstem habitats behave or survive differently than those from tributaries?
  – See page 11 (unable to answer now, but see page 29, 30).
- Do wild juveniles from distant source populations behave differently than local ones?
  – See page 11 (unable to answer now, but see page 29, 30).
- How do wild fish held in captivity compare to freshly collected wild fish?
  – See page 11 (unable to answer now, but see page 29, 30).
- [Stuart Fety, USFWS]: By using lamprey from upstream sources can we reasonably assume that those study fish will each be an active migrants? Are there other indicators (e.g., physiological) that can indicate if a fish is actively migrating?
  – See page 12 (unable to answer now, but see page 29, 30).

Release Location

- Do migration behavior and survival vary depending on where the tagged fish are released (e.g., differences in survival and behavior of fish released in the reservoir versus upstream of the reservoir)?
  – See page 12 (unable to answer now, but see page 30).
- How far upstream from a dam should juvenile lamprey be released to maximize detection and survival?
  – See page 12 (unable to answer now but see page 30).

Precision and Survival

- What is the relationship between sample size (i.e., number of juveniles tagged) and precision of route-specific survival rates?
  - See page 5, 6, 9, 30, 31.
- What level of precision can be expected in survival estimates?
  - See page 5, 6, 9, 32.
- What are the standard error rates and confidence intervals based on in current studies?
  - See page 6, 32.
- [Douglas PUD]: RE: Alternate Sample Size, I am also curious about the pros and cons of so many different release groups. Why Feb to June? Are there advantages to combine?
  - See page 6, 7, 32, 33.
- [Douglas PUD]: RE: Reservoir Survival Estimation, any value to paired releases?
  - See page 9, 10, 33, 34.
- [Douglas PUD]: RE: Reservoir survival, without a baseline for undammed riverine survival, how do we determine a negative effect of the reservoir?
  - See page 12 (unable to answer now but see page 34).

Tag Detection and Residency

- What proportion of tagged migrants delay their migration through the reservoir?
  - See page 4, 7, 29.
- How many juveniles reside in the reservoir without migrating through the dam?
  - See page 4, 7, 15, 34, 35.
- Do the tags last long enough to track the slow migrants through the reservoir and dam?
  - See page 7, 9, 11, 17, 18, 19, 35, 36.
- How does seasonality affect movement and survival within reservoirs?
  - See page 8, 12, 18, 37, 38.
- [Stuart Fety, USFWS]: If is my understanding juvenile lamprey can be expected to have a preference for benthic travel and will thus be more likely to be exposed turbine intake structures, different than salmonids. Could this limit the utility of using study arrays/deployments designed for salmonid passage studies? Could such arrays easily be added to create 3D arrays?
  - See page 8, 9, 38.
- [Stuart Fety, USFWS]: If reservoir passage can be assumed to take multiple days due to diurnal movements would additional sensor arrays be needed in the reservoir? What could be the spacing? At a minimum I think reservoir arrays would need to be spaced close enough to enable detection and survival estimates of lamprey between reservoir points. Are there any battery life considerations needed in longer reservoirs?
  - See page 9, 39.

Tag Availability

- Are suitable tags readily available for a juvenile lamprey tagging study?
  - See page 12.

Modeling Approaches

- What are the pros and cons of using the Virtual/Paired Release (ViPRe) Model and the Virtual Release/Dead-Fish Correction (ViRDCt) Model?
  - See page 9, 10, 11, 17, 18, 39.
- Why is the ViRDCt model the most appropriate model for a juvenile lamprey survival study?
  - See page 9, 10, 11, 17, 39, 40.
- [Kirk Truscott, CTCR]: Agree that the full ViRDCt model replicated similar to those juvenile lamprey studies in the Snake and lower Columbia is likely the most reasonable approach.
  - No questions identified.
- [Stuart Fety, USFWS]: What are the ViRDCt model assumptions for lamprey movement?
  - See page 7, 10, 12, 39, 40.
- [Stuart Fety, USFWS]: Does the ViRDCt model make any assumptions about how juvenile lamprey might be swimming in a water column; as drift or active swimmers?
  - See page 10, 11, 12, 40.
- [Stuart Fety, USFWS]: Can the ViRDCt model be equally applied for use with 2D and 3D arrays?
  - See page 9, 10, 40.
- [Douglas PUD]: How is the likelihood of not migrating handled. I assume this model assumes a tag fish is a migrating fish, or will migrate?
  - See page 10, 11, 41, 49.

Scale of Study

- Are the tags capable of assessing unbiased project-scale (upstream end of the reservoir through the dam and into the tailrace) survival rates?
  - See page 7, 9, 11, 12, 17, 18, 19.

- What are the limitations in estimating full project-scale survival (e.g., battery life, reservoir length, flow conditions, etc.)?
  - See page 7, 10, 13, 14, 15, 16, 18, 19.

Run Timing and Environmental Conditions

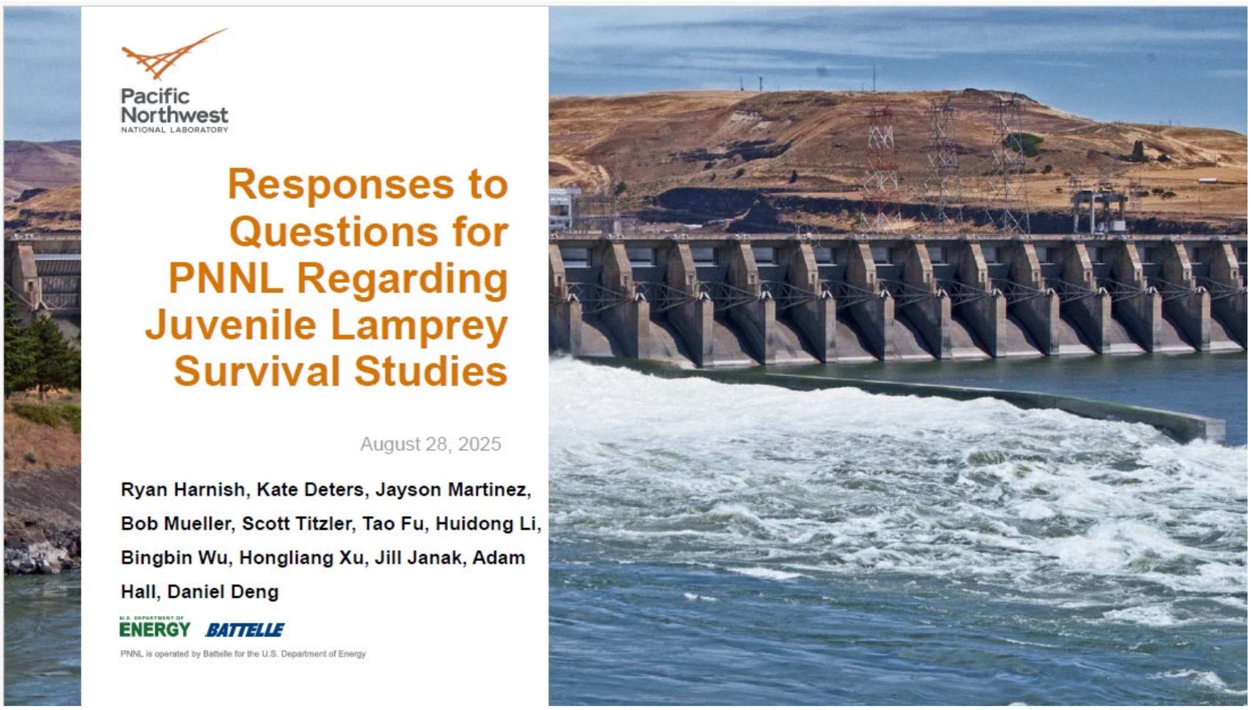
- Are there optimal run timing windows or environmental conditions (e.g., flow, temperature) that reduce variability in migration and improve detection?
  - See page 8, 12.
- What factors contribute to fish holding or staging behavior?

  - See page 4, 6, 8, 10, 11.
- How long should tagged juveniles be held before releasing them into the study area?
  - See page 11, 41.
- [Kirk Truscott, CTCR]: Collection and relatively quick release timing of "highest priority fish" for study subjects with abundance and synchrony of increasing/high discharge may be the studies greatest challenge (i.e. if RST are a major contributor to collection of study subjects, the RSTs may not be operable during peak freshets or may be positioned in the river where they are less effective in collection of juvenile lamprey). This may be most difficult for the upper most hydro facilities.
- [Stuart Fety, USFWS]: What behaviors do we anticipate from juvenile lamprey released into the reservoir?
  - See page 42.
  - My thought would be that lamprey are likely to sucker during the day and swim/drift during the night.
    - See page 11, 26.
  - Could fish also sucker for multiple days until there is a flow stimulus?
    - See page 4, 6, 8, 10, 11, 27, 28.
  - Can observed travel rates of between 23.7 mi/day to 38.8 mi/d be assumed for our efforts? (Liedtke , T.L., Lampman, R.T., Deng, D.Z., Beals, T.E., Porter, M.S., Hansen, A.C., Kock, T.J., Tomka, R.G., and Monk, P., 2019, Movements of juvenile Pacific Lamprey (Entosphenus tridentatus) in the Yakima and Columbia Rivers, Washington, 2018—A pilot study using acoustic telemetry: U.S. Geological Survey Open-File Report 2019-1058, 29 p., https://doi.org/10.3133/ofr20191058.ISSN 2331-1258)
    - See page 11.
  - Should study design consider releases to occur with the onset of nautical dusk when some studies have suggested lamprey will begin to make volitional movements?
    - See page 12 (unable to answer now but see page 21)
- Stuart Fety, USFWS]: Stream flow influences on lamprey migration seems well established; higher flows correlate with increased lamprey movements. The General Study Design mentions flow conditions could be influenced by dam spill and that lamprey releases will be attempted to be timed with observed high flows. I suspect pulse influences could be moderated due to reservoir impoundments and might have a more limited influence as one approaches a dam. What is not mentioned is the influence routine (non-spill) operation of dams could have on flow. Dams variously impound and release water. While this influence is moderated by the small storage of each facility in the lake-like conditions of the reservoirs could be a more dominant signal? I think the multi-release date approach will help control for various phases of dam operation, but could be a confounding variable? Data on dam operation should be collected during the study period.

- See page 12 (unable to answer now but see page 21).

Attachment 2

Presentation by Ryan Harnish on Responses to Questions for PNNL Regarding Juvenile Lamprey Survival Studies

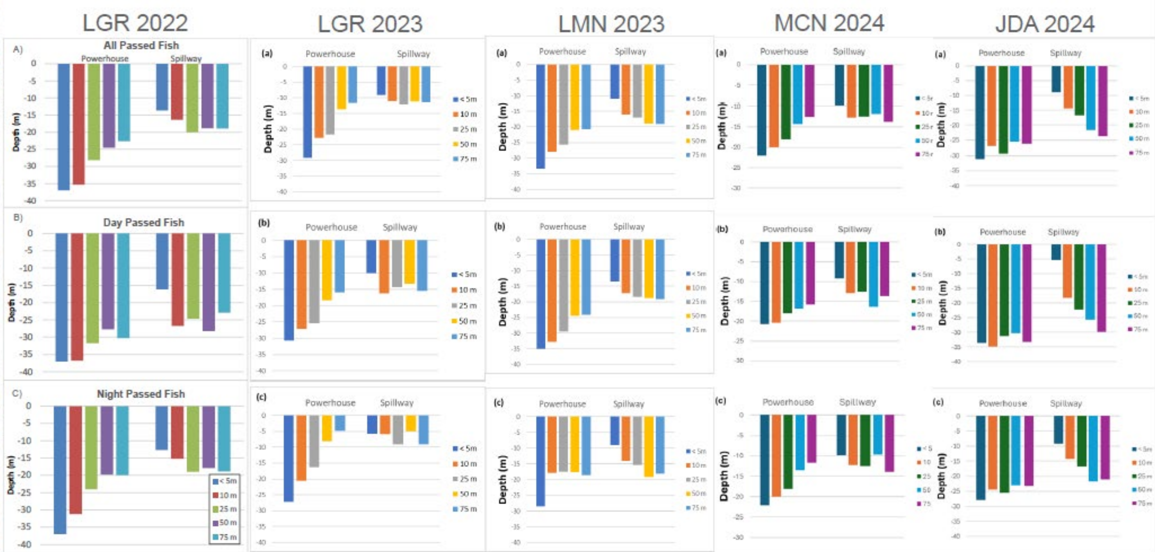


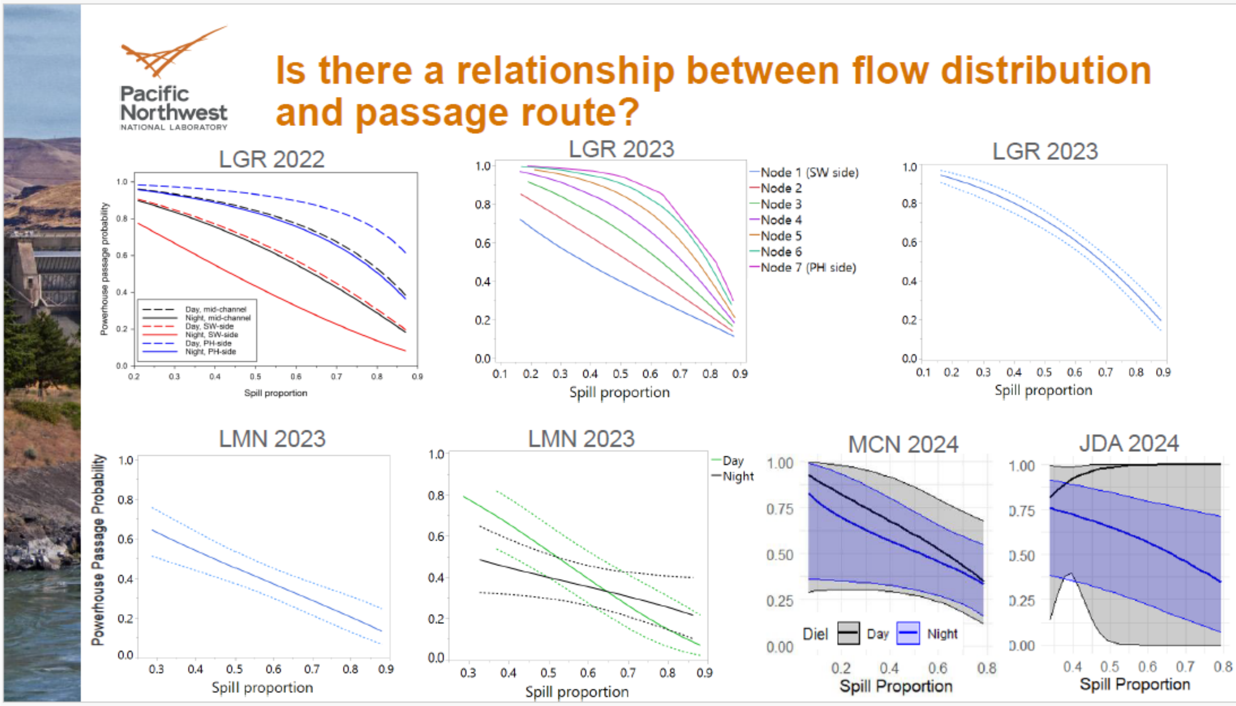
What routes through dams are juvenile lamprey most likely to take?

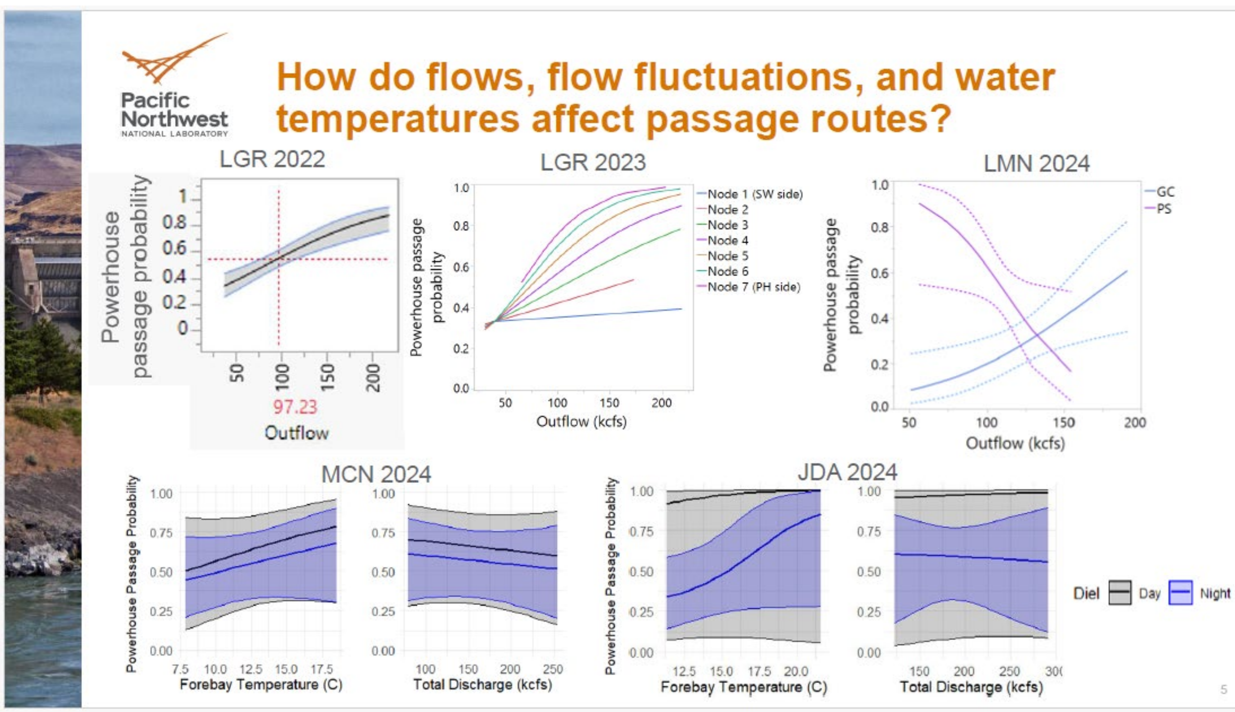
Dam/Year/Diel	Powerhouse	Conventional Spill	Spillway Weir
LGR 2022 Both	**54%**	**34%**	**12%**
LGR 2022 Day	74%	21%	5%
LGR 2022 Night	36%	45%	19%
LGR 2023 Both	**59%**	**33%**	**7%**
LGR 2023 Day	68%	28%	4%
LGR 2023 Night	45%	42%	13%
LMN 2023 Both	**39%**	**54%**	**8%**
LMN 2023 Day	41%	54%	5%
LMN 2023 Night	37%	53%	10%
MCN 2024 Both	**49%**	**40%**	**11%**
MCN 2024 Day	48%	37%	15%
MCN 2024 Night	49%	41%	10%
JDA 2024 Both	**52%**	**32%**	**16%**
JDA 2024 Day	85%	4%	11%
JDA 2024 Night	44%	39%	17%

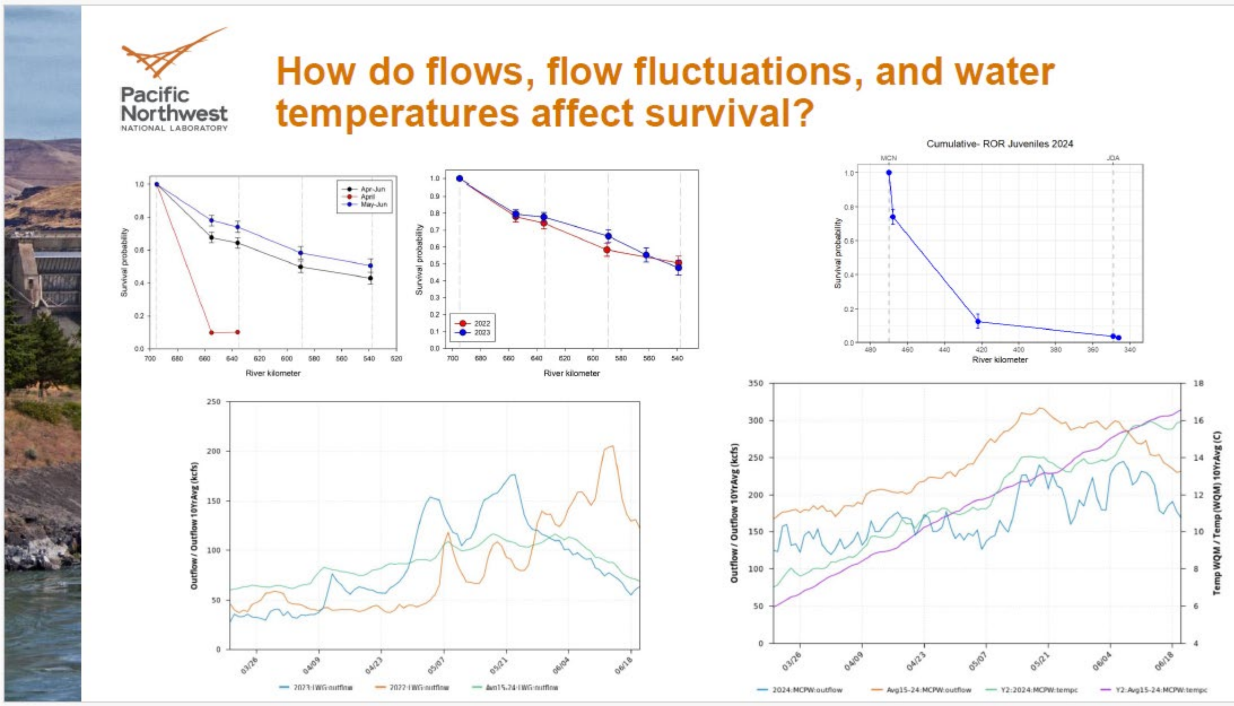
2

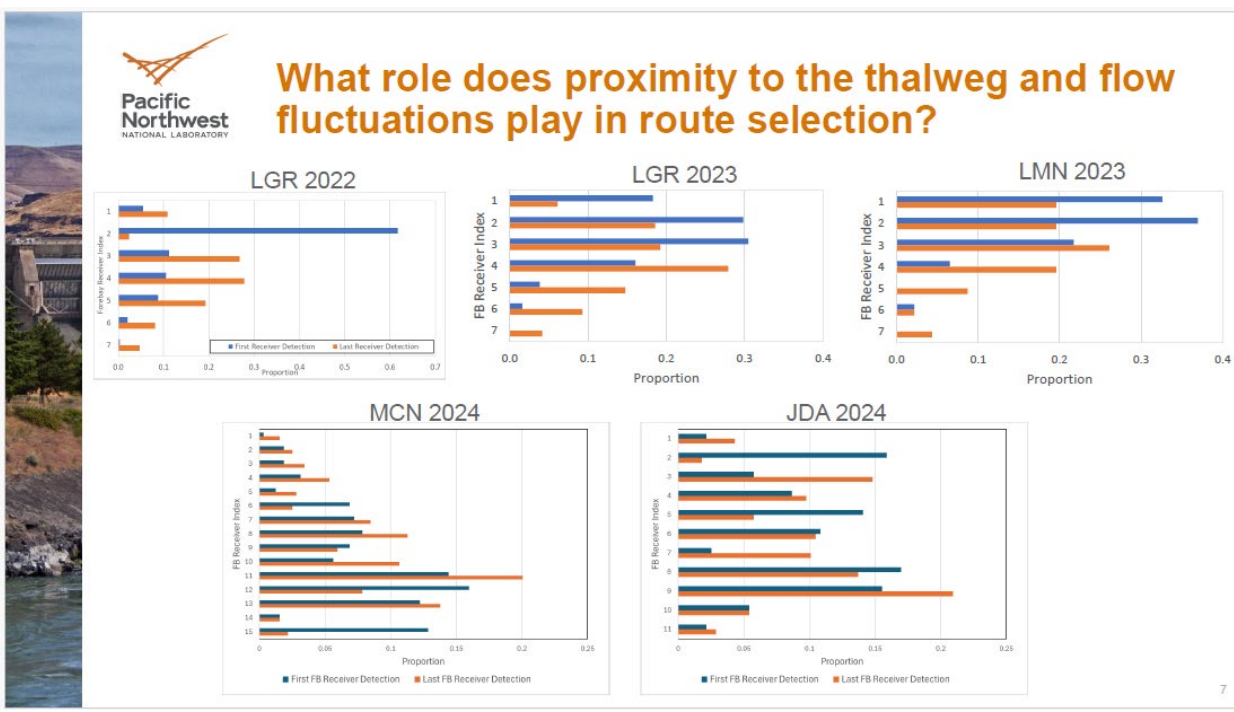
How does migration vary by time of day and water column depth?




Pacific Northwest NATIONAL LABORATORY
Is there a relationship between flow distribution and passage route?
LGR 2022
Powerhouse passage probability
Spill proportion
Day, mid-channel
Night, mid-channel
Day, SW-side
Night, SW-side
Day, PH-side
Night, PH-side
LGR 2023
Node 1 (SW side)
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7 (PH side)
Spill proportion
LGR 2023
Spill proportion
LMN 2023
Powerhouse Passage Probability
Spill proportion
LMN 2023
Day
Night
Spill proportion
MCN 2024
Diel
Day
Night
Spill Proportion
JDA 2024
Spill Proportion


Pacific Northwest NATIONAL LABORATORY
How do flows, flow fluctuations, and water temperatures affect passage routes?
LGR 2022
Powerhouse passage probability
97.23
Outflow
LGR 2023
Powerhouse passage probability
Node 1 (SW side)
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7 (PH side)
Outflow (kcfs)
LMN 2024
Powerhouse passage probability
GC
PS
Outflow (kcfs)
MCN 2024
Powerhouse Passage Probability
Forebay Temperature (C)
Total Discharge (kcfs)
JDA 2024
Powerhouse Passage Probability
Forebay Temperature (C)
Total Discharge (kcfs)
Diel
Day
Night
5


Pacific Northwest
NATIONAL LABORATORY
How do flows, flow fluctuations, and water temperatures affect survival?
Apr-Jun
April
May-Jun
Survival probability
River kilometer
2022
2023
Survival probability
River kilometer
Cumulative- ROR Juveniles 2024
MCN
JDA
Survival probability
River kilometer
Outflow / Outflow 10YrAvg (kcfs)
Outflow / Outflow 10YrAvg (kcfs)
Temp WQM / Temp (WQM) 10YrAvg (C)
2024:MCPW:outflow
Avg15-24:MCPW:outflow
Y2:2024:MCPW:tempc
Y2:Avg15-24:MCPW:tempc


Pacific Northwest
NATIONAL LABORATORY
What role does proximity to the thalweg and flow fluctuations play in route selection?
LGR 2022
Forebay Receiver Index
Proportion
First Receiver Detection
Last Receiver Detection
LGR 2023
FB Receiver Index
Proportion
LMN 2023
FB Receiver Index
Proportion
MCN 2024
FB Receiver Index
Proportion
First FB Receiver Detection
Last FB Receiver Detection
JDA 2024
FB Receiver Index
Proportion
First FB Receiver Detection
Last FB Receiver Detection
7

What information is available on the type of screen infrastructure across Mid-C projects and is it currently "lamprey friendly"?

- Powerhouse survival
- 0.8058 (0.0537) at LGR in 2023 (ESBS)
- 0.7924 (0.0929) at LMN in 2023 (STS)
- 0.7295 (0.0495) at MCN in 2024 (ESBS)
- 0.5910 (0.0510) at JDA in 2024 (0.7063 [0.0543] @ night) (STS)

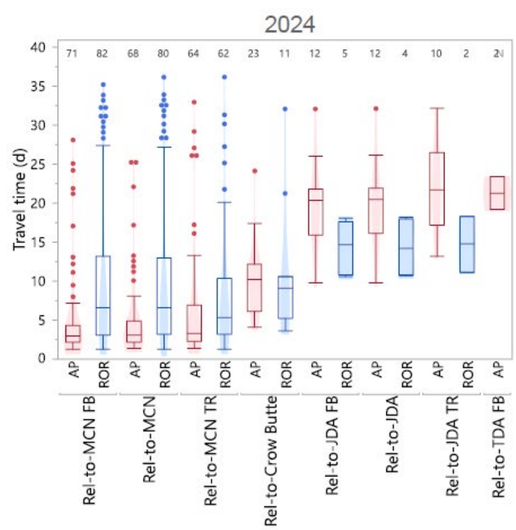
8

Are there differences in behavior between hatchery- and natural-origin juveniles?

2023

LGR	FB residence time (hr)			TR egress time (hr)		
Release	Median	10th %	90th %	Median	10th %	90th %
ROR	2.7	1.3	4.7	0.6	0.3	63.9
Art. Prop.	1.6	1.3	3.2	0.4	0.3	0.8

LMN	FB residence time (hr)			TR egress time (hr)		
Release	Median	10th %	90th %	Median	10th %	90th %
ROR	1.1	0.7	1.6	0.4	0.2	86.9
Art. Prop.	1.0	0.8	1.6	0.4	0.3	4.0



9

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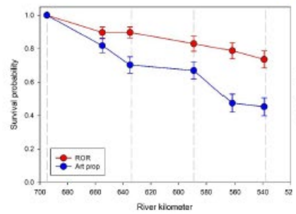
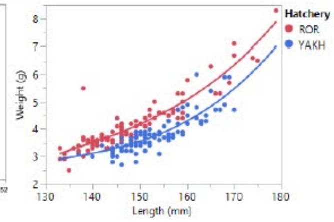
Are there differences in route selection and survival rates between hatchery- and natural-origin juveniles?

Group	N	Powerhouse %	Conv. Spill %	RSW %
		2023 LGR		
ROR	91	89%	11%	0%
Art. Prop.	87	82%	16%	2%
		2023 LMN		
ROR	73	47%	48%	6%
Art. Prop.	58	31%	59%	10%
		2024 MCN		
ROR	80	48%	41%	11%
Art. Prop.	68	43%	34%	24%

2023

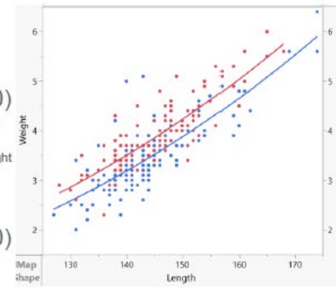




2024
Release-to-MCN S
ROR = 0.7248 (0.0460)
AP = 0.5967 (0.0465)*

*Significantly correlated w/length & weight

MCN-to-JDA S
ROR = 0.0514 (0.0250)
AP = 0.1900 (0.0498)



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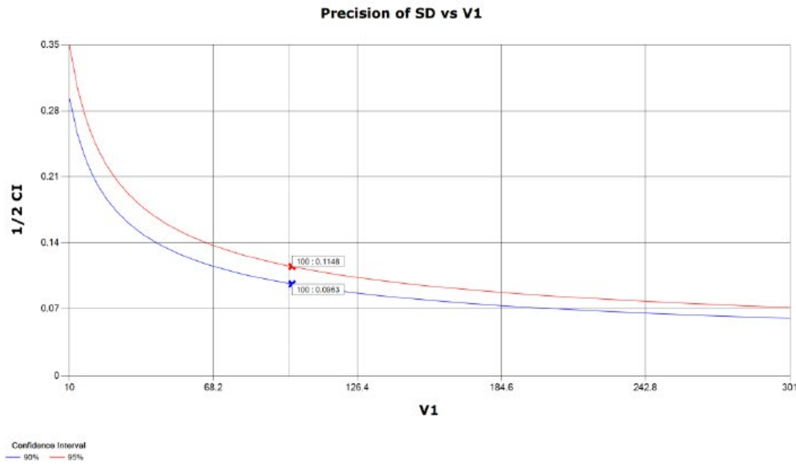
How far upstream from a dam should juvenile lamprey be released to maximize detection and survival?

- 2022 Blyton Landing to LGR (20 km): S = 0.884 (0.022)
  - April release: S = 0.697 (0.060)
  - May/June releases: S = 0.921 (0.021)
- 2023 Blyton Landing to LGR (20 km): S = 0.907 (0.017)
- 2024 Port Kelley to MCN (34 km): S = 0.735 (0.022)
- 2024 Arlington to JDA (39 km): S = 0.454 (0.023)

11

What is the relationship between sample size (i.e., number of juveniles tagged) and precision of route-specific survival rates?

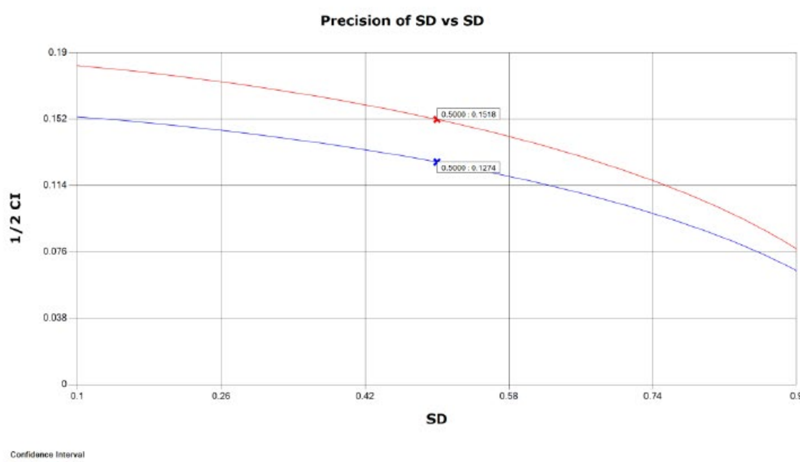
- Assumptions: ViRDCt; $D_1 = 100$; $S_D = 0.75$; $\lambda = 0.7$; $\phi = 0.3$; $p = 0.98$



12

What is the relationship between survival and precision of route-specific survival rates?

- Assumptions: ViRDCt; $D_1 = 100$; $V_1 = 100$; $\lambda = 0.7$; $\phi = 0.3$; $p = 0.98$



13

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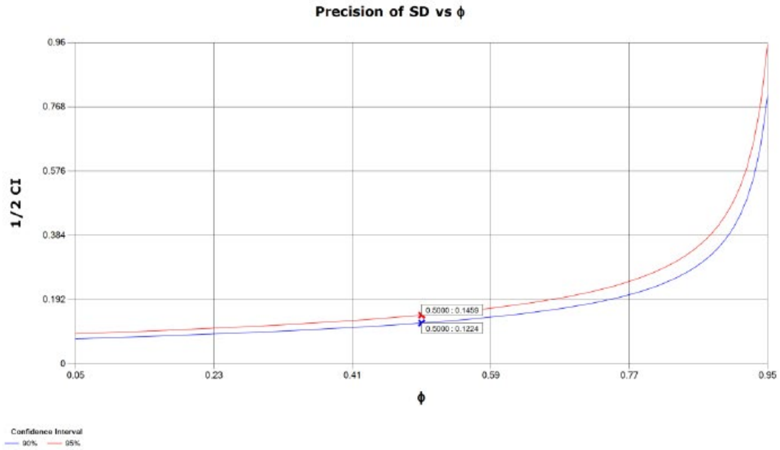
What is the relationship between dead fish detection rate and precision of route-specific survival rates?

- Assumptions: ViRDCt; $D_1 = 100$; $V_1 = 100$; $S_D = 0.75$; $\lambda = 0.7$; $p = 0.98$



14

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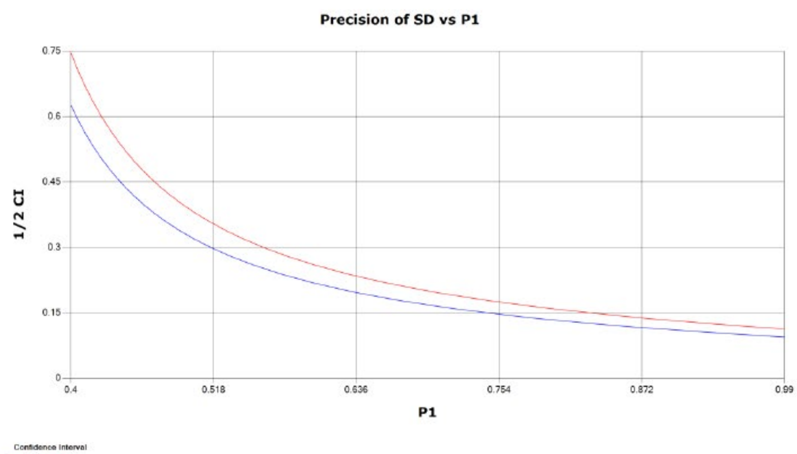
What is the relationship between detection probability and precision of route-specific survival rates?

- Assumptions: ViRDCt; $D_1 = 100$; $V_1 = 100$; $S_D = 0.75$; $\lambda = 0.7$; $\phi = 0.3$



15

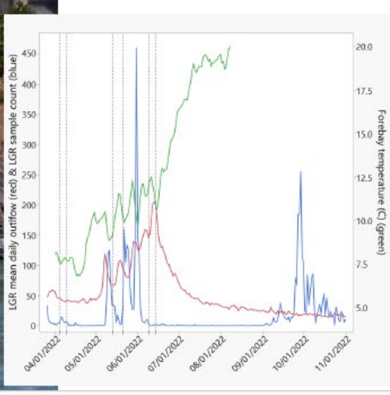
What level of precision can be expected in survival estimates?

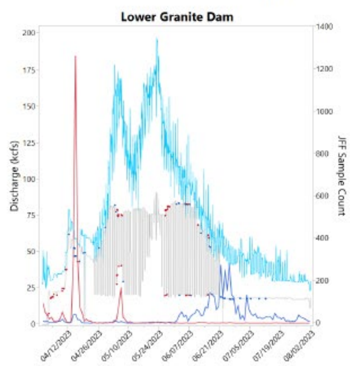
- 2022 LGR: V_1 = 270; S_D = 0.911; SE = 0.029
- 2023 LGR: V_1 = 312; S_D = 0.815; SE = 0.044
- 2023 LMN: V_2 = 178; S_D = 0.867; SE = 0.059
- 2024 MCN: V_1 = 306; S_D = 0.739; SE = 0.044
- 2024 JDA: V_2 = 232; S_D = 0.714; SE = 0.032

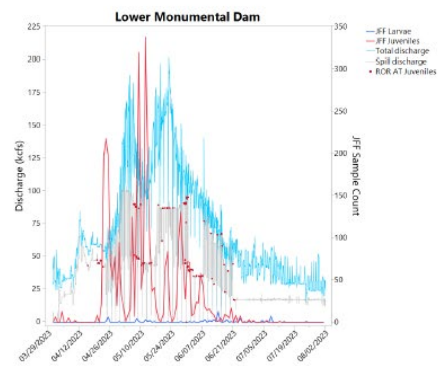
16

Pros and cons of so many different release groups? Why Feb to June? Are there advantages to combine?

- Capture variability in environmental and operational conditions experienced by the run-at-large
- Run timing difficult to predict
- Difficult to obtain sufficient numbers to tag







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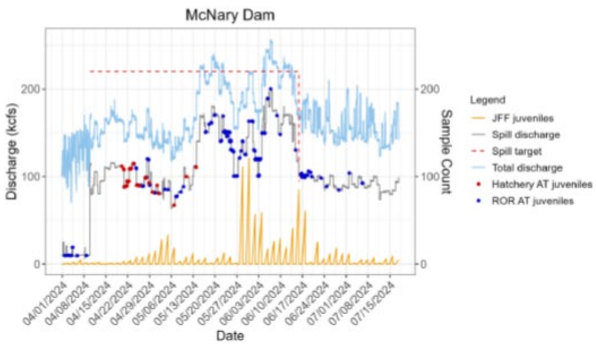
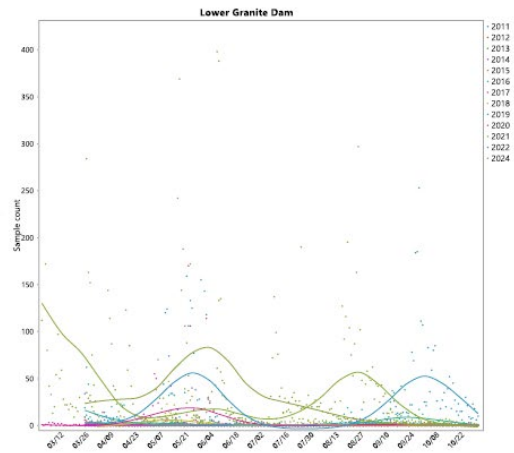
Pros and cons of so many different release groups? Why Feb to June? Are there advantages to combine?





18

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RE: Reservoir survival estimation, any value to paired releases?

Reach	2022 S (SE)	2022 S/km	2023 S (SE)	2023 S/km
Release-LGR	0.884 (0.022)	0.9938	0.9068 (0.0173)	0.9951
LGR-C.F.	0.677 (0.032)	0.9903	0.7961 (0.0247)	0.9943
C.F.-LGS FB*	0.952 (0.032)	0.9975	0.9776 (0.0139)	0.9989
LGS FB-LMN FB	0.775 (0.045)	0.9943	0.8541 (0.0387)	0.9966
LMN FB-IHR pool			0.8333 (0.0445)	0.9933
LMN FB-IHR FB	0.860 (0.058)	0.9971		
IHR pool-IHR FB*			0.8631 (0.0571)[1]	0.9936

[1]May have been underestimated due to premature battery failure of one release group.

19

How many juveniles reside in the reservoir without migrating through the dam? What proportion of tagged migrants delay their migration through the reservoir?

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- 2022 Blyton Landing to LGR (20 km): S = 0.884 (0.022)
  - April release: S = 0.697 (0.060)
  - May/June releases: S = 0.921 (0.021)
- 2023 Blyton Landing to LGR (20 km): S = 0.907 (0.017)
- 2024 Port Kelley to MCN (34 km): S = 0.735 (0.022)
- 2024 Arlington to JDA (39 km): S = 0.454 (0.023)

20

Do the tags last long enough to track the slow migrants through the reservoir and dam? Are the tags capable of assessing unbiased project-scale (reservoir + dam) survival rates? Limitations (battery life, reservoir length, flow conditions)?

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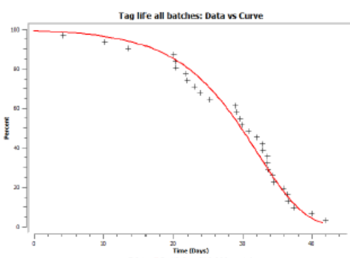
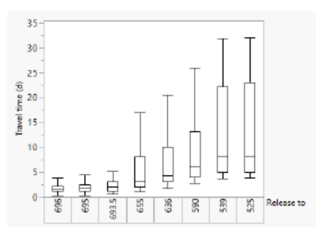
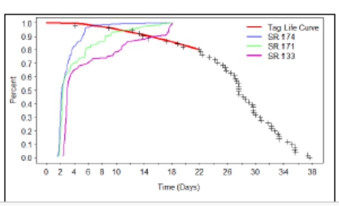
- Estimating joint probability of migration & survival.

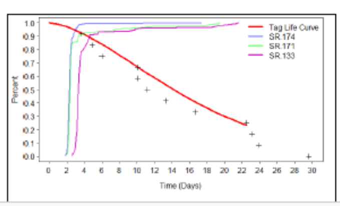
2022

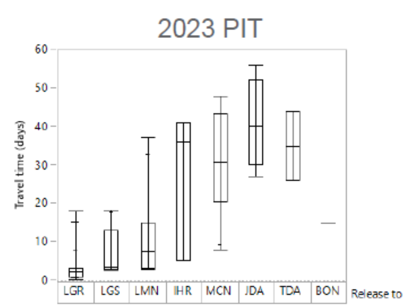




2023







21

Do the tags last long enough to track the slow migrants through the reservoir and dam? Are the tags capable of assessing unbiased project-scale (reservoir + dam) survival rates? Limitations (battery life, reservoir length, flow conditions)?

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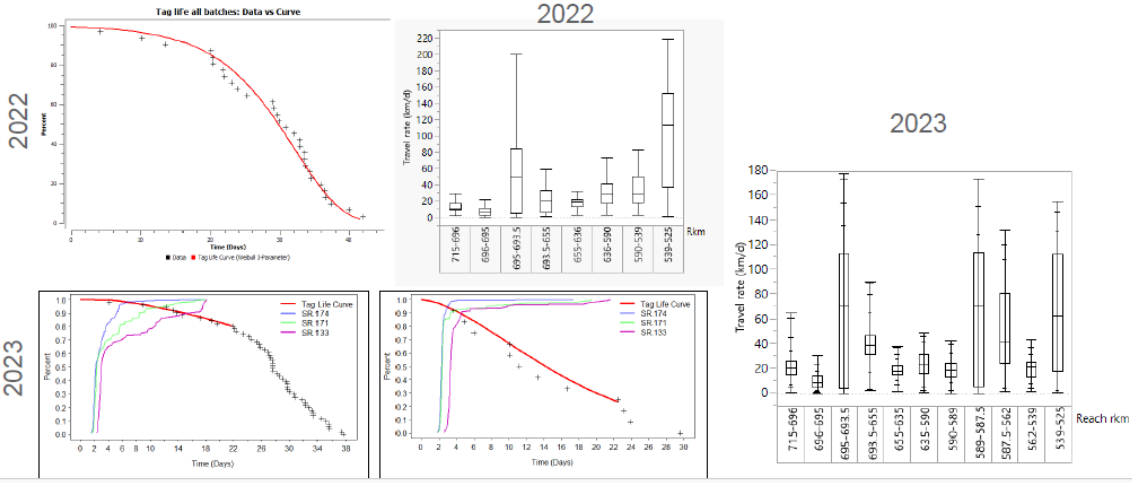
- Estimating joint probability of migration & survival.



Do the tags last long enough to track the slow migrants through the reservoir and dam? Are the tags capable of assessing unbiased project-scale (reservoir + dam) survival rates? Limitations (battery life, reservoir length, flow conditions)?

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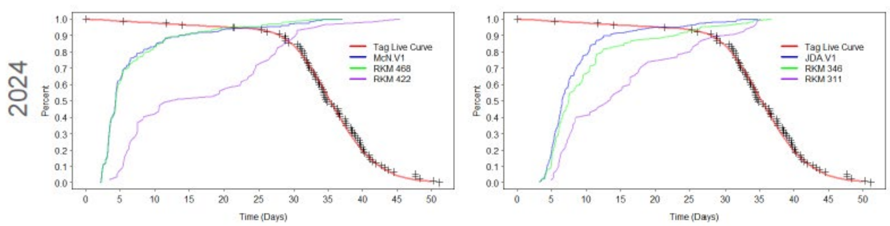
- Estimating joint probability of migration & survival.



23

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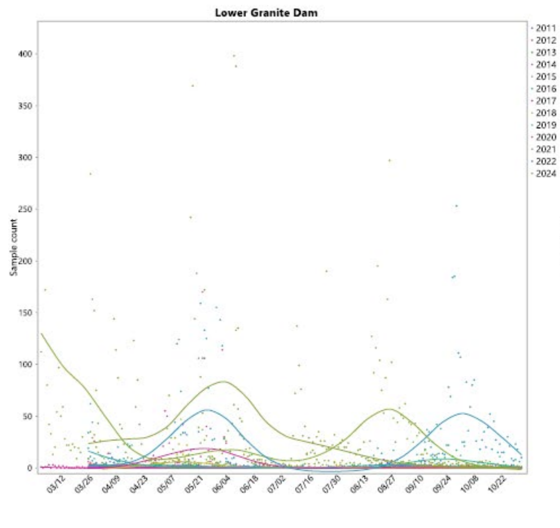
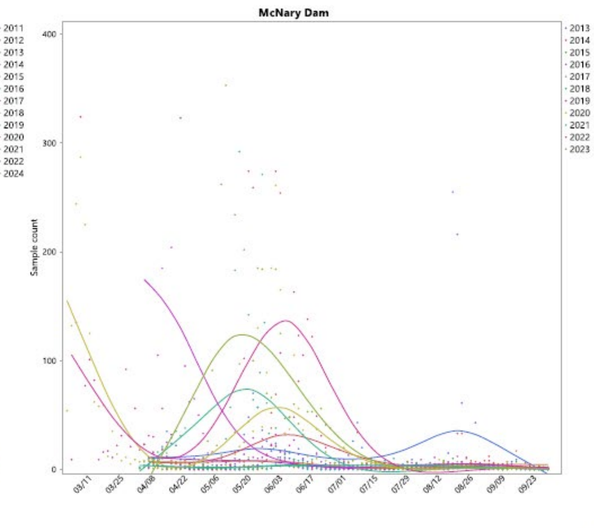
How does seasonality affect movement and survival within reservoirs? Are there optimal run timing windows or environmental conditions (e.g., flow, temperature) that reduce variability in migration and improve detection?





24

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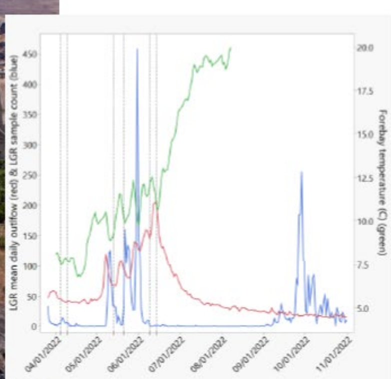
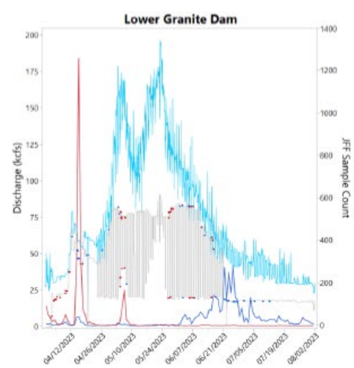
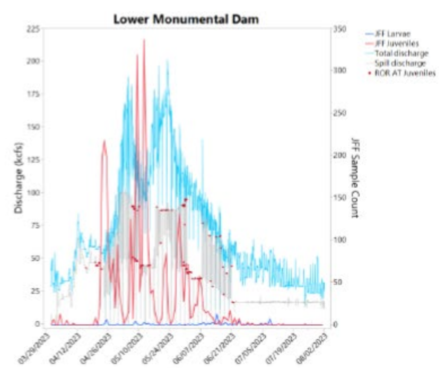
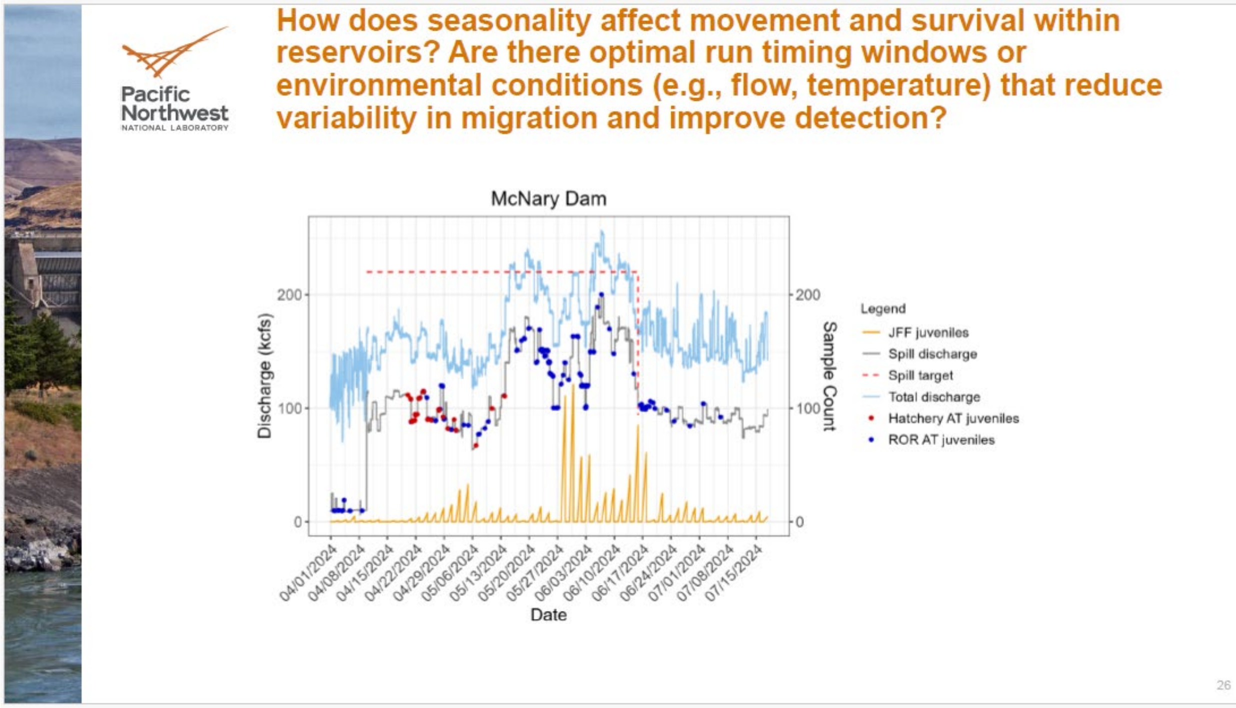
How does seasonality affect movement and survival within reservoirs? Are there optimal run timing windows or environmental conditions (e.g., flow, temperature) that reduce variability in migration and improve detection?

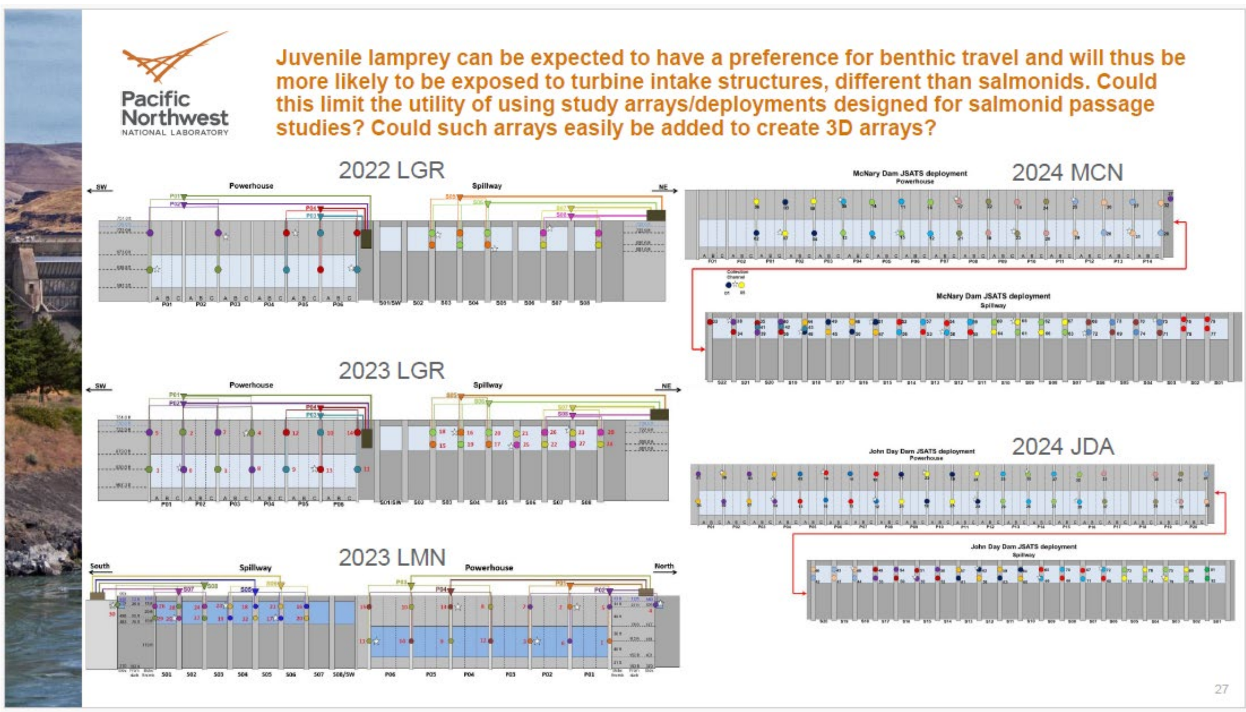






25


Pacific Northwest
NATIONAL LABORATORY
How does seasonality affect movement and survival within reservoirs? Are there optimal run timing windows or environmental conditions (e.g., flow, temperature) that reduce variability in migration and improve detection?
McNary Dam
Discharge (kcfs)
Sample Count
0
100
200
Legend
JFF juveniles
Spill discharge
Spill target
Total discharge
Hatchery AT juveniles
ROR AT juveniles
04/01/2024
04/08/2024
04/15/2024
04/22/2024
04/29/2024
05/06/2024
05/13/2024
05/20/2024
05/27/2024
06/03/2024
06/10/2024
06/17/2024
06/24/2024
07/01/2024
07/08/2024
07/15/2024
Date
26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Juvenile lamprey can be expected to have a preference for benthic travel and will thus be more likely to be exposed to turbine intake structures, different than salmonids. Could this limit the utility of using study arrays/deployments designed for salmonid passage studies? Could such arrays easily be added to create 3D arrays?
2022 LGR
Powerhouse
Spillway
2023 LGR
Powerhouse
Spillway
2023 LMN
Spillway
Powerhouse
2024 MCN
McNary Dam JSATS deployment
2024 JDA
John Day Dam JSATS deployment
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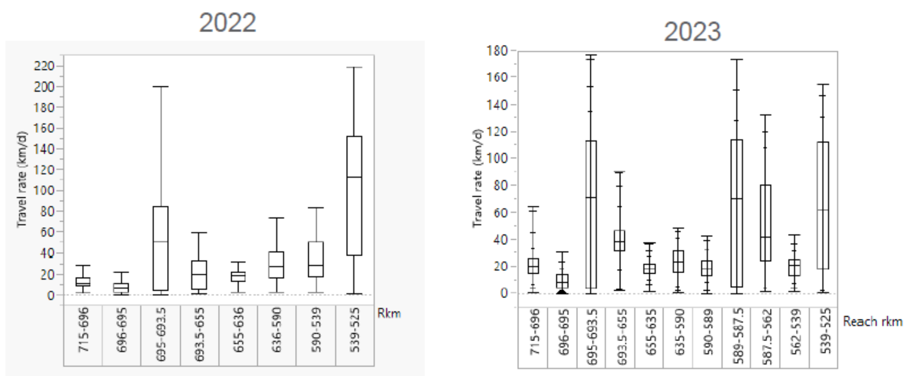
If reservoir passage can be assumed to take multiple days due to diurnal movements would additional sensor arrays be needed in the reservoir? What could be the spacing? At a minimum I think reservoir arrays would need to be spaced close enough to enable detection and survival estimates of lamprey between reservoir points? Are there any battery life considerations needed in longer reservoirs?



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What are the pros and cons of using the Virtual/Paired Release (ViPRe) Model and the Virtual Release/Dead-Fish Correction (ViRDCt) Model?

- ViRDCt requires substantially fewer tags/fish, releases, and arrays to achieve precise estimates of dam passage survival
- ViRDCt allows for a more straightforward approach to estimating dam passage survival over shorter time periods (e.g., specific operations, etc.)
- ViRDCt dead tagged fish releases must match the spatiotemporal distribution of virtual release group mortality
  - Helps to have some prior knowledge of timing/routes of mortality
  - Requires frequent releases of dead tagged fish
  - Post-study random sampling can be used if spatiotemporal distributions differ
- ViPRe model $S_2 > S_3$ assumption violations occurred in ~10% of FCRPS BiOp studies

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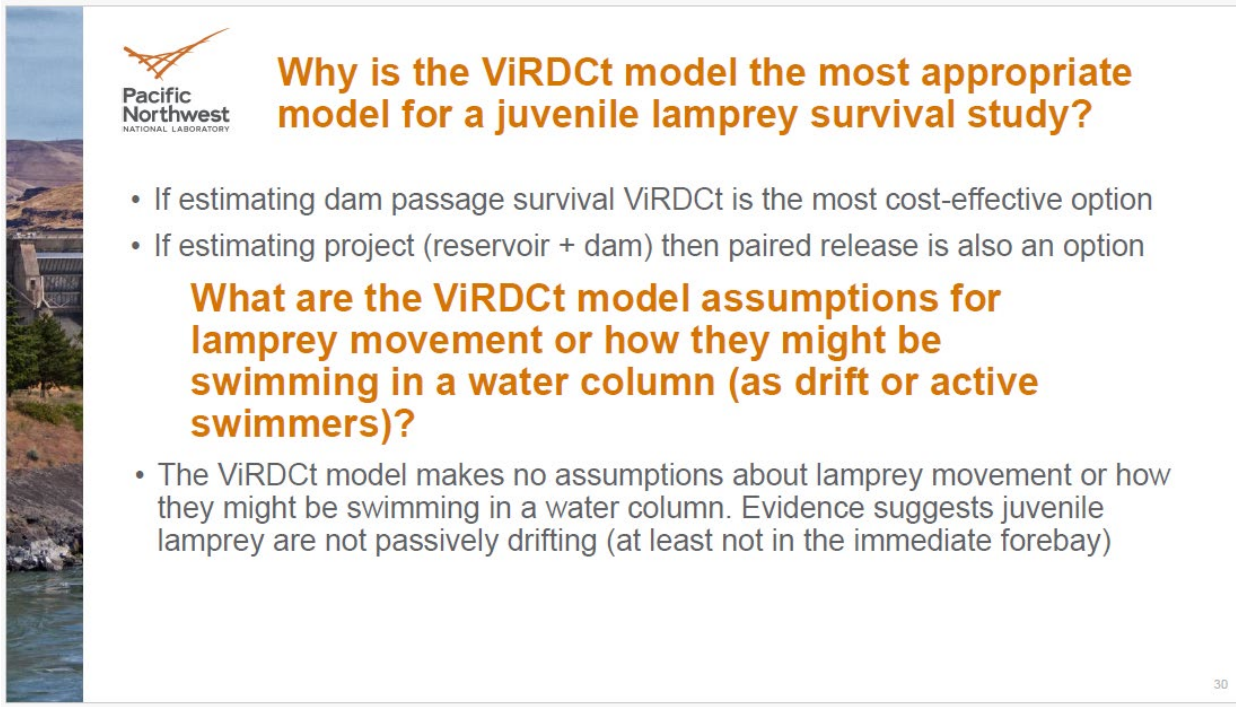
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Why is the ViRDCt model the most appropriate model for a juvenile lamprey survival study?
• If estimating dam passage survival ViRDCt is the most cost-effective option
• If estimating project (reservoir + dam) then paired release is also an option
What are the ViRDCt model assumptions for lamprey movement or how they might be swimming in a water column (as drift or active swimmers)?
• The ViRDCt model makes no assumptions about lamprey movement or how they might be swimming in a water column. Evidence suggests juvenile lamprey are not passively drifting (at least not in the immediate forebay)
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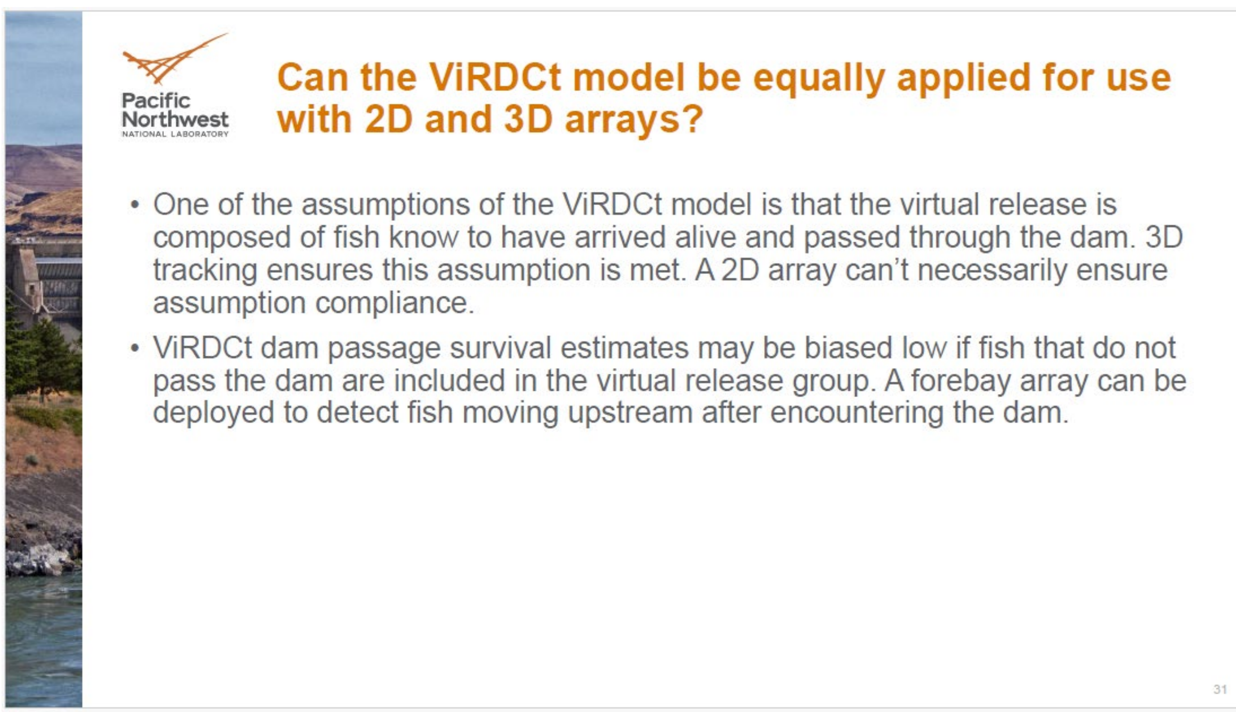
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Can the ViRDCt model be equally applied for use with 2D and 3D arrays?
• One of the assumptions of the ViRDCt model is that the virtual release is composed of fish know to have arrived alive and passed through the dam. 3D tracking ensures this assumption is met. A 2D array can't necessarily ensure assumption compliance.
• ViRDCt dam passage survival estimates may be biased low if fish that do not pass the dam are included in the virtual release group. A forebay array can be deployed to detect fish moving upstream after encountering the dam.
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How is the likelihood of not migrating handled? I assume this model assumes a tagged fish is a migrating fish or will migrate. What factors contribute to fish holding or staging behavior?

- The ViRDCt model only estimates survival from the time of passage through the immediate (~1-2 km) tailrace. Therefore, a fish must be an active migrant to be included in the virtual release group and only must be motivated to migrate ~1-2 km once they've passed the dam.
- Can't say for certain whether fish held/staged or suffered mortality
  - Estimated "survival" lowest during low flow conditions of early spring 2022 and 2024

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How long should tagged juveniles be held before releasing them into the study area?

- 24-36 h

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What behaviors do we anticipate from juvenile lamprey released into the reservoir?

- Do they sucker during the day and swim/drift during the night?
  - They do pass dams during both day and night
- Could they sucker for multiple days until there is a flow stimulus?
  - This doesn't seem likely based on the travel times/rates we've observed – except maybe during low flows.

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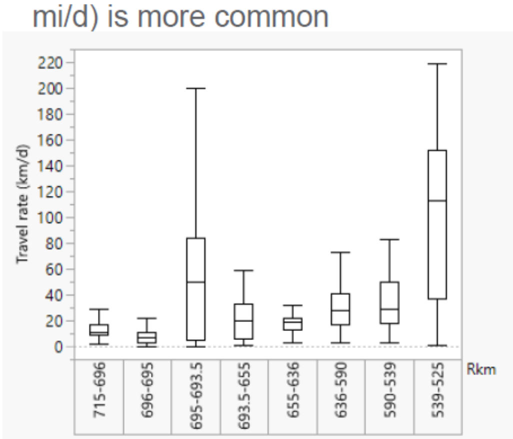
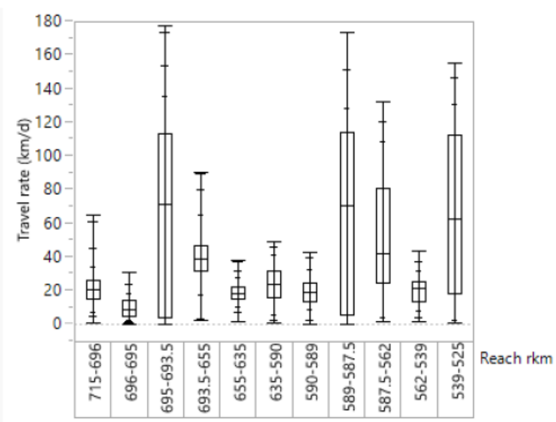
What behaviors do we anticipate from juvenile lamprey released into the reservoir?

- Can observed travel rates of 23.7–38.8 mi/d (38.1–62.4 km/d) be assumed for our efforts? That seems a bit fast through most reaches. 10-40 km/d (6.2–24.9 mi/d) is more common





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Questions we have not addressed

- Is there a difference in survival rates and behavior of fish that are captured downstream of the project area and used in an upstream study area compared to those captured upstream from the study area?
- Do juveniles from mainstem habitats behave or survive differently than those from tributaries?
- Do wild juveniles from distant source populations behave differently than local ones?
- How do wild fish held in captivity compare to freshly collected wild fish?
- By using lamprey from upstream sources can we reasonably assume that those study fish will be active migrants? Are there other indicators (e.g., physiological) that can indicate if a fish is actively migrating?
- Do migration behavior and survival vary depending on where the tagged fish are released (e.g., differences in survival and behavior of fish released in the reservoir versus upstream of the reservoir)?

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Questions we have not addressed

- RE: Reservoir survival, without a baseline for undammed riverine survival, how do we determine a negative effect of the reservoir?
- Are suitable tags readily available for a juvenile lamprey tagging study?
- Should study design consider releases to occur with the onset of nautical dusk when some studies have suggested lamprey will begin to make volitional movements?
- Stream flow influences on lamprey migration seems well established; higher flows correlate with increased lamprey movements. The General Study Design mentions flow conditions could be influenced by dam spill and that lamprey releases will be attempted to be timed with observed high flows. I suspect pulse influences could be moderated due to reservoir impoundments and might have a more limited influence as one approaches a dam. What is not mentioned is the influence routine (non-spill) operation of dams could have on flow. Dams variously impound and release water. While this influence is moderated by the small storage of each facility in the lake-like conditions of the reservoirs could be a more dominant signal? I think the multi-release date approach will help control for various phases of dam operation, but could be a confounding variable? Data on dam operation should be collected during the study period.

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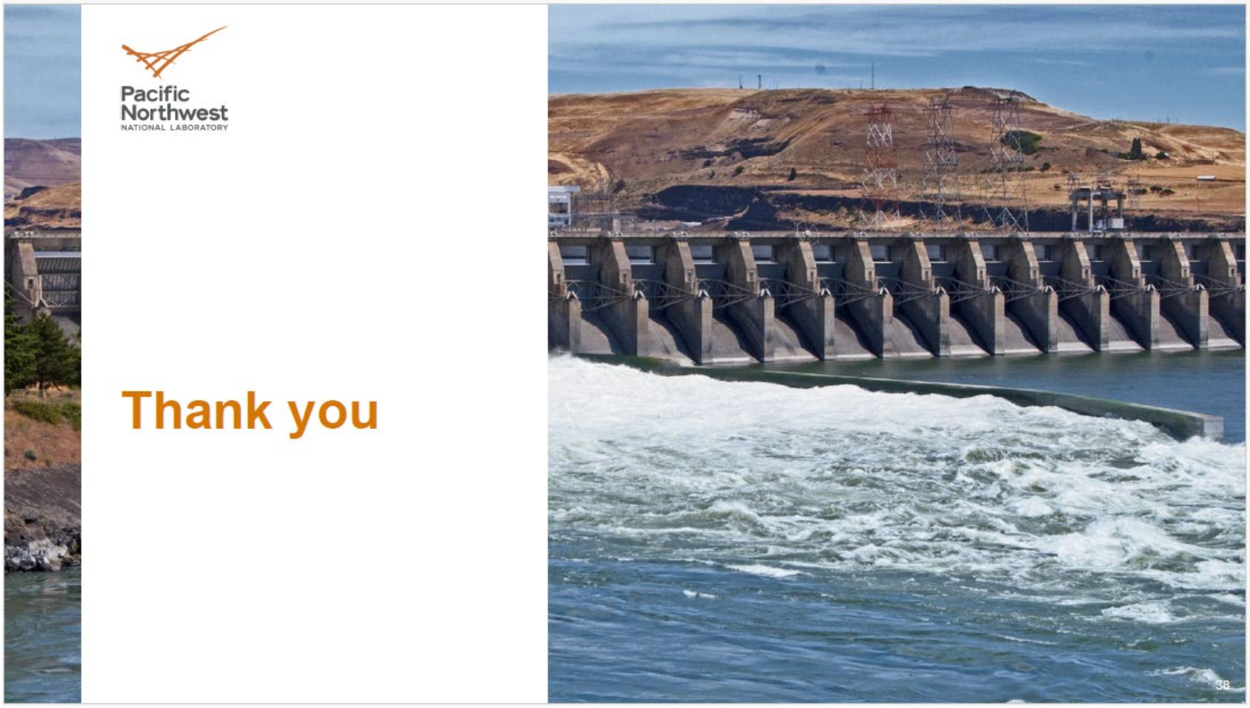
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Thank you
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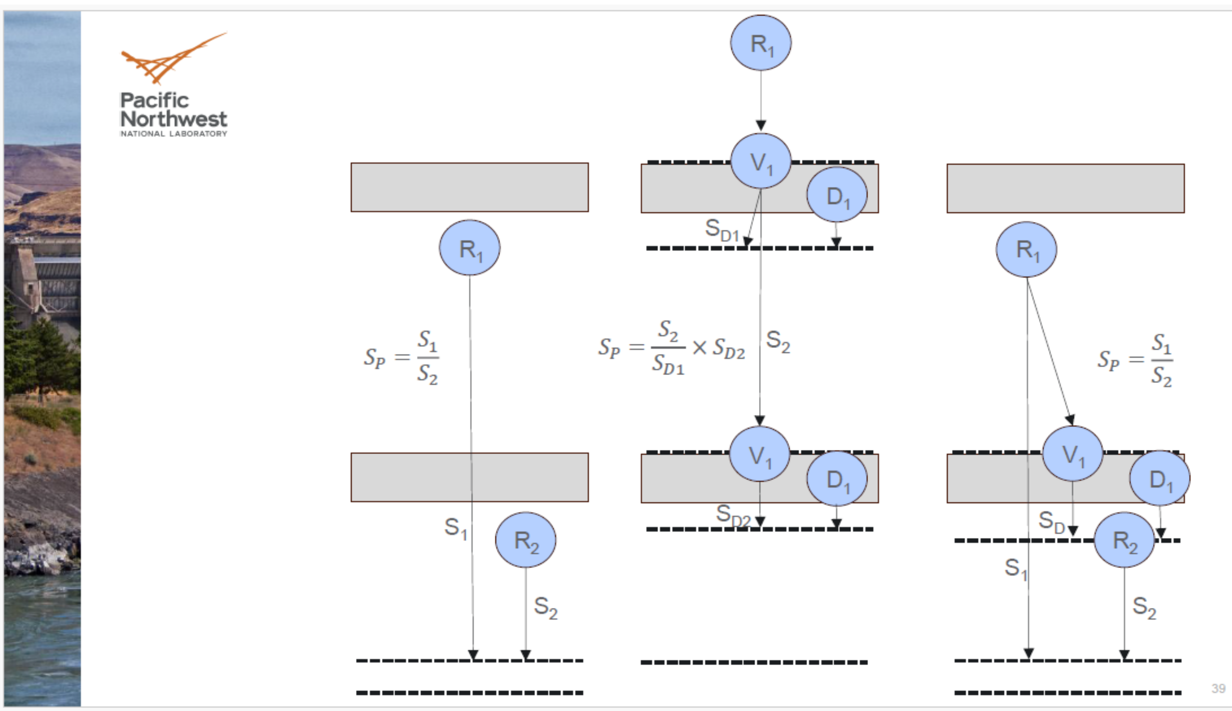
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R_1
V_1
D_1
S_{D1}
$S_P = \frac{S_1}{S_2}$
$S_P = \frac{S_2}{S_{D1}} \times S_{D2}$
S_2
S_{D2}
S_D
S_1
R_2
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