2022 Columbia Basin Research Report

A Bayesian multidirectional, multistate model to resolve the migration pathways of adult Steelhead within the Columbia River Basin

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# Introduction

Steelhead (anadromous *Oncorhynchus mykiss*) in the Columbia River Basin, including all those found above Bonneville Dam, are listed under the Endangered Species Act. The five Columbia River Basin distinct population segments (DPSs) were first listed in the late 1990s, and are all currently listed as threatened. Despite their protected status and continued recovery efforts, counts of returning Steelhead to Bonneville Dam have been lower in the last five years than they were at the time of listing, and recently completed 5-year reviews for Columbia River Steelhead reaffirmed their status as threatened (**NMFS2022d?**).

One element of the life history of Columbia River Basin Steelhead that may make them more vulnerable to anthropogenic modifications of the Columbia River is their adult migration. Relative to other salmonids, Steelhead from the Columbia River Basin spend longer in freshwater as adults. Essentially all populations of Steelhead in the Columbia River Basin are stream-maturing (Busby *et al.* 1996), meaning that these fish enter freshwater in a sexually immature state and then spend up to a year in freshwater prior to spawning. Also known as summer Steelhead, these fish enter freshwater between May and October and spawn the following spring, typically between March and May (Busby *et al.* 1996). Between their entry into freshwater and arrival at spawning grounds, Columbia River Steelhead exhibit considerable variability in their migration patterns. Virtually all interior Columbia River Steelhead overwinter in freshwater; the majority of individuals are known to overwinter in tributaries, but up to 20% of individuals in a given year have been observed to overwinter in the hydrosystem, which comprises of the mainstem habitat between the 10 hydroelectric dams in the federal Columbia River power system (Keefer *et al.* 2008). Additionally, as individuals migrate upstream toward natal tributaries, the majority of individuals have been observed to temporarily stage in nonnatal tributaries downstream of their natal tributary (High *et al.* 2006). This behavior increases with increasing mainstem river temperature, indicating the use of these colder waters as coldwater refugia (High *et al.* 2006). These highly variable movement patterns and increased duration in freshwater make Steelhead more vulnerable to the hazards faced in freshwater.

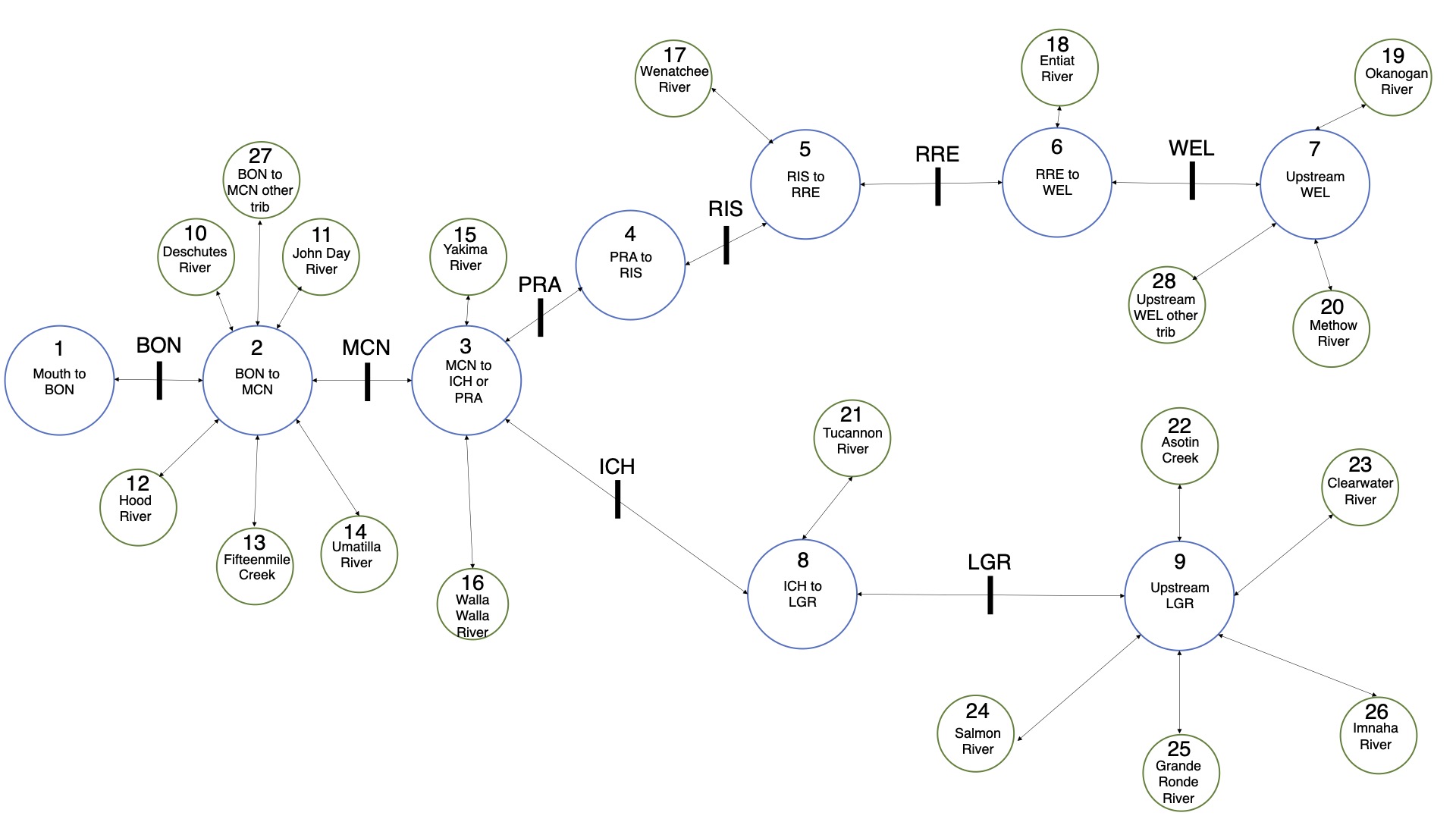
Descending dams, also known as fallback (Boggs *et al.* 2004), is another common behavior observed in Steelhead, with about 20% of Steelhead observed to fall back over at at least one mainstem dam (Boggs *et al.* 2004). This behavior can occur as individuals are migrating upstream to natal tributaries, but can also occur once individuals have ascended mainstem dams upstream of natal tributaries (a behavior known as overshoot), in which case this fallback is called post-overshoot fallback and is necessary for individuals to return to natal tributaries. Overshoot and fallback affect the ability of individuals to successfully spawn, and therefore are consequential for the persistence of ESA-listed populations. Individuals that fall back during their upstream migration (prior to reaching or overshooting their natal tributary) are less likely to return to their natal tributaries or hatcheries (Bjornn *et al.* 2000; Keefer *et al.* 2005). Furthermore, migration success to natal tributaries decreases with overshooting rates (Richins and Skalski 2018), and many overshooting fish are observed to stray to tributaries upstream of the overshoot dam.

The decreased migration success associated with overshoot and fallback is likely due to the hazardous nature of downstream passage for adults, which is often limited to the powerhouse during the primary months that Steelhead are overwintering (Khan *et al.* 2013). Mortality rates for adult Steelhead passing downstream at dams are highly variable, but recent estimates of 48-hour survival at McNary Dam indicate around 90% survival for individuals passing through turbines and 97% survival for individuals passing through the spillway (**Normandeau2014?**). Mortality in downstream passage routes is implicated by low survival rates of Steelhead kelts, which decrease with increasing number of dams that must be navigated as they move downstream to the ocean, with mortality rates of 84-96% for kelts released at Lower Granite Dam, 38-40% at McNary Dam, and 20-37% at John Day Dam (**Westrheim2005?**).

Because of the association between overshoot and fallback and decreased migration success, previous studies have investigated the influence of various factors on these rates. Rates of overshoot have been shown to vary considerably among populations, but have a positive relationship with increasing mainstem water temperature and hatchery rearing upstream of the natal tributary (Richins and Skalski 2018). In spring-summer Chinook, fallback rates have a positive relationship with river discharge (Boggs *et al.* 2004). However, these previous studies have looked at these various factors only in isolation and for specific movements. In this study, we developed a multistate model that is capable of modeling the entire adult Steelhead migration, from first detection at Bonneville Dam to arrival in natal tributaries. This model, which does not constrain movement to only be upstream, allows the complexity of multidirectional movement to be modeled and allows many movements of interest, including fallback, overshoot, and homing, to be estimated in a single framework. The data used in this model were passive integrated transponder (PIT) tag detection histories. This modeling framework accommodates the effect of multiple categorical and continuous covariates at movement probabilities at each step within the migration. By examining how Steelhead movement probabilities, particularly those of conservation concern, such as overshoot, fallback, homing, and straying, vary by population and are influenced by various factors, this modeling framework will improve our understanding of how both environmental and anthropogenically influenced conditions affect how Steelhead move within the Columbia River and its tributaries.

# Methods

## Modeling overview



The model schematic.

In our model, the Columbia River and its tributaries are modeled as a series of connected states, with states defined as either reaches of the mainstem Columbia or Snake River between dams with PIT tag detection capabilities in the adult ladders or tributaries with PIT tag detectors. Fig. 1 shows all of the states in our model; movements over some dams (e.g., The Dalles or John Day Dams) were not explicitly modeled due to these dams not having PIT tag detection capabilities for the duration of our study period. Future iterations of the model could be configured to include these dams for part of the time series by splitting state 2 (mainstem, Bonneville Dam to McNary Dam) into three states: 1) mainstem, Bonneville Dam to The Dalles Dam; 2) mainstem, The Dalles Dam to John Day Dam; and 3) mainstem, John Day Dam to McNary Dam. This would allow the estimation of fallback and overshoot at The Dalles Dam and John Day Dam (which would be of particular interest to populations near these dams, such as the Deschutes River or Fifteenmile Creek), but would require a temporally-varying state configuration.

Description of loss

## Accessing PIT tag data

PIT tag data were obtained from the Columbia Basin PIT Tag Information System (PTAGIS). Only known-origin individuals (based on known release sites) were included in this dataset. To ensure that only individuals marked as juveniles were kept in the dataset, all individuals that were greater than 350 mm at time of marking were removed. To select returning adults, only individuals that were seen in the adult fishways at Bonneville Dam were selected. To ensure that there were enough data for each population included in this dataset, only populations (defined as tributaries in which PIT-tagged juveniles were released) that had at least 250 individuals distributed across 8 run years were kept. Additionally, only populations with instream PIT tag detections sites in their natal tributaries were kept; if sufficient instream detection sites only became available during the later part of our study period, only individuals from those years were kept. Run years were separated by June 1 of each year, and run year 2005/2006 (beginning on June 1, 2005) was selected as the first year in our dataset. In total, populations from 17 natal tributaries met this criteria: 11 tributaries of the Columbia (Deschutes River, John Day River, Hood River, Fifteenmile Creek, Umatilla River, Yakima River, Walla Walla River, Wenatchee River, Entiat River, Okanogan River, and Methow River) and six tributaries of the Snake (Tucannon River, Asotin Creek, Clearwater River, Salmon River, Grande Ronde River, and Imnaha River). Once the tag codes were identified for each of these tributary populations, a complete tag history report was run in PTAGIS for all of the tag codes in our dataset.

## Processing PIT tag data into detections at various sites

In order to convert detections of fish at individual PIT tag antennas into a history of movements between different reaches of the Columbia, Snake, and their tributaries, the first step with the PIT tag data from PTAGIS was to interpret detections at different PIT tag antennas. For instream tributary detection sites, as well as mainstem sites in between dams, no processing was required, and these detections were interpreted as the fish being in that associated state. For detection sites at dams, additional processing was required to interpret detections.

The first step in interpreting detections at dams was to identify the multiple passage routes associated with each dam. In many cases, multiple passage routes were grouped together into a single interrogation site, and assigning antennas to these different passage routes was necessary to interpret how fish were utilizing these passage routes. For example, antennas at Ice Harbor Dam are all grouped together in PTAGIS as “Ice Harbor Dam (combined)”, when these antennas are actually in three different passage routes: the North Shore Ladder, the South Shore Ladder, and the Juvenile Bypass System.

The second step was to identify, when possible, entrance and exit antennas within each upstream passage route. Entrance and exit antennas were only distinguished when either two distinct groupings of antennas existed in separate parts of the same passage route, or in the case of Bonneville Dam, when there are enough consecutive weirs with PIT tag detection antennas to separate these weirs into entrance and exit antennas. By distinguishing entrance and exit antennas, we were able to identify when fish detections in adult fishways were not ascents, but were rather aborted ascent attempts or descents. When fish were only seen at entrance antennas, this was noted to be an aborted ascension attempt. When fish were first seen at the exit antennas at an adult fish ladder and last seen at the entrance antennas of the same fish ladder, this was noted to be a descent through the ladder. If a fish was first seen at the entrance antennas and last seen at the exit antennas, this was noted to be an ascent. Entrance and exit antennas were identified at all adult fishways except for McNary Dam Washington Shore Ladder (prior to March 2006), Priest Rapids Dam, Rock Island Dam, Rocky Reach Dam, Wells Dam (prior to 2013), and Ice Harbor Dam.

An additional step was to identify antennas in adult fish facilities/traps at ladders. For most dams, detections in the adult fish facility were treated the same as detections in other parts of the adult ladder, as adults were not removed (e.g., Ice Harbor Dam, Priest Rapids Dam, or Lower Granite Dam, where traps were operated but adults were returned after processing). However, in the case of Wells Dam, fish that were trapped were removed and either moved to the hatchery or trucked off-site. As such, any terminal detections in the trap at Wells Dam were classified as terminal trapping events, and were classified as fish moving to the absorbing “loss” state.

Once the antennas had been appropriately assigned, a 48 hour threshold was utilized to distinguish separate visits to a site. However, in some passage routes, due to fish being observed in the same route for days at a time, no time threshold was utilized, and instead the sequence of antennas was used to distinguish separate visits to a site. For example, because individual fish were observed not exiting the Washington shore passage route at Bonneville Dam for upwards of 100 days, new visits to this site were only distinguished by new visits to the entrance antennas, regardless of time between detections at other antennas in the passage route.

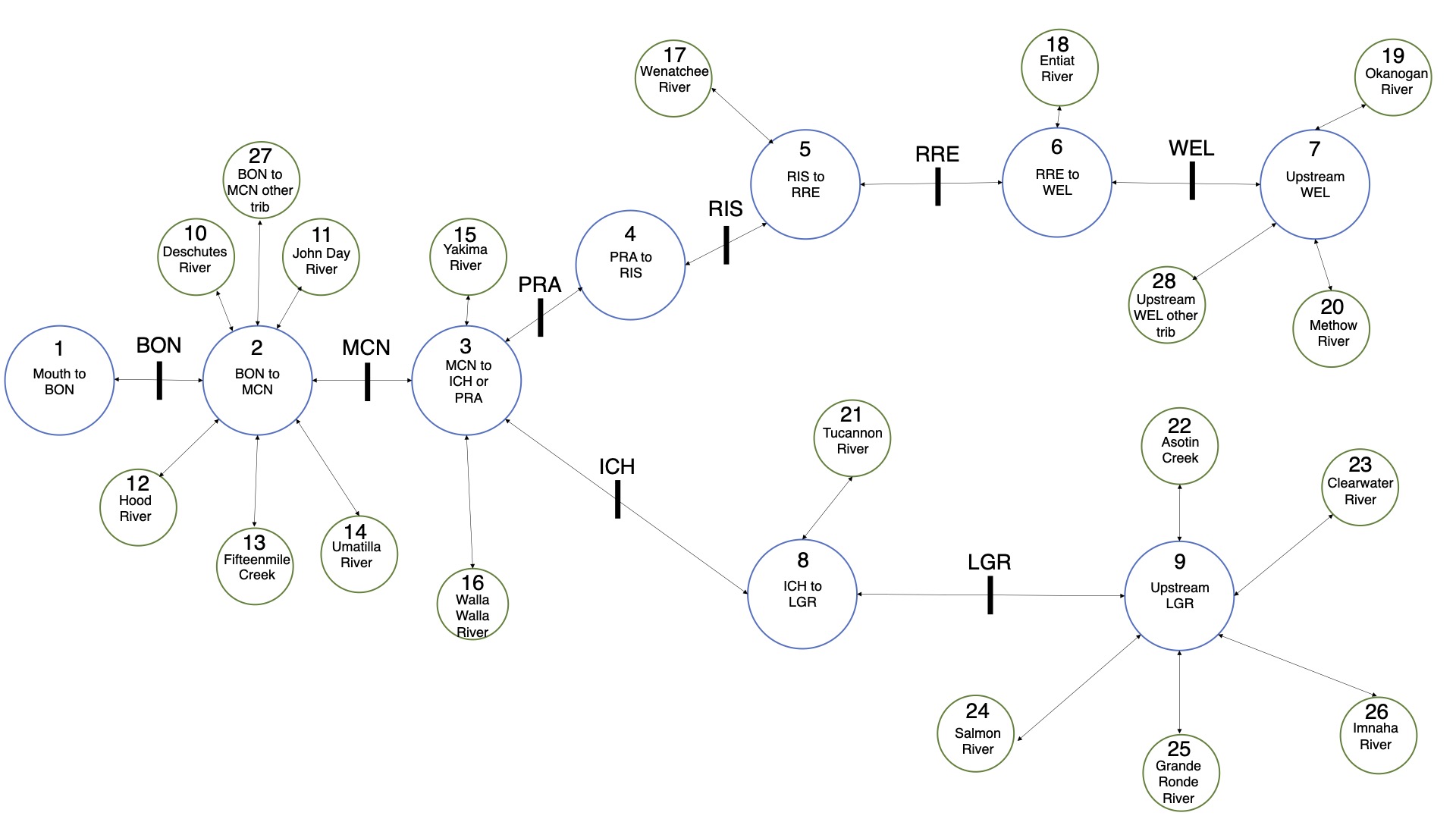
## Turning detections at different sites into state visits

With antennas appropriately assigned to different passage routes and the sequence of antenna detections used at the adult fishways to interpret directionality, the output from the previous script was used as input into the next script, which converted a history of detections at sites into a history of movements between states, as defined in Figure 1. For detections at sites in the fish passage routes at dams, the directionality of movement, as assigned in the previous script, was used to inform transitions between states. Ascents at dams indicated a transition from the downstream state to the upstream state; descents at dams (either through the juvenile bypass system or through descents through the ladder) indicated a transition from the upstream state to the downstream state. Aborted ascension attempts were noted, but interpreted as no transition from the current state. Detections in tributary sites were interpreted as transitions from the mainstem state into the tributary. Once a fish transitioned into a given state, any subsequent detections in that state were ignored, as they did represent transitions between states. Therefore, if fish were detected at sites within the same tributary consecutively, or if fish were detected at instream sites in the mainstem following transition into that mainstem state, these detections were ignored.

With the exception of a few downstream routes, such as the spillway at Lower Granite Dam following the installation of the PIT tag antennas in 2020, or the Bonneville Corner Collector, PIT tag detection capabilities were limited to the adult fish ladders and the juvenile bypass system at each dam. As such, PIT tag antennas have historically been unable to directly monitor fallback at dams, unless an individual subsequently reascends the dam (Boggs *et al.* 2004). With the installation of instream antennas in natal tributaries, fallback to home has been monitored (Richins and Skalski 2018), by noting when individuals entered natal tributaries downstream of a dam that was previously ascended. In this study, we monitored fallback to the greatest extent possible with the current configuration of PIT tag antennas by using our knowledge of the connections between states in our model to note when downstream movements must have occurred. In this way, we included fallback that occurred on the mainstem downstream of the natal tributary (similar to (Boggs *et al.* 2004)), fallback to home (similar to (Richins and Skalski 2018)), and other fallback movements, such as fallback upstream of the natal tributary that did not end in homing.

Once we determined a history of movement between states, we then subset this movement history to eliminate any movement that occurred as a juvenile or as a kelt in order to isolate only the portion of the adult migration prior to reaching spawning areas. Based on manual inspection of detection histories, juvenile movements were identified using the following criteria: 1) any detections within 90 days of juvenile release; 2) any detections on or before June 15 of the the same year that an individual was released, or detections on or before June 15 in a given year if individual was released on or after July 1 of the previous year. The June 15 cutoff date was chosen based on the timing of juvenile outmigration at Bonneville Dam, 95% of which occurs before this date in nearly every run year (data from CBR DART). Kelt movement was identified as any downstream movement occurring between March and July (following spawning). Repeat spawners were also identified in the dataset based on detections at the Bonneville adult ladders occurring at least 180 days after they were initially seen at Bonneville. For the purposes of our analysis, repeat spawners were treated as new fish when they returned to Bonneville.

## The model in stan



The model schematic.

The history of state transitions for each individual PIT-tagged fish, as well as the information on that fish’s natal origin, were the inputs for the multistate model. The multistate model was implemented in a Bayesian framework using the Stan programming language (Carpenter *et al.* 2017). The multistate model is constructed as a series of states, defined as either reaches of the mainstem Columbia or Snake Rivers between dams with active PIT tag antennas for the duration of our study period or tributaries that flow into the Columbia or Snake Rivers (Figure 1). All fish in our model begin when they are first detected as adults in the fish ladders at Bonneville Dam. At each state in our model, each fish is assigned a probability of moving to any of the states connected to the current states. This probability is evaluated through a multinomial logit.

(*MDS: This would be a good place to add/introduce the actual equations.*)

Due to the computational requirements of evaluating the detection histories of over 60,000 individual fish, the model was fit to three different datasets, corresponding to the three Steelhead DPSs found exclusively upstream of Bonneville Dam: the Middle Columbia DPS, the Upper Columbia DPS, and the Snake River Basin DPS. To reduce the number of parameters in the model,

The history of state transitions for each individual PIT-tagged fish, as well as the information on that fish’s natal origin, were the inputs for the multistate model. The multistate model was implemented in a Bayesian framework in Stan (Carpenter *et al.* 2017). The multistate model is constructed as a series of states, defined as either reaches of the mainstem Columbia or Snake Rivers between dams with active PIT tag antennas for the duration of our study period or tributaries that flow into the Columbia or Snake Rivers (Fig. 1). All fish in our model begin when they are first detected as adults in the fish ladders at Bonneville Dam. At each state in our model, each fish is assigned a probability of moving to any of the states connected to the current states, or into the absorbing loss category, which a fish enters once the detection history ends. Each of these probabilities is evaluated through a multinomial logit, with the loss probability calculated as 1 - the sum of the other probabilities, enforcing a constraint that all movement probabilities have to sum to 1.

Due to the computational requirements of evaluating the detection histories of over 60,000 individual fish, the model was fit to three different datasets, corresponding to the three Steelhead DPSs found exclusively upstream of Bonneville Dam: the Middle Columbia DPS, the Upper Columbia DPS, and the Snake River Basin DPS. To reduce the number of parameters in the model, an effect of natal origin was only included for state transitions into or out of states within the DPS boundaries, whereas for states outside of the DPS, all origins shared a common movement probability. This model structure allowed different natal origins to differentiate as they neared natal tributaries.

All code is available at <https://github.com/markusmin/steelhead>.

# Results

A total of 662 different movement probabilities, based on the combination of state transition and origin/DPS, were estimated by the model (Tables 1-6). The model schematic in Fig. 1 is necessary to interpret the ecological significance of these movement probabilities, in terms of which movements constitute the probabilities of certain movements, such as overshoot, fallback, homing, or straying. Furthermore, each movement probability represents only the probability of an individual making that movement conditional on it already being in the “from” state. Due to poor detection probabilities in tributaries and in downstream passage routes, only overshoot probabilities (which have near 100% detection probability) are discussed in the Results; see [Current Limitations](#current-limitations) for a discussion of these issues and future directions to address them. Overshoot probabilities, or the probability of ascending the dam upstream of the natal tributary in the model schematic (Fig. 1), varied considerably by natal origin.

## Final population distribution probability

### Middle Columbia River Steelhead

![Figure 1. Fifteenmile Creek Final Fate Probabilities.](data:application/pdf;base64,)

Figure 1. Fifteenmile Creek Final Fate Probabilities.

![Figure 2. Deschutes River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 2. Deschutes River Final Fate Probabilities.

![Figure 3. John Day River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 3. John Day River Final Fate Probabilities.

![Figure 4. Umatilla River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 4. Umatilla River Final Fate Probabilities.

![Figure 5. Walla Walla River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 5. Walla Walla River Final Fate Probabilities.

![Figure 6. Yakima River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 6. Yakima River Final Fate Probabilities.

### Upper Columbia River Steelhead

![Figure 7. Wenatchee River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 7. Wenatchee River Final Fate Probabilities.

![Figure 8. Entiat River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 8. Entiat River Final Fate Probabilities.

![Figure 9. Methow River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 9. Methow River Final Fate Probabilities.

![Figure 10. Okanogan River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 10. Okanogan River Final Fate Probabilities.

### Middle Columbia River Steelhead

![Figure 11. Tucannon River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 11. Tucannon River Final Fate Probabilities.

![Figure 12. Clearwater River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 12. Clearwater River Final Fate Probabilities.

![Figure 13. Asotin Creek Final Fate Probabilities.](data:application/pdf;base64,)

Figure 13. Asotin Creek Final Fate Probabilities.

![Figure 14. Grande Ronde River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 14. Grande Ronde River Final Fate Probabilities.

![Figure 15. Salmon River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 15. Salmon River Final Fate Probabilities.

![Figure 16. Imnaha River Final Fate Probabilities.](data:application/pdf;base64,)

Figure 16. Imnaha River Final Fate Probabilities.

## Homing probabilities, conditional on overshoot

**Table** : Probability of successfully homing, conditional on making it to the section of mainstem into which the home tributary flows, or conditional on overshooting the dam directly upstream of the home tributary.

| Natal Origin | Non-overshoot | Overshoot |
| --- | --- | --- |
| Fifteenmile Creek | 0.27 (0.22 - 0.34) | 0.13 (0.087 - 0.18) |
| Deschutes River | 0.66 (0.56 - 0.77) | 0.28 (0.12 - 0.58) |
| John Day River | 0.36 (0.33 - 0.4) | 0.2 (0.18 - 0.23) |
| Umatilla River | 0.52 (0.48 - 0.56) | 0.27 (0.24 - 0.31) |
| Walla Walla River | 0.46 (0.36 - 0.48) | PRA: 0.29 (0.21 - 0.34)/ ICH: 0.14 (0.11 - 0.15) |
| Yakima River | 0.92 (0.86 - 0.95) | PRA: 0.65 (0.55 - 0.73)/ ICH: 0.57 (0.37 - 0.72) |
| Wenatchee River | 0.44 (0.42 - 0.47) | 0.11 (0.1 - 0.12) |
| Entiat River | 0.78 (0.73 - 0.84) | 0.59 (0.5 - 0.69) |
| Tucannon River | 0.46 (0.43 - 0.49) | 0.18 (0.17 - 0.2) |

## Middle Columbia River Steelhead

Of the natal tributaries downstream of McNary Dam, John Day River and Umatilla River Steelhead each had a high mean probability of overshooting McNary Dam (46.4% and 33.8%, respectively; Table 2), while Deschutes River and Fifteenmile Creek Steelhead had a low mean probability (0.7% and 9%, respectively; Table 2). Conditional on overshooting McNary Dam, John Day River and Umatilla River Steelhead had an approximately 20% chance of additionally overshooting Ice Harbor Dam on the Snake River, but only a very low probability of overshooting Priest Rapids Dam on the Columbia River (Table 2). For Yakima River and Walla Walla River Steelhead, whose natal tributaries are upstream of McNary Dam, Yakima River Steelhead were more likely to overshoot Priest Rapids Dam (13.8% mean probability) than Ice Harbor Dam (3.5% mean probabiltiy) whereas Wallla Walla River Steelhead were much more likely to overshoot Ice Harbor Dam (57.4% mean probability) than Priest Rapids Dam (2% mean probability) (Table 2).

## Upper Columbia River Steelhead

Wenatchee River Steelhead, whose natal tributary is between Rock Island Dam and Rocky Reach Dam, had a 58.3% (90% CI 57%-59.6%) probability of overshooting Rocky Reach Dam. Entiat River Steelhead, whose natal tribuatry is between Rocky Reach Dam and Wells Dam, had a 36.3% (90% CI 33%-39.5%) probability of overshooting Wells Dam. Because no dam with PIT tag detectors in the adult fishways exists above Wells Dam, overshoot probabilities on the Columbia River could not be calculated for Okanogan River or Methow River Steelhead. Overshoot probabilities at Ice Harbor Dam for all four Upper Columbia River origins were exceedingly low (0-0.1%).

## Snake River Basin Steelhead

Tucannon River Steelhead are the only Snake River Steelhead population for which overshoot probabiltiies at the upstream dam could be calculated. Tucannon River Steelhead had a 57% (90% CI 55.8%-58.2%) probability of overshooting Lower Granite Dam. All six origins had probabilities of overshooting Priest Rapids Dam on the Columbia River between 1% and 3%.

# Discussion

## Current limitations and next steps

### Detection probabilties in tributaries

Over the course of our study period, detection efficiencies in tributaries varied wildly as arrays were installed and decommissioned. For example, from 2010 to 2018, the number of tag detection arrays in tributaries almost tripled (Morrisett 2018). In some years of our study, the tributaries in our model had no active antennas at all (Richins 2017). However, our current model configuration does not explicitly account for detection efficiency in any state transition. The consequences of this are that movement probabilities into tributaries will be biased low, whereas loss probabilities both from the mainstem state that is connected to the tributary and any mainstem states that are overshoot states will be biased high, as missed detections in tributaries will be interpreted as loss from the state in which an individual was last detected. As a result, post-overshoot fallback to natal tributaries is also biased low, as this type of fallback is not able to be captured well due to low detection efficiencies in tributaries.

In future iterations of the model, detection probabilities in tributaries, as well as when tributaries had active arrays, will be explicitly modeled. When tributaries had multiple active arrays, detection probabilities will be calculated for the array furthest downstream (closest to the confluence with the mainstem) by examining what percentage of fish that were eventually seen at upstream arrays were also seen at the furthest downstream array. The model will account for years in which tributaries had no active arrays by removing those states from the model for movements occurring in that year.

### Detection probabilities in downstream passage routes

Steelhead fallback is difficult to monitor using PIT tags because of the lack of detection capabilities in the primary downstream passage routes for Steelhead, which include spillways, the Juvenile Bypass System (JBS), navigation locks, ice/trash sluiceways, and turbines. While some passage routes, such as the JBS, the corner collector at Bonneville Dam, and as of 2020, the spillway at Lower Granite Dam, have PIT tag detection capability, the majority of downstream movements are only detected by examining the rest of the detection history. For example, Boggs *et al.* (2004) used consecutive detections in the same adult fish ladder to monitor rates of fallback, whereas Richins and Skalski (2018) calculated fallback to home following overshoot as detections in tributaries following detections in the adult fish ladder at a dam upstream of the tributary. Our modeling framework includes both of these ways of detecting fallback, but this is still an underestimate of total fallback. Fallback such as fallback that leads to mortality cannot be detected using PIT tags, and any time a fish is not seen after fallback (i.e., either due to a fish entering a tributary with PIT tag arrays but not being detected, entering a tributary without PIT tag arrays, spawning in the mainstem, or mortality following fallback), the fallback event will not be observed. While accounting for detection probability in tributaries in future iterations of the model should allow us to achieve a better estimate of post-overshoot fallback, the current network of PIT tag arrays is incapable of monitoring all fallback, and as such all estimates of fallback from this model will be lower bound estimates. However, the current modeling framework will give us the closest estimate of fallback possible using PIT tag data.

### Final fates

The final fate of an individual fish is of central concern to the management and conservation of Steelhead. Whether an individual strayed (and to which tributary), reached its natal tributary, or died before spawning (and where) is one of the core questions that we set out to answer with this model. Final fates are not directly estimated directly as parameters in this model, but can be derived from the stepwise movement probabilities presented in Tables 1-6. This can be done either using a simulation-based approach, where a large number of simulated fish (e.g., 1,000,000) enter the model at Bonneville Dam and subsequently move through the states, with movements governed by random draws from the movement probabilities estimated in the model. It can also be calculated analytically by multiplying out the probabilities of each possible sequence of movements. It is of note that the biases for certain movements mentioned in the preceding sections will be perpetuated in any calculation of final fates, and thus some final fates (primarily associated with entering tributaries) would currently be underestimated due to detection probability issues.

### Adding additional covariates

The model structure and the use of the multinomial logit to evaluate movement probabilities allows for the inclusion of both categorical and continuous covariates in the model. The next covariates that we plan to include in future iterations of the model are rear type (hatchery or wild), temperature (mainstem temperatures from dam tailraces), flow, and spill. We are also considering the addition of covariates related to juvenile experiences (barged vs. not barged, acclimated vs. not acclimated hatchery releases). The inclusion of these covariates will further our understanding of what environmental conditions (e.g., temperature or flow conditions) lead to increased probability of Steelhead choosing more dangerous migration pathways to natal tributaries, such as overshooting natal tributaries, and the inclusion of covariates that can be influenced by hydropower managers (e.g., spill or flow) or fishery managers (e.g., hatchery practices or assisted juvenile migration) would help inform how we can help Steelhead return safely to natal tributaries. Given the increased interest in assisting downstream Steelhead passage, such as via spill practices (Ham *et al.* 2021), the inclusion of these covariates would improve our understanding of how to help recover these populations by informing management practices.

# References

# Appendix 1: Individual movement probabilities

## Appendix 1a. Middle Columbia River Steelhead

**Table** : Movement probabilities for Upper Columbia Steelhead, outside of the DPS boundaries.

| from | to | probability |
| --- | --- | --- |
| mainstem, RIS to RRE | mainstem, PRA to RIS | 0.37 (0.3 - 0.45) |
| mainstem, RIS to RRE | mainstem, RRE to WEL | 0.38 (0.31 - 0.46) |
| mainstem, RIS to RRE | Wenatchee River Mouth | 0.084 (0.022 - 0.17) |
| mainstem, RIS to RRE | loss | 0.16 (0.089 - 0.24) |
| mainstem, RRE to WEL | mainstem, RIS to RRE | 0.31 (0.19 - 0.45) |
| mainstem, RRE to WEL | mainstem, upstream of WEL | 0.43 (0.31 - 0.55) |
| mainstem, RRE to WEL | Entiat River Mouth | 0.052 (0.000000012 - 0.28) |
| mainstem, RRE to WEL | loss | 0.21 (0.00025 - 0.37) |
| mainstem, upstream of WEL | mainstem, RRE to WEL | 0.41 (0.24 - 0.58) |
| mainstem, upstream of WEL | Okanogan River Mouth | 0.12 (0.009 - 0.34) |
| mainstem, upstream of WEL | Methow River Mouth | 0.19 (0.054 - 0.37) |
| mainstem, upstream of WEL | Upstream WEL other tributaries | 0.0041 (0.00000000098 - 0.026) |
| mainstem, upstream of WEL | loss | 0.29 (0.11 - 0.46) |
| mainstem, upstream of LGR | mainstem, ICH to LGR | 0.38 (0.36 - 0.4) |
| mainstem, upstream of LGR | Asotin Creek Mouth | 0.014 (0.0051 - 0.027) |
| mainstem, upstream of LGR | Clearwater River | 0.017 (0.012 - 0.025) |
| mainstem, upstream of LGR | Salmon River | 0.0022 (0.00056 - 0.0054) |
| mainstem, upstream of LGR | Grande Ronde River | 0.016 (0.0098 - 0.022) |
| mainstem, upstream of LGR | Imnaha River Mouth | 0.0051 (0.0013 - 0.011) |
| mainstem, upstream of LGR | loss | 0.57 (0.54 - 0.59) |
| Wenatchee River Mouth | mainstem, RIS to RRE | 0.66 (0.19 - 0.98) |
| Wenatchee River Mouth | loss | 0.34 (0.02 - 0.81) |
| Entiat River Mouth | mainstem, RRE to WEL | 0.53 (0.00000031 - 1) |
| Entiat River Mouth | loss | 0.47 (0.00000011 - 1) |
| Okanogan River Mouth | mainstem, upstream of WEL | 0.094 (0.00000000029 - 0.61) |
| Okanogan River Mouth | loss | 0.91 (0.39 - 1) |
| Okanogan River Upstream | mainstem, upstream of WEL | 0.094 (0.00000000029 - 0.61) |
| Okanogan River Upstream | loss | 0.91 (0.39 - 1) |
| Methow River Mouth | mainstem, upstream of WEL | 0.67 (0.25 - 0.98) |
| Methow River Mouth | loss | 0.33 (0.022 - 0.75) |
| Methow River Upstream | mainstem, upstream of WEL | 0.67 (0.25 - 0.98) |
| Methow River Upstream | loss | 0.33 (0.022 - 0.75) |
| Tucannon River Mouth | mainstem, ICH to LGR | 0.1 (0.079 - 0.14) |
| Tucannon River Mouth | loss | 0.9 (0.86 - 0.92) |
| Asotin Creek Mouth | mainstem, upstream of LGR | 0.013 (0.0000000086 - 0.071) |
| Asotin Creek Mouth | loss | 0.99 (0.93 - 1) |
| Asotin Creek Upstream | mainstem, upstream of LGR | 0.013 (0.0000000086 - 0.071) |
| Asotin Creek Upstream | loss | 0.99 (0.93 - 1) |
| Clearwater River | mainstem, upstream of LGR | 0.063 (0.0025 - 0.21) |
| Clearwater River | loss | 0.94 (0.79 - 1) |
| Salmon River | mainstem, upstream of LGR | 0.038 (0.0000000092 - 0.23) |
| Salmon River | loss | 0.96 (0.77 - 1) |
| Grande Ronde River | mainstem, upstream of LGR | 0.0058 (0.00000000062 - 0.039) |
| Grande Ronde River | loss | 0.99 (0.96 - 1) |
| Imnaha River Mouth | mainstem, upstream of LGR | 0.023 (0.000000013 - 0.14) |
| Imnaha River Mouth | loss | 0.98 (0.86 - 1) |

**Table** : Movement probabilities for Upper Columbia Steelhead by natal origin, inside the DPS boundaries.

| origin | from | to | probability |
| --- | --- | --- | --- |
| Deschutes River | mainstem, mouth to BON | mainstem, BON to MCN | 0.92 (0.81 - 0.98) |
| Fifteenmile Creek | mainstem, mouth to BON | mainstem, BON to MCN | 0.99 (0.96 - 1) |
| John Day River | mainstem, mouth to BON | mainstem, BON to MCN | 0.96 (0.92 - 0.99) |
| Umatilla River | mainstem, mouth to BON | mainstem, BON to MCN | 0.95 (0.89 - 0.99) |
| Yakima River | mainstem, mouth to BON | mainstem, BON to MCN | 1 (0.98 - 1) |
| Walla Walla River | mainstem, mouth to BON | mainstem, BON to MCN | 0.97 (0.93 - 0.99) |
| Deschutes River | mainstem, mouth to BON | loss | 0.082 (0.019 - 0.19) |
| Fifteenmile Creek | mainstem, mouth to BON | loss | 0.0065 (0.000000000011 - 0.042) |
| John Day River | mainstem, mouth to BON | loss | 0.036 (0.005 - 0.081) |
| Umatilla River | mainstem, mouth to BON | loss | 0.048 (0.01 - 0.11) |
| Yakima River | mainstem, mouth to BON | loss | 0.0047 (0.000000000037 - 0.022) |
| Walla Walla River | mainstem, mouth to BON | loss | 0.028 (0.0055 - 0.072) |
| Deschutes River | mainstem, BON to MCN | mainstem, mouth to BON | 0.0083 (0.0051 - 0.013) |
| Fifteenmile Creek | mainstem, BON to MCN | mainstem, mouth to BON | 0.0052 (0.0022 - 0.0094) |
| John Day River | mainstem, BON to MCN | mainstem, mouth to BON | 0.007 (0.005 - 0.0088) |
| Umatilla River | mainstem, BON to MCN | mainstem, mouth to BON | 0.0075 (0.0049 - 0.011) |
| Yakima River | mainstem, BON to MCN | mainstem, mouth to BON | 0.0061 (0.0025 - 0.013) |
| Walla Walla River | mainstem, BON to MCN | mainstem, mouth to BON | 0.015 (0.011 - 0.018) |
| Deschutes River | mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.0036 (0.0017 - 0.0059) |
| Fifteenmile Creek | mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.041 (0.032 - 0.052) |
| John Day River | mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.38 (0.37 - 0.4) |
| Umatilla River | mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.31 (0.3 - 0.33) |
| Yakima River | mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.69 (0.65 - 0.72) |
| Walla Walla River | mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.71 (0.69 - 0.73) |
| Deschutes River | mainstem, BON to MCN | Deschutes River Mouth | 0.65 (0.56 - 0.74) |
| Fifteenmile Creek | mainstem, BON to MCN | Deschutes River Mouth | 0.51 (0.43 - 0.58) |
| John Day River | mainstem, BON to MCN | Deschutes River Mouth | 0.17 (0.15 - 0.19) |
| Umatilla River | mainstem, BON to MCN | Deschutes River Mouth | 0.2 (0.17 - 0.22) |
| Yakima River | mainstem, BON to MCN | Deschutes River Mouth | 0.19 (0.15 - 0.23) |
| Walla Walla River | mainstem, BON to MCN | Deschutes River Mouth | 0.13 (0.11 - 0.16) |
| Deschutes River | mainstem, BON to MCN | John Day River Mouth | 0.0017 (0.00018 - 0.0053) |
| Fifteenmile Creek | mainstem, BON to MCN | John Day River Mouth | 0.0091 (0.0015 - 0.023) |
| John Day River | mainstem, BON to MCN | John Day River Mouth | 0.24 (0.22 - 0.27) |
| Umatilla River | mainstem, BON to MCN | John Day River Mouth | 0.000079 (0.0000000000022 - 0.00037) |
| Yakima River | mainstem, BON to MCN | John Day River Mouth | 0.00014 (0.00000000000008 - 0.00056) |
| Walla Walla River | mainstem, BON to MCN | John Day River Mouth | 0.000026 (0.000000000000000000000016 - 0.00021) |
| Deschutes River | mainstem, BON to MCN | Hood River Mouth | 0.0065 (0.0015 - 0.014) |
| Fifteenmile Creek | mainstem, BON to MCN | Hood River Mouth | 0.00027 (0.00000000000014 - 0.0014) |
| John Day River | mainstem, BON to MCN | Hood River Mouth | 0.0018 (0.00028 - 0.0047) |
| Umatilla River | mainstem, BON to MCN | Hood River Mouth | 0.0071 (0.0029 - 0.013) |
| Yakima River | mainstem, BON to MCN | Hood River Mouth | 0.0002 (0.00000000000039 - 0.0014) |
| Walla Walla River | mainstem, BON to MCN | Hood River Mouth | 0.000031 (0.000000000000000000000015 - 0.00014) |
| Deschutes River | mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.00005 (0.000000000000027 - 0.00028) |
| Fifteenmile Creek | mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.23 (0.18 - 0.28) |
| John Day River | mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.000042 (0.000000000000064 - 0.00027) |
| Umatilla River | mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.000023 (0.000000000000016 - 0.00021) |
| Yakima River | mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.000087 (0.000000000000054 - 0.00054) |
| Walla Walla River | mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.000022 (0.00000000000000000000000041 - 0.000068) |
| Deschutes River | mainstem, BON to MCN | Umatilla River Mouth | 0.00013 (0.000000000002 - 0.00072) |
| Fifteenmile Creek | mainstem, BON to MCN | Umatilla River Mouth | 0.0017 (0.000082 - 0.005) |
| John Day River | mainstem, BON to MCN | Umatilla River Mouth | 0.025 (0.021 - 0.031) |
| Umatilla River | mainstem, BON to MCN | Umatilla River Mouth | 0.37 (0.35 - 0.4) |
| Yakima River | mainstem, BON to MCN | Umatilla River Mouth | 0.00018 (0.000000000000067 - 0.0011) |
| Walla Walla River | mainstem, BON to MCN | Umatilla River Mouth | 0.000024 (0.000000000000000000002 - 0.00011) |
| Deschutes River | mainstem, BON to MCN | BON to MCN other tributaries | 0.00055 (0.000048 - 0.0016) |
| Fifteenmile Creek | mainstem, BON to MCN | BON to MCN other tributaries | 0.012 (0.0077 - 0.018) |
| John Day River | mainstem, BON to MCN | BON to MCN other tributaries | 0.001 (0.00041 - 0.0018) |
| Umatilla River | mainstem, BON to MCN | BON to MCN other tributaries | 0.0027 (0.0014 - 0.0045) |
| Yakima River | mainstem, BON to MCN | BON to MCN other tributaries | 0.0012 (0.000093 - 0.0039) |
| Walla Walla River | mainstem, BON to MCN | BON to MCN other tributaries | 0.00028 (0.000016 - 0.00087) |
| Deschutes River | mainstem, BON to MCN | loss | 0.33 (0.24 - 0.41) |
| Fifteenmile Creek | mainstem, BON to MCN | loss | 0.2 (0.16 - 0.24) |
| John Day River | mainstem, BON to MCN | loss | 0.17 (0.16 - 0.18) |
| Umatilla River | mainstem, BON to MCN | loss | 0.1 (0.071 - 0.13) |
| Yakima River | mainstem, BON to MCN | loss | 0.12 (0.097 - 0.14) |
| Walla Walla River | mainstem, BON to MCN | loss | 0.14 (0.13 - 0.15) |
| Deschutes River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.4 (0.18 - 0.69) |
| Fifteenmile Creek | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.48 (0.37 - 0.59) |
| John Day River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.51 (0.5 - 0.53) |
| Umatilla River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.48 (0.45 - 0.5) |
| Yakima River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.0099 (0.0044 - 0.018) |
| Walla Walla River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.045 (0.039 - 0.05) |
| Deschutes River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.0073 (0.0000000000027 - 0.043) |
| Fifteenmile Creek | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.0017 (0.0000000000084 - 0.01) |
| John Day River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.014 (0.01 - 0.018) |
| Umatilla River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.021 (0.014 - 0.03) |
| Yakima River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.14 (0.12 - 0.16) |
| Walla Walla River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.02 (0.017 - 0.024) |
| Deschutes River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.23 (0.053 - 0.47) |
| Fifteenmile Creek | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.12 (0.058 - 0.22) |
| John Day River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.21 (0.2 - 0.23) |
| Umatilla River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.19 (0.17 - 0.21) |
| Yakima River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.035 (0.025 - 0.049) |
| Walla Walla River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.58 (0.56 - 0.59) |
| Deschutes River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.0043 (0.000000000000011 - 0.029) |
| Fifteenmile Creek | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.0016 (0.0000000000047 - 0.0066) |
| John Day River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.0012 (0.00029 - 0.0027) |
| Umatilla River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.0014 (0.000074 - 0.0042) |
| Yakima River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.8 (0.76 - 0.83) |
| Walla Walla River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.00072 (0.00012 - 0.0019) |
| Deschutes River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.13 (0.00000000025 - 0.53) |
| Fifteenmile Creek | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.037 (0.00094 - 0.13) |
| John Day River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0076 (0.0038 - 0.012) |
| Umatilla River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.012 (0.0057 - 0.02) |
| Yakima River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.00016 (0.000000000011 - 0.00083) |
| Walla Walla River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.35 (0.29 - 0.38) |
| Deschutes River | mainstem, MCN to ICH or PRA | loss | 0.23 (0.000012 - 0.56) |
| Fifteenmile Creek | mainstem, MCN to ICH or PRA | loss | 0.36 (0.26 - 0.49) |
| John Day River | mainstem, MCN to ICH or PRA | loss | 0.26 (0.24 - 0.27) |
| Umatilla River | mainstem, MCN to ICH or PRA | loss | 0.3 (0.27 - 0.32) |
| Yakima River | mainstem, MCN to ICH or PRA | loss | 0.02 (0.000029 - 0.052) |
| Walla Walla River | mainstem, MCN to ICH or PRA | loss | 0.011 (0.000000023 - 0.067) |
| Deschutes River | mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.56 (0.0000000043 - 1) |
| Fifteenmile Creek | mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.54 (0.00000012 - 1) |
| John Day River | mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.52 (0.39 - 0.64) |
| Umatilla River | mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.55 (0.38 - 0.73) |
| Yakima River | mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.6 (0.52 - 0.68) |
| Walla Walla River | mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.53 (0.43 - 0.61) |
| Deschutes River | mainstem, PRA to RIS | mainstem, RIS to RRE | 0.35 (0.0000003 - 0.82) |
| Fifteenmile Creek | mainstem, PRA to RIS | mainstem, RIS to RRE | 0.37 (0.000000014 - 0.83) |
| John Day River | mainstem, PRA to RIS | mainstem, RIS to RRE | 0.38 (0.27 - 0.49) |
| Umatilla River | mainstem, PRA to RIS | mainstem, RIS to RRE | 0.35 (0.21 - 0.52) |
| Yakima River | mainstem, PRA to RIS | mainstem, RIS to RRE | 0.31 (0.25 - 0.38) |
| Walla Walla River | mainstem, PRA to RIS | mainstem, RIS to RRE | 0.37 (0.3 - 0.45) |
| Deschutes River | mainstem, PRA to RIS | loss | 0.089 (0.000000075 - 0.24) |
| Fifteenmile Creek | mainstem, PRA to RIS | loss | 0.097 (0.0000000035 - 0.26) |
| John Day River | mainstem, PRA to RIS | loss | 0.1 (0.064 - 0.14) |
| Umatilla River | mainstem, PRA to RIS | loss | 0.093 (0.054 - 0.14) |
| Yakima River | mainstem, PRA to RIS | loss | 0.083 (0.057 - 0.12) |
| Walla Walla River | mainstem, PRA to RIS | loss | 0.099 (0.066 - 0.14) |
| Deschutes River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.2 (0.0077 - 0.59) |
| Fifteenmile Creek | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.29 (0.07 - 0.59) |
| John Day River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.27 (0.23 - 0.31) |
| Umatilla River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.33 (0.27 - 0.38) |
| Yakima River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.56 (0.4 - 0.71) |
| Walla Walla River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.26 (0.24 - 0.27) |
| Deschutes River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.37 (0.19 - 0.47) |
| Fifteenmile Creek | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.33 (0.19 - 0.43) |
| John Day River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.34 (0.32 - 0.36) |
| Umatilla River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.31 (0.28 - 0.34) |
| Yakima River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.2 (0.13 - 0.28) |
| Walla Walla River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.34 (0.33 - 0.36) |
| Deschutes River | mainstem, ICH to LGR | Tucannon River Mouth | 0.14 (0.063 - 0.18) |
| Fifteenmile Creek | mainstem, ICH to LGR | Tucannon River Mouth | 0.12 (0.07 - 0.16) |
| John Day River | mainstem, ICH to LGR | Tucannon River Mouth | 0.12 (0.11 - 0.14) |
| Umatilla River | mainstem, ICH to LGR | Tucannon River Mouth | 0.11 (0.096 - 0.13) |
| Yakima River | mainstem, ICH to LGR | Tucannon River Mouth | 0.074 (0.049 - 0.11) |
| Walla Walla River | mainstem, ICH to LGR | Tucannon River Mouth | 0.13 (0.11 - 0.14) |
| Deschutes River | mainstem, ICH to LGR | loss | 0.29 (0.15 - 0.37) |
| Fifteenmile Creek | mainstem, ICH to LGR | loss | 0.26 (0.15 - 0.34) |
| John Day River | mainstem, ICH to LGR | loss | 0.27 (0.24 - 0.29) |
| Umatilla River | mainstem, ICH to LGR | loss | 0.25 (0.22 - 0.28) |
| Yakima River | mainstem, ICH to LGR | loss | 0.16 (0.1 - 0.22) |
| Walla Walla River | mainstem, ICH to LGR | loss | 0.27 (0.25 - 0.29) |
| Deschutes River | Deschutes River Mouth | mainstem, BON to MCN | 0.00037 (0.00000000013 - 0.0019) |
| Fifteenmile Creek | Deschutes River Mouth | mainstem, BON to MCN | 0.26 (0.18 - 0.36) |
| John Day River | Deschutes River Mouth | mainstem, BON to MCN | 0.64 (0.57 - 0.7) |
| Umatilla River | Deschutes River Mouth | mainstem, BON to MCN | 0.49 (0.43 - 0.57) |
| Yakima River | Deschutes River Mouth | mainstem, BON to MCN | 0.95 (0.88 - 0.99) |
| Walla Walla River | Deschutes River Mouth | mainstem, BON to MCN | 0.81 (0.73 - 0.87) |
| Deschutes River | Deschutes River Mouth | loss | 1 ( 1 - 1) |
| Fifteenmile Creek | Deschutes River Mouth | loss | 0.74 (0.64 - 0.82) |
| John Day River | Deschutes River Mouth | loss | 0.36 (0.3 - 0.43) |
| Umatilla River | Deschutes River Mouth | loss | 0.51 (0.43 - 0.57) |
| Yakima River | Deschutes River Mouth | loss | 0.051 (0.0089 - 0.12) |
| Walla Walla River | Deschutes River Mouth | loss | 0.19 (0.13 - 0.27) |
| Deschutes River | Deschutes River Upstream | mainstem, BON to MCN | 0.00037 (0.00000000013 - 0.0019) |
| Fifteenmile Creek | Deschutes River Upstream | mainstem, BON to MCN | 0.26 (0.18 - 0.36) |
| John Day River | Deschutes River Upstream | mainstem, BON to MCN | 0.64 (0.57 - 0.7) |
| Umatilla River | Deschutes River Upstream | mainstem, BON to MCN | 0.49 (0.43 - 0.57) |
| Yakima River | Deschutes River Upstream | mainstem, BON to MCN | 0.95 (0.88 - 0.99) |
| Walla Walla River | Deschutes River Upstream | mainstem, BON to MCN | 0.81 (0.73 - 0.87) |
| Deschutes River | Deschutes River Upstream | loss | 1 ( 1 - 1) |
| Fifteenmile Creek | Deschutes River Upstream | loss | 0.74 (0.64 - 0.82) |
| John Day River | Deschutes River Upstream | loss | 0.36 (0.3 - 0.43) |
| Umatilla River | Deschutes River Upstream | loss | 0.51 (0.43 - 0.57) |
| Yakima River | Deschutes River Upstream | loss | 0.051 (0.0089 - 0.12) |
| Walla Walla River | Deschutes River Upstream | loss | 0.19 (0.13 - 0.27) |
| Deschutes River | John Day River Mouth | mainstem, BON to MCN | 0.048 (0.00000000000014 - 0.34) |
| Fifteenmile Creek | John Day River Mouth | mainstem, BON to MCN | 0.012 (0.000000000000098 - 0.065) |
| John Day River | John Day River Mouth | mainstem, BON to MCN | 0.0014 (0.000069 - 0.0037) |
| Umatilla River | John Day River Mouth | mainstem, BON to MCN | 0.037 (0.0000000000000071 - 0.17) |
| Yakima River | John Day River Mouth | mainstem, BON to MCN | 0.21 (0.000000000004 - 1) |
| Walla Walla River | John Day River Mouth | mainstem, BON to MCN | 0.46 (0.0000000000000000036 - 1) |
| Deschutes River | John Day River Mouth | loss | 0.95 (0.66 - 1) |
| Fifteenmile Creek | John Day River Mouth | loss | 0.99 (0.94 - 1) |
| John Day River | John Day River Mouth | loss | 1 ( 1 - 1) |
| Umatilla River | John Day River Mouth | loss | 0.96 (0.83 - 1) |
| Yakima River | John Day River Mouth | loss | 0.79 (0.00016 - 1) |
| Walla Walla River | John Day River Mouth | loss | 0.54 (0 - 1) |
| Deschutes River | Hood River Mouth | mainstem, BON to MCN | 0.35 (0.069 - 0.74) |
| Fifteenmile Creek | Hood River Mouth | mainstem, BON to MCN | 0.64 (0.000012 - 1) |
| John Day River | Hood River Mouth | mainstem, BON to MCN | 0.97 (0.78 - 1) |
| Umatilla River | Hood River Mouth | mainstem, BON to MCN | 0.99 (0.96 - 1) |
| Yakima River | Hood River Mouth | mainstem, BON to MCN | 0.66 (0.0000018 - 1) |
| Walla Walla River | Hood River Mouth | mainstem, BON to MCN | 0.53 (0.00000000000000014 - 1) |
| Deschutes River | Hood River Mouth | loss | 0.65 (0.26 - 0.93) |
| Fifteenmile Creek | Hood River Mouth | loss | 0.36 (0.000000000011 - 1) |
| John Day River | Hood River Mouth | loss | 0.033 (0.00000000028 - 0.22) |
| Umatilla River | Hood River Mouth | loss | 0.0085 (0.000000000048 - 0.044) |
| Yakima River | Hood River Mouth | loss | 0.34 (0.0000000000025 - 1) |
| Walla Walla River | Hood River Mouth | loss | 0.47 (0 - 1) |
| Deschutes River | Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.29 (0.000000000000071 - 1) |
| Fifteenmile Creek | Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.00061 (0.00000000000000076 - 0.0025) |
| John Day River | Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.31 (0.00000000000031 - 1) |
| Umatilla River | Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.26 (0.00000000000064 - 1) |
| Yakima River | Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.25 (0.00000000000033 - 1) |
| Walla Walla River | Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.48 (0.00000000000000042 - 1) |
| Deschutes River | Fifteenmile Creek Mouth | loss | 0.71 (0.00000033 - 1) |
| Fifteenmile Creek | Fifteenmile Creek Mouth | loss | 1 ( 1 - 1) |
| John Day River | Fifteenmile Creek Mouth | loss | 0.69 (0.0000026 - 1) |
| Umatilla River | Fifteenmile Creek Mouth | loss | 0.74 (0.0000065 - 1) |
| Yakima River | Fifteenmile Creek Mouth | loss | 0.75 (0.0000031 - 1) |
| Walla Walla River | Fifteenmile Creek Mouth | loss | 0.52 (0.0000000000000012 - 1) |
| Deschutes River | Umatilla River Mouth | mainstem, BON to MCN | 0.34 (0.000000000028 - 1) |
| Fifteenmile Creek | Umatilla River Mouth | mainstem, BON to MCN | 0.045 (0.00000000017 - 0.34) |
| John Day River | Umatilla River Mouth | mainstem, BON to MCN | 0.067 (0.028 - 0.12) |
| Umatilla River | Umatilla River Mouth | mainstem, BON to MCN | 0.0016 (0.000082 - 0.0044) |
| Yakima River | Umatilla River Mouth | mainstem, BON to MCN | 0.35 (0.000000011 - 1) |
| Walla Walla River | Umatilla River Mouth | mainstem, BON to MCN | 0.58 (0.000000000000011 - 1) |
| Deschutes River | Umatilla River Mouth | loss | 0.66 (0.00000019 - 1) |
| Fifteenmile Creek | Umatilla River Mouth | loss | 0.95 (0.66 - 1) |
| John Day River | Umatilla River Mouth | loss | 0.93 (0.88 - 0.97) |
| Umatilla River | Umatilla River Mouth | loss | 1 ( 1 - 1) |
| Yakima River | Umatilla River Mouth | loss | 0.65 (0.0000012 - 1) |
| Walla Walla River | Umatilla River Mouth | loss | 0.42 (0.00000000000000021 - 1) |
| Deschutes River | Umatilla River Upstream | mainstem, BON to MCN | 0.34 (0.000000000028 - 1) |
| Fifteenmile Creek | Umatilla River Upstream | mainstem, BON to MCN | 0.045 (0.00000000017 - 0.34) |
| John Day River | Umatilla River Upstream | mainstem, BON to MCN | 0.067 (0.028 - 0.12) |
| Umatilla River | Umatilla River Upstream | mainstem, BON to MCN | 0.0016 (0.000082 - 0.0044) |
| Yakima River | Umatilla River Upstream | mainstem, BON to MCN | 0.35 (0.000000011 - 1) |
| Walla Walla River | Umatilla River Upstream | mainstem, BON to MCN | 0.58 (0.000000000000011 - 1) |
| Deschutes River | Umatilla River Upstream | loss | 0.66 (0.00000019 - 1) |
| Fifteenmile Creek | Umatilla River Upstream | loss | 0.95 (0.66 - 1) |
| John Day River | Umatilla River Upstream | loss | 0.93 (0.88 - 0.97) |
| Umatilla River | Umatilla River Upstream | loss | 1 ( 1 - 1) |
| Yakima River | Umatilla River Upstream | loss | 0.65 (0.0000012 - 1) |
| Walla Walla River | Umatilla River Upstream | loss | 0.42 (0.00000000000000021 - 1) |
| Deschutes River | Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.24 (0.0000000000038 - 1) |
| Fifteenmile Creek | Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.27 (0.00000000000092 - 1) |
| John Day River | Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.023 (0.00000000000064 - 0.17) |
| Umatilla River | Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.05 (0.00000000000072 - 0.29) |
| Yakima River | Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.0044 (0.00077 - 0.011) |
| Walla Walla River | Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.48 (0.046 - 0.94) |
| Deschutes River | Yakima River Mouth | loss | 0.76 (0.000016 - 1) |
| Fifteenmile Creek | Yakima River Mouth | loss | 0.73 (0.000048 - 1) |
| John Day River | Yakima River Mouth | loss | 0.98 (0.83 - 1) |
| Umatilla River | Yakima River Mouth | loss | 0.95 (0.71 - 1) |
| Yakima River | Yakima River Mouth | loss | 1 (0.99 - 1) |
| Walla Walla River | Yakima River Mouth | loss | 0.52 (0.061 - 0.95) |
| Deschutes River | Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.43 (0.000000017 - 1) |
| Fifteenmile Creek | Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.071 (0.0000000001 - 0.42) |
| John Day River | Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.41 (0.17 - 0.67) |
| Umatilla River | Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.56 (0.26 - 0.82) |
| Yakima River | Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.51 (0.0000000067 - 1) |
| Walla Walla River | Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.011 (0.0061 - 0.019) |
| Deschutes River | Walla Walla River Mouth | loss | 0.57 (0.00000017 - 1) |
| Fifteenmile Creek | Walla Walla River Mouth | loss | 0.93 (0.58 - 1) |
| John Day River | Walla Walla River Mouth | loss | 0.59 (0.33 - 0.83) |
| Umatilla River | Walla Walla River Mouth | loss | 0.44 (0.18 - 0.74) |
| Yakima River | Walla Walla River Mouth | loss | 0.49 (0.0000001 - 1) |
| Walla Walla River | Walla Walla River Mouth | loss | 0.99 (0.98 - 0.99) |
| Deschutes River | BON to MCN other tributaries | mainstem, BON to MCN | 0.07 (0.000000000016 - 0.47) |
| Fifteenmile Creek | BON to MCN other tributaries | mainstem, BON to MCN | 0.14 (0.024 - 0.27) |
| John Day River | BON to MCN other tributaries | mainstem, BON to MCN | 0.18 (0.021 - 0.43) |
| Umatilla River | BON to MCN other tributaries | mainstem, BON to MCN | 0.7 (0.41 - 0.94) |
| Yakima River | BON to MCN other tributaries | mainstem, BON to MCN | 0.071 (0.0000000000037 - 0.51) |
| Walla Walla River | BON to MCN other tributaries | mainstem, BON to MCN | 0.96 (0.67 - 1) |
| Deschutes River | BON to MCN other tributaries | loss | 0.93 (0.53 - 1) |
| Fifteenmile Creek | BON to MCN other tributaries | loss | 0.86 (0.73 - 0.98) |
| John Day River | BON to MCN other tributaries | loss | 0.82 (0.57 - 0.98) |
| Umatilla River | BON to MCN other tributaries | loss | 0.3 (0.06 - 0.59) |
| Yakima River | BON to MCN other tributaries | loss | 0.93 (0.49 - 1) |
| Walla Walla River | BON to MCN other tributaries | loss | 0.039 (0 - 0.33) |
| Deschutes River | Upstream WEL other tributaries | mainstem, upstream of WEL | 0.51 (0.000000026 - 1) |
| Fifteenmile Creek | Upstream WEL other tributaries | mainstem, upstream of WEL | 0.51 (0.000000026 - 1) |
| John Day River | Upstream WEL other tributaries | mainstem, upstream of WEL | 0.51 (0.000000026 - 1) |
| Umatilla River | Upstream WEL other tributaries | mainstem, upstream of WEL | 0.51 (0.000000026 - 1) |
| Yakima River | Upstream WEL other tributaries | mainstem, upstream of WEL | 0.51 (0.000000026 - 1) |
| Walla Walla River | Upstream WEL other tributaries | mainstem, upstream of WEL | 0.51 (0.000000026 - 1) |
| Deschutes River | Upstream WEL other tributaries | loss | 0.49 (0.00000017 - 1) |
| Fifteenmile Creek | Upstream WEL other tributaries | loss | 0.49 (0.00000017 - 1) |
| John Day River | Upstream WEL other tributaries | loss | 0.49 (0.00000017 - 1) |
| Umatilla River | Upstream WEL other tributaries | loss | 0.49 (0.00000017 - 1) |
| Yakima River | Upstream WEL other tributaries | loss | 0.49 (0.00000017 - 1) |
| Walla Walla River | Upstream WEL other tributaries | loss | 0.49 (0.00000017 - 1) |

## Appendix 1b. Upper Columbia River Steelhead

**Table** : Movement probabilities for Upper Columbia Steelhead, outside of the DPS boundaries.

| from | to | probability |
| --- | --- | --- |
| mainstem, mouth to BON | mainstem, BON to MCN | 0.98 (0.96 - 0.99) |
| mainstem, mouth to BON | loss | 0.023 (0.0096 - 0.038) |
| mainstem, BON to MCN | mainstem, mouth to BON | 0.011 (0.0098 - 0.012) |
| mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.7 (0.69 - 0.71) |
| mainstem, BON to MCN | Deschutes River Mouth | 0.082 (0.07 - 0.092) |
| mainstem, BON to MCN | John Day River Mouth | 0.000068 (0.0000000000003 - 0.00046) |
| mainstem, BON to MCN | Hood River Mouth | 0.00044 (0.000047 - 0.001) |
| mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.000027 (0.000000000026 - 0.00018) |
| mainstem, BON to MCN | Umatilla River Mouth | 0.000015 (0.0000000000031 - 0.000085) |
| mainstem, BON to MCN | BON to MCN other tributaries | 0.000012 (0.0000000000068 - 0.000057) |
| mainstem, BON to MCN | loss | 0.2 (0.2 - 0.21) |
| mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.0097 (0.0077 - 0.012) |
| mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.98 (0.98 - 0.98) |
| mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.00062 (0.00025 - 0.0011) |
| mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.0000083 (0.000000000032 - 0.000038) |
| mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.000065 (0.0000000000096 - 0.00022) |
| mainstem, MCN to ICH or PRA | loss | 0.0091 (0.0073 - 0.011) |
| mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.014 (0.011 - 0.018) |
| mainstem, PRA to RIS | mainstem, RIS to RRE | 0.95 (0.95 - 0.96) |
| mainstem, PRA to RIS | loss | 0.034 (0.03 - 0.039) |
| mainstem, RIS to RRE | mainstem, PRA to RIS | 0.011 (0.0088 - 0.013) |
| mainstem, RIS to RRE | mainstem, RRE to WEL | 0.49 (0.47 - 0.51) |
| mainstem, RIS to RRE | Wenatchee River Mouth | 0.4 (0.38 - 0.42) |
| mainstem, RIS to RRE | loss | 0.11 (0.097 - 0.12) |
| mainstem, RRE to WEL | mainstem, RIS to RRE | 0.23 (0.21 - 0.24) |
| mainstem, RRE to WEL | mainstem, upstream of WEL | 0.56 (0.54 - 0.58) |
| mainstem, RRE to WEL | Entiat River Mouth | 0.034 (0.028 - 0.04) |
| mainstem, RRE to WEL | loss | 0.18 (0.17 - 0.19) |
| mainstem, upstream of WEL | mainstem, RRE to WEL | 0.2 (0.18 - 0.21) |
| mainstem, upstream of WEL | Okanogan River Mouth | 0.00063 (0.00000000000033 - 0.0045) |
| mainstem, upstream of WEL | Methow River Mouth | 0.18 (0.16 - 0.2) |
| mainstem, upstream of WEL | Upstream WEL other tributaries | 0.003 (0.0013 - 0.0053) |
| mainstem, upstream of WEL | loss | 0.62 (0.59 - 0.65) |
| mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.083 (0.0019 - 0.27) |
| mainstem, ICH to LGR | mainstem, upstream of LGR | 0.91 (0.7 - 0.99) |
| mainstem, ICH to LGR | Tucannon River Mouth | 0.0036 (0.000000000000075 - 0.018) |
| mainstem, ICH to LGR | loss | 0.006 (0.0000000021 - 0.027) |
| mainstem, upstream of LGR | mainstem, ICH to LGR | 0.34 (0.12 - 0.62) |
| mainstem, upstream of LGR | Asotin Creek Mouth | 0.019 (0.00000000054 - 0.088) |
| mainstem, upstream of LGR | Clearwater River | 0.11 (0.0045 - 0.3) |
| mainstem, upstream of LGR | Salmon River | 0.0093 (0.000000018 - 0.045) |
| mainstem, upstream of LGR | Grande Ronde River | 0.0087 (0.0000000031 - 0.045) |
| mainstem, upstream of LGR | Imnaha River Mouth | 0.0097 (0.00000000025 - 0.057) |
| mainstem, upstream of LGR | loss | 0.51 (0.2 - 0.76) |
| Deschutes River Mouth | mainstem, BON to MCN | 0.87 (0.82 - 0.92) |
| Deschutes River Mouth | loss | 0.13 (0.084 - 0.18) |
| Deschutes River Upstream | mainstem, BON to MCN | 0.87 (0.82 - 0.92) |
| Deschutes River Upstream | loss | 0.13 (0.084 - 0.18) |
| John Day River Mouth | mainstem, BON to MCN | 0.48 (0.000000069 - 1) |
| John Day River Mouth | loss | 0.52 (0.00000017 - 1) |
| Hood River Mouth | mainstem, BON to MCN | 0.96 (0.77 - 1) |
| Hood River Mouth | loss | 0.04 (0.000000026 - 0.23) |
| Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.51 (0.00000041 - 1) |
| Fifteenmile Creek Mouth | loss | 0.49 (0.00000025 - 1) |
| Umatilla River Mouth | mainstem, BON to MCN | 0.45 (0.000000068 - 1) |
| Umatilla River Mouth | loss | 0.55 (0.00000053 - 1) |
| Umatilla River Upstream | mainstem, BON to MCN | 0.45 (0.000000068 - 1) |
| Umatilla River Upstream | loss | 0.55 (0.00000053 - 1) |
| Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.5 (0.00000023 - 1) |
| Yakima River Mouth | loss | 0.5 (0.0000016 - 1) |
| Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.49 (0.0000000052 - 1) |
| Walla Walla River Mouth | loss | 0.51 (0.00000096 - 1) |
| Tucannon River Mouth | mainstem, ICH to LGR | 0.52 (0.00000064 - 1) |
| Tucannon River Mouth | loss | 0.48 (0.000000076 - 1) |
| Asotin Creek Mouth | mainstem, upstream of LGR | 0.52 (0.000000046 - 1) |
| Asotin Creek Mouth | loss | 0.48 (0.0000002 - 1) |
| Asotin Creek Upstream | mainstem, upstream of LGR | 0.52 (0.000000046 - 1) |
| Asotin Creek Upstream | loss | 0.48 (0.0000002 - 1) |
| Clearwater River | mainstem, upstream of LGR | 0.059 (0.000000016 - 0.31) |
| Clearwater River | loss | 0.94 (0.69 - 1) |
| Salmon River | mainstem, upstream of LGR | 0.56 (0.00000032 - 1) |
| Salmon River | loss | 0.44 (0.000003 - 1) |
| Grande Ronde River | mainstem, upstream of LGR | 0.54 (0.0000005 - 1) |
| Grande Ronde River | loss | 0.46 (0.0000018 - 1) |
| Imnaha River Mouth | mainstem, upstream of LGR | 0.49 (0.00000012 - 1) |
| Imnaha River Mouth | loss | 0.51 (0.000000073 - 1) |
| BON to MCN other tributaries | mainstem, BON to MCN | 0.51 (0.00000092 - 1) |
| BON to MCN other tributaries | loss | 0.49 (0.00000043 - 1) |
| Upstream WEL other tributaries | mainstem, upstream of WEL | 0.0096 (0.000000000000033 - 0.048) |
| Upstream WEL other tributaries | loss | 0.99 (0.95 - 1) |

**Table** : Movement probabilities for Upper Columbia Steelhead by natal origin, inside the DPS boundaries.

| origin | from | to | probability |
| --- | --- | --- | --- |
| Wenatchee River | Wenatchee River Mouth | mainstem, RIS to RRE | 0.049 (0.034 - 0.066) |
| Entiat River | Wenatchee River Mouth | mainstem, RIS to RRE | 0.98 (0.9 - 1) |
| Okanogan River | Wenatchee River Mouth | mainstem, RIS to RRE | 0.97 (0.86 - 1) |
| Methow River | Wenatchee River Mouth | mainstem, RIS to RRE | 0.91 (0.78 - 0.99) |
| Wenatchee River | Wenatchee River Mouth | loss | 0.95 (0.93 - 0.97) |
| Entiat River | Wenatchee River Mouth | loss | 0.02 (0.000000000013 - 0.1) |
| Okanogan River | Wenatchee River Mouth | loss | 0.028 (0.0000000000013 - 0.14) |
| Methow River | Wenatchee River Mouth | loss | 0.094 (0.0052 - 0.22) |
| Wenatchee River | Entiat River Mouth | mainstem, RRE to WEL | 0.13 (0.071 - 0.19) |
| Entiat River | Entiat River Mouth | mainstem, RRE to WEL | 0.03 (0.017 - 0.045) |
| Okanogan River | Entiat River Mouth | mainstem, RRE to WEL | 0.38 (0.000000002 - 1) |
| Methow River | Entiat River Mouth | mainstem, RRE to WEL | 0.45 (0.00000000000043 - 1) |
| Wenatchee River | Entiat River Mouth | loss | 0.87 (0.81 - 0.93) |
| Entiat River | Entiat River Mouth | loss | 0.97 (0.95 - 0.98) |
| Okanogan River | Entiat River Mouth | loss | 0.62 (0.0000000038 - 1) |
| Methow River | Entiat River Mouth | loss | 0.55 (0.0000000000000033 - 1) |
| Wenatchee River | Okanogan River Mouth | mainstem, upstream of WEL | 0.042 (0.00000000068 - 0.28) |
| Entiat River | Okanogan River Mouth | mainstem, upstream of WEL | 0.92 (0.47 - 1) |
| Okanogan River | Okanogan River Mouth | mainstem, upstream of WEL | 0.0049 (0.00081 - 0.011) |
| Methow River | Okanogan River Mouth | mainstem, upstream of WEL | 0.00043 (0.000000000000000018 - 0.0025) |
| Wenatchee River | Okanogan River Mouth | loss | 0.96 (0.72 - 1) |
| Entiat River | Okanogan River Mouth | loss | 0.083 (0.00000000016 - 0.53) |
| Okanogan River | Okanogan River Mouth | loss | 1 (0.99 - 1) |
| Methow River | Okanogan River Mouth | loss | 1 ( 1 - 1) |
| Wenatchee River | Okanogan River Upstream | mainstem, upstream of WEL | 0.042 (0.00000000068 - 0.28) |
| Entiat River | Okanogan River Upstream | mainstem, upstream of WEL | 0.92 (0.47 - 1) |
| Okanogan River | Okanogan River Upstream | mainstem, upstream of WEL | 0.0049 (0.00081 - 0.011) |
| Methow River | Okanogan River Upstream | mainstem, upstream of WEL | 0.00043 (0.000000000000000018 - 0.0025) |
| Wenatchee River | Okanogan River Upstream | loss | 0.96 (0.72 - 1) |
| Entiat River | Okanogan River Upstream | loss | 0.083 (0.00000000016 - 0.53) |
| Okanogan River | Okanogan River Upstream | loss | 1 (0.99 - 1) |
| Methow River | Okanogan River Upstream | loss | 1 ( 1 - 1) |
| Wenatchee River | Methow River Mouth | mainstem, upstream of WEL | 0.13 (0.095 - 0.17) |
| Entiat River | Methow River Mouth | mainstem, upstream of WEL | 0.7 (0.58 - 0.82) |
| Okanogan River | Methow River Mouth | mainstem, upstream of WEL | 0.02 (0.00094 - 0.059) |
| Methow River | Methow River Mouth | mainstem, upstream of WEL | 0.0076 (0.0038 - 0.012) |
| Wenatchee River | Methow River Mouth | loss | 0.87 (0.83 - 0.91) |
| Entiat River | Methow River Mouth | loss | 0.3 (0.18 - 0.42) |
| Okanogan River | Methow River Mouth | loss | 0.98 (0.94 - 1) |
| Methow River | Methow River Mouth | loss | 0.99 (0.99 - 1) |
| Wenatchee River | Methow River Upstream | mainstem, upstream of WEL | 0.13 (0.095 - 0.17) |
| Entiat River | Methow River Upstream | mainstem, upstream of WEL | 0.7 (0.58 - 0.82) |
| Okanogan River | Methow River Upstream | mainstem, upstream of WEL | 0.02 (0.00094 - 0.059) |
| Methow River | Methow River Upstream | mainstem, upstream of WEL | 0.0076 (0.0038 - 0.012) |
| Wenatchee River | Methow River Upstream | loss | 0.87 (0.83 - 0.91) |
| Entiat River | Methow River Upstream | loss | 0.3 (0.18 - 0.42) |
| Okanogan River | Methow River Upstream | loss | 0.98 (0.94 - 1) |
| Methow River | Methow River Upstream | loss | 0.99 (0.99 - 1) |

## Appendix 1c. Snake River Basin Steelhead

**Table** : Movement probabilities for Upper Columbia Steelhead, outside of the DPS boundaries.

| from | to | probability |
| --- | --- | --- |
| mainstem, mouth to BON | mainstem, BON to MCN | 0.98 (0.97 - 0.99) |
| mainstem, mouth to BON | loss | 0.02 (0.014 - 0.027) |
| mainstem, BON to MCN | mainstem, mouth to BON | 0.019 (0.018 - 0.02) |
| mainstem, BON to MCN | mainstem, MCN to ICH or PRA | 0.69 (0.69 - 0.7) |
| mainstem, BON to MCN | Deschutes River Mouth | 0.12 (0.11 - 0.13) |
| mainstem, BON to MCN | John Day River Mouth | 0.0037 (0.0028 - 0.005) |
| mainstem, BON to MCN | Hood River Mouth | 0.0018 (0.0011 - 0.0027) |
| mainstem, BON to MCN | Fifteenmile Creek Mouth | 0.00018 (0.00006 - 0.00035) |
| mainstem, BON to MCN | Umatilla River Mouth | 0.0014 (0.001 - 0.0018) |
| mainstem, BON to MCN | BON to MCN other tributaries | 0.001 (0.00079 - 0.0014) |
| mainstem, BON to MCN | loss | 0.16 (0.16 - 0.17) |
| mainstem, PRA to RIS | mainstem, MCN to ICH or PRA | 0.47 (0.44 - 0.5) |
| mainstem, PRA to RIS | mainstem, RIS to RRE | 0.47 (0.44 - 0.5) |
| mainstem, PRA to RIS | loss | 0.057 (0.044 - 0.074) |
| mainstem, RIS to RRE | mainstem, PRA to RIS | 0.38 (0.34 - 0.42) |
| mainstem, RIS to RRE | mainstem, RRE to WEL | 0.57 (0.53 - 0.6) |
| mainstem, RIS to RRE | Wenatchee River Mouth | 0.014 (0.0024 - 0.034) |
| mainstem, RIS to RRE | loss | 0.042 (0.025 - 0.064) |
| mainstem, RRE to WEL | mainstem, RIS to RRE | 0.26 (0.22 - 0.3) |
| mainstem, RRE to WEL | mainstem, upstream of WEL | 0.63 (0.59 - 0.67) |
| mainstem, RRE to WEL | Entiat River Mouth | 0.037 (0.005 - 0.11) |
| mainstem, RRE to WEL | loss | 0.074 (0.000056 - 0.12) |
| mainstem, upstream of WEL | mainstem, RRE to WEL | 0.29 (0.24 - 0.35) |
| mainstem, upstream of WEL | Okanogan River Mouth | 0.18 (0.11 - 0.25) |
| mainstem, upstream of WEL | Methow River Mouth | 0.14 (0.097 - 0.19) |
| mainstem, upstream of WEL | Upstream WEL other tributaries | 0.0063 (0.00045 - 0.018) |
| mainstem, upstream of WEL | loss | 0.38 (0.31 - 0.47) |
| Deschutes River Mouth | mainstem, BON to MCN | 0.8 (0.78 - 0.82) |
| Deschutes River Mouth | loss | 0.2 (0.18 - 0.22) |
| Deschutes River Upstream | mainstem, BON to MCN | 0.8 (0.78 - 0.82) |
| Deschutes River Upstream | loss | 0.2 (0.18 - 0.22) |
| John Day River Mouth | mainstem, BON to MCN | 0.29 (0.22 - 0.36) |
| John Day River Mouth | loss | 0.71 (0.64 - 0.78) |
| Hood River Mouth | mainstem, BON to MCN | 0.73 (0.58 - 0.86) |
| Hood River Mouth | loss | 0.27 (0.14 - 0.42) |
| Fifteenmile Creek Mouth | mainstem, BON to MCN | 0.026 (0.0000000001 - 0.16) |
| Fifteenmile Creek Mouth | loss | 0.97 (0.84 - 1) |
| Umatilla River Mouth | mainstem, BON to MCN | 0.14 (0.059 - 0.24) |
| Umatilla River Mouth | loss | 0.86 (0.76 - 0.94) |
| Umatilla River Upstream | mainstem, BON to MCN | 0.14 (0.059 - 0.24) |
| Umatilla River Upstream | loss | 0.86 (0.76 - 0.94) |
| Yakima River Mouth | mainstem, MCN to ICH or PRA | 0.35 (0.15 - 0.59) |
| Yakima River Mouth | loss | 0.65 (0.41 - 0.85) |
| Walla Walla River Mouth | mainstem, MCN to ICH or PRA | 0.24 (0.14 - 0.38) |
| Walla Walla River Mouth | loss | 0.76 (0.62 - 0.86) |
| Wenatchee River Mouth | mainstem, RIS to RRE | 0.49 (0.078 - 0.93) |
| Wenatchee River Mouth | loss | 0.51 (0.073 - 0.92) |
| Entiat River Mouth | mainstem, RRE to WEL | 0.03 (0.0000000055 - 0.22) |
| Entiat River Mouth | loss | 0.97 (0.78 - 1) |
| Okanogan River Mouth | mainstem, upstream of WEL | 0.14 (0.03 - 0.31) |
| Okanogan River Mouth | loss | 0.86 (0.69 - 0.97) |
| Okanogan River Upstream | mainstem, upstream of WEL | 0.14 (0.03 - 0.31) |
| Okanogan River Upstream | loss | 0.86 (0.69 - 0.97) |
| Methow River Mouth | mainstem, upstream of WEL | 0.25 (0.1 - 0.43) |
| Methow River Mouth | loss | 0.75 (0.57 - 0.9) |
| Methow River Upstream | mainstem, upstream of WEL | 0.25 (0.1 - 0.43) |
| Methow River Upstream | loss | 0.75 (0.57 - 0.9) |
| BON to MCN other tributaries | mainstem, BON to MCN | 0.24 (0.15 - 0.34) |
| BON to MCN other tributaries | loss | 0.76 (0.66 - 0.85) |
| Upstream WEL other tributaries | mainstem, upstream of WEL | 0.06 (0.00000001 - 0.42) |
| Upstream WEL other tributaries | loss | 0.94 (0.58 - 1) |

**Table** : Movement probabilities for Upper Columbia Steelhead by natal origin, inside the DPS boundaries.

| origin | from | to | probability |
| --- | --- | --- | --- |
| Tucannon River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.073 (0.067 - 0.079) |
| Asotin Creek | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.059 (0.047 - 0.071) |
| Clearwater River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.031 (0.028 - 0.034) |
| Salmon River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.048 (0.045 - 0.051) |
| Grande Ronde | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.029 (0.027 - 0.032) |
| Imnaha River | mainstem, MCN to ICH or PRA | mainstem, BON to MCN | 0.046 (0.042 - 0.049) |
| Tucannon River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.028 (0.025 - 0.031) |
| Asotin Creek | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.022 (0.018 - 0.027) |
| Clearwater River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.012 (0.011 - 0.013) |
| Salmon River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.018 (0.017 - 0.02) |
| Grande Ronde | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.011 (0.0097 - 0.012) |
| Imnaha River | mainstem, MCN to ICH or PRA | mainstem, PRA to RIS | 0.017 (0.016 - 0.019) |
| Tucannon River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.85 (0.84 - 0.87) |
| Asotin Creek | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.88 (0.86 - 0.91) |
| Clearwater River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.94 (0.93 - 0.94) |
| Salmon River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.91 (0.9 - 0.91) |
| Grande Ronde | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.94 (0.94 - 0.95) |
| Imnaha River | mainstem, MCN to ICH or PRA | mainstem, ICH to LGR | 0.91 (0.9 - 0.92) |
| Tucannon River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.0009 (0.00055 - 0.0013) |
| Asotin Creek | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.00073 (0.00044 - 0.0011) |
| Clearwater River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.00038 (0.00024 - 0.00054) |
| Salmon River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.00059 (0.00037 - 0.00083) |
| Grande Ronde | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.00036 (0.00023 - 0.0005) |
| Imnaha River | mainstem, MCN to ICH or PRA | Yakima River Mouth | 0.00056 (0.00036 - 0.00079) |
| Tucannon River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0055 (0.0022 - 0.016) |
| Asotin Creek | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0044 (0.0017 - 0.015) |
| Clearwater River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0023 (0.00094 - 0.0072) |
| Salmon River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0036 (0.0014 - 0.011) |
| Grande Ronde | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0022 (0.00086 - 0.007) |
| Imnaha River | mainstem, MCN to ICH or PRA | Walla Walla River Mouth | 0.0034 (0.0014 - 0.011) |
| Tucannon River | mainstem, MCN to ICH or PRA | loss | 0.038 (0.026 - 0.043) |
| Asotin Creek | mainstem, MCN to ICH or PRA | loss | 0.03 (0.021 - 0.038) |
| Clearwater River | mainstem, MCN to ICH or PRA | loss | 0.016 (0.011 - 0.019) |
| Salmon River | mainstem, MCN to ICH or PRA | loss | 0.025 (0.017 - 0.028) |
| Grande Ronde | mainstem, MCN to ICH or PRA | loss | 0.015 (0.01 - 0.018) |
| Imnaha River | mainstem, MCN to ICH or PRA | loss | 0.023 (0.016 - 0.027) |
| Tucannon River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.029 (0.025 - 0.034) |
| Asotin Creek | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.034 (0.02 - 0.05) |
| Clearwater River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.01 (0.0079 - 0.012) |
| Salmon River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.021 (0.019 - 0.024) |
| Grande Ronde | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.019 (0.016 - 0.022) |
| Imnaha River | mainstem, ICH to LGR | mainstem, MCN to ICH or PRA | 0.038 (0.033 - 0.043) |
| Tucannon River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.52 (0.5 - 0.54) |
| Asotin Creek | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.91 (0.88 - 0.93) |
| Clearwater River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.95 (0.95 - 0.96) |
| Salmon River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.94 (0.93 - 0.94) |
| Grande Ronde | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.94 (0.93 - 0.94) |
| Imnaha River | mainstem, ICH to LGR | mainstem, upstream of LGR | 0.91 (0.9 - 0.92) |
| Tucannon River | mainstem, ICH to LGR | Tucannon River Mouth | 0.36 (0.33 - 0.38) |
| Asotin Creek | mainstem, ICH to LGR | Tucannon River Mouth | 0.017 (0.0079 - 0.03) |
| Clearwater River | mainstem, ICH to LGR | Tucannon River Mouth | 0.0022 (0.001 - 0.0037) |
| Salmon River | mainstem, ICH to LGR | Tucannon River Mouth | 0.0028 (0.0016 - 0.0042) |
| Grande Ronde | mainstem, ICH to LGR | Tucannon River Mouth | 0.0029 (0.0014 - 0.0048) |
| Imnaha River | mainstem, ICH to LGR | Tucannon River Mouth | 0.0015 (0.00044 - 0.0033) |
| Tucannon River | mainstem, ICH to LGR | loss | 0.092 (0.082 - 0.1) |
| Asotin Creek | mainstem, ICH to LGR | loss | 0.043 (0.029 - 0.061) |
| Clearwater River | mainstem, ICH to LGR | loss | 0.034 (0.029 - 0.038) |
| Salmon River | mainstem, ICH to LGR | loss | 0.037 (0.034 - 0.04) |
| Grande Ronde | mainstem, ICH to LGR | loss | 0.042 (0.037 - 0.047) |
| Imnaha River | mainstem, ICH to LGR | loss | 0.048 (0.043 - 0.055) |
| Tucannon River | mainstem, upstream of LGR | mainstem, ICH to LGR | 0.4 (0.38 - 0.42) |
| Asotin Creek | mainstem, upstream of LGR | mainstem, ICH to LGR | 0.033 (0.022 - 0.049) |
| Clearwater River | mainstem, upstream of LGR | mainstem, ICH to LGR | 0.018 (0.015 - 0.022) |
| Salmon River | mainstem, upstream of LGR | mainstem, ICH to LGR | 0.02 (0.018 - 0.023) |
| Grande Ronde | mainstem, upstream of LGR | mainstem, ICH to LGR | 0.019 (0.016 - 0.022) |
| Imnaha River | mainstem, upstream of LGR | mainstem, ICH to LGR | 0.019 (0.016 - 0.022) |
| Tucannon River | mainstem, upstream of LGR | Asotin Creek Mouth | 0.06 (0.044 - 0.079) |
| Asotin Creek | mainstem, upstream of LGR | Asotin Creek Mouth | 0.82 (0.75 - 0.88) |
| Clearwater River | mainstem, upstream of LGR | Asotin Creek Mouth | 0.000045 (0.00000000000047 - 0.00021) |
| Salmon River | mainstem, upstream of LGR | Asotin Creek Mouth | 0.000026 (0.000000000055 - 0.00012) |
| Grande Ronde | mainstem, upstream of LGR | Asotin Creek Mouth | 0.0048 (0.0028 - 0.0072) |
| Imnaha River | mainstem, upstream of LGR | Asotin Creek Mouth | 0.000028 (0.0000000000000000000009 - 0.0001) |
| Tucannon River | mainstem, upstream of LGR | Clearwater River | 0.023 (0.018 - 0.029) |
| Asotin Creek | mainstem, upstream of LGR | Clearwater River | 0.00012 (0.00000000000011 - 0.00046) |
| Clearwater River | mainstem, upstream of LGR | Clearwater River | 0.3 (0.29 - 0.32) |
| Salmon River | mainstem, upstream of LGR | Clearwater River | 0.0000099 (0.00000000000013 - 0.000056) |
| Grande Ronde | mainstem, upstream of LGR | Clearwater River | 0.000015 (0.0000000000000035 - 0.000083) |
| Imnaha River | mainstem, upstream of LGR | Clearwater River | 0.0000044 (0.000000000000000000000027 - 0.000016) |
| Tucannon River | mainstem, upstream of LGR | Salmon River | 0.0015 (0.0004 - 0.0031) |
| Asotin Creek | mainstem, upstream of LGR | Salmon River | 0.000078 (0.0000000000002 - 0.0004) |
| Clearwater River | mainstem, upstream of LGR | Salmon River | 0.000013 (0.000000000000043 - 0.000073) |
| Salmon River | mainstem, upstream of LGR | Salmon River | 0.28 (0.27 - 0.29) |
| Grande Ronde | mainstem, upstream of LGR | Salmon River | 0.000019 (0.00000000000042 - 0.00011) |
| Imnaha River | mainstem, upstream of LGR | Salmon River | 0.000007 (0.0000000000000000000006 - 0.000053) |
| Tucannon River | mainstem, upstream of LGR | Grande Ronde River | 0.0063 (0.0039 - 0.0092) |
| Asotin Creek | mainstem, upstream of LGR | Grande Ronde River | 0.014 (0.0065 - 0.023) |
| Clearwater River | mainstem, upstream of LGR | Grande Ronde River | 0.000014 (0.00000000000077 - 0.000084) |
| Salmon River | mainstem, upstream of LGR | Grande Ronde River | 0.0000082 (0.0000000000021 - 0.000037) |
| Grande Ronde | mainstem, upstream of LGR | Grande Ronde River | 0.084 (0.078 - 0.092) |
| Imnaha River | mainstem, upstream of LGR | Grande Ronde River | 0.0000081 (0.0000000000000000000063 - 0.000039) |
| Tucannon River | mainstem, upstream of LGR | Imnaha River Mouth | 0.0033 (0.00095 - 0.0066) |
| Asotin Creek | mainstem, upstream of LGR | Imnaha River Mouth | 0.00012 (0.00000000000074 - 0.00045) |
| Clearwater River | mainstem, upstream of LGR | Imnaha River Mouth | 0.000018 (0.00000000000032 - 0.000094) |
| Salmon River | mainstem, upstream of LGR | Imnaha River Mouth | 0.00019 (0.000011 - 0.00053) |
| Grande Ronde | mainstem, upstream of LGR | Imnaha River Mouth | 0.00086 (0.00025 - 0.0017) |
| Imnaha River | mainstem, upstream of LGR | Imnaha River Mouth | 0.61 (0.59 - 0.63) |
| Tucannon River | mainstem, upstream of LGR | loss | 0.51 (0.49 - 0.52) |
| Asotin Creek | mainstem, upstream of LGR | loss | 0.13 (0.083 - 0.19) |
| Clearwater River | mainstem, upstream of LGR | loss | 0.68 (0.67 - 0.69) |
| Salmon River | mainstem, upstream of LGR | loss | 0.7 (0.69 - 0.71) |
| Grande Ronde | mainstem, upstream of LGR | loss | 0.89 (0.88 - 0.9) |
| Imnaha River | mainstem, upstream of LGR | loss | 0.37 (0.36 - 0.39) |
| Tucannon River | Tucannon River Mouth | mainstem, ICH to LGR | 0.028 (0.02 - 0.036) |
| Asotin Creek | Tucannon River Mouth | mainstem, ICH to LGR | 0.25 (0.06 - 0.54) |
| Clearwater River | Tucannon River Mouth | mainstem, ICH to LGR | 0.13 (0.011 - 0.39) |
| Salmon River | Tucannon River Mouth | mainstem, ICH to LGR | 0.35 (0.17 - 0.52) |
| Grande Ronde | Tucannon River Mouth | mainstem, ICH to LGR | 0.17 (0.029 - 0.38) |
| Imnaha River | Tucannon River Mouth | mainstem, ICH to LGR | 0.48 (0.19 - 0.74) |
| Tucannon River | Tucannon River Mouth | loss | 0.97 (0.96 - 0.98) |
| Asotin Creek | Tucannon River Mouth | loss | 0.75 (0.46 - 0.94) |
| Clearwater River | Tucannon River Mouth | loss | 0.87 (0.61 - 0.99) |
| Salmon River | Tucannon River Mouth | loss | 0.65 (0.48 - 0.83) |
| Grande Ronde | Tucannon River Mouth | loss | 0.83 (0.62 - 0.97) |
| Imnaha River | Tucannon River Mouth | loss | 0.52 (0.26 - 0.81) |
| Tucannon River | Asotin Creek Mouth | mainstem, upstream of LGR | 0.083 (0.032 - 0.16) |
| Asotin Creek | Asotin Creek Mouth | mainstem, upstream of LGR | 0.0045 (0.00025 - 0.015) |
| Clearwater River | Asotin Creek Mouth | mainstem, upstream of LGR | 0.33 (0.00000000005 - 1) |
| Salmon River | Asotin Creek Mouth | mainstem, upstream of LGR | 0.3 (0.0000000003 - 1) |
| Grande Ronde | Asotin Creek Mouth | mainstem, upstream of LGR | 0.006 (0.000000000013 - 0.025) |
| Imnaha River | Asotin Creek Mouth | mainstem, upstream of LGR | 0.52 (0.00000000000000018 - 1) |
| Tucannon River | Asotin Creek Mouth | loss | 0.92 (0.84 - 0.97) |
| Asotin Creek | Asotin Creek Mouth | loss | 1 (0.99 - 1) |
| Clearwater River | Asotin Creek Mouth | loss | 0.67 (0.0000024 - 1) |
| Salmon River | Asotin Creek Mouth | loss | 0.7 (0.0000023 - 1) |
| Grande Ronde | Asotin Creek Mouth | loss | 0.99 (0.98 - 1) |
| Imnaha River | Asotin Creek Mouth | loss | 0.48 (0.00000000000000075 - 1) |
| Tucannon River | Asotin Creek Upstream | mainstem, upstream of LGR | 0.083 (0.032 - 0.16) |
| Asotin Creek | Asotin Creek Upstream | mainstem, upstream of LGR | 0.0045 (0.00025 - 0.015) |
| Clearwater River | Asotin Creek Upstream | mainstem, upstream of LGR | 0.33 (0.00000000005 - 1) |
| Salmon River | Asotin Creek Upstream | mainstem, upstream of LGR | 0.3 (0.0000000003 - 1) |
| Grande Ronde | Asotin Creek Upstream | mainstem, upstream of LGR | 0.006 (0.000000000013 - 0.025) |
| Imnaha River | Asotin Creek Upstream | mainstem, upstream of LGR | 0.52 (0.00000000000000018 - 1) |
| Tucannon River | Asotin Creek Upstream | loss | 0.92 (0.84 - 0.97) |
| Asotin Creek | Asotin Creek Upstream | loss | 1 (0.99 - 1) |
| Clearwater River | Asotin Creek Upstream | loss | 0.67 (0.0000024 - 1) |
| Salmon River | Asotin Creek Upstream | loss | 0.7 (0.0000023 - 1) |
| Grande Ronde | Asotin Creek Upstream | loss | 0.99 (0.98 - 1) |
| Imnaha River | Asotin Creek Upstream | loss | 0.48 (0.00000000000000075 - 1) |
| Tucannon River | Clearwater River | mainstem, upstream of LGR | 0.002 (0.00000000000032 - 0.01) |
| Asotin Creek | Clearwater River | mainstem, upstream of LGR | 0.26 (0.000000000015 - 1) |
| Clearwater River | Clearwater River | mainstem, upstream of LGR | 0.0032 (0.0014 - 0.0059) |
| Salmon River | Clearwater River | mainstem, upstream of LGR | 0.35 (0.0000000000018 - 1) |
| Grande Ronde | Clearwater River | mainstem, upstream of LGR | 0.26 (0.0000000000083 - 1) |
| Imnaha River | Clearwater River | mainstem, upstream of LGR | 0.48 (0.00000000000000068 - 1) |
| Tucannon River | Clearwater River | loss | 1 (0.99 - 1) |
| Asotin Creek | Clearwater River | loss | 0.74 (0.00021 - 1) |
| Clearwater River | Clearwater River | loss | 1 (0.99 - 1) |
| Salmon River | Clearwater River | loss | 0.65 (0.0000028 - 1) |
| Grande Ronde | Clearwater River | loss | 0.74 (0.000016 - 1) |
| Imnaha River | Clearwater River | loss | 0.52 (0.0000000000000023 - 1) |
| Tucannon River | Salmon River | mainstem, upstream of LGR | 0.017 (0.000000000002 - 0.11) |
| Asotin Creek | Salmon River | mainstem, upstream of LGR | 0.33 (0.000000000013 - 1) |
| Clearwater River | Salmon River | mainstem, upstream of LGR | 0.28 (0.0000000000029 - 1) |
| Salmon River | Salmon River | mainstem, upstream of LGR | 0.0012 (0.00031 - 0.0024) |
| Grande Ronde | Salmon River | mainstem, upstream of LGR | 0.3 (0.000000000025 - 1) |
| Imnaha River | Salmon River | mainstem, upstream of LGR | 0.49 (0.0000000000000000079 - 1) |
| Tucannon River | Salmon River | loss | 0.98 (0.89 - 1) |
| Asotin Creek | Salmon River | loss | 0.67 (0.0000011 - 1) |
| Clearwater River | Salmon River | loss | 0.72 (0.000009 - 1) |
| Salmon River | Salmon River | loss | 1 ( 1 - 1) |
| Grande Ronde | Salmon River | loss | 0.7 (0.0000091 - 1) |
| Imnaha River | Salmon River | loss | 0.51 (0 - 1) |
| Tucannon River | Grande Ronde River | mainstem, upstream of LGR | 0.002 (0.000000000000018 - 0.0098) |
| Asotin Creek | Grande Ronde River | mainstem, upstream of LGR | 0.0023 (0.000000000000013 - 0.0089) |
| Clearwater River | Grande Ronde River | mainstem, upstream of LGR | 0.21 (0.00000000000000017 - 1) |
| Salmon River | Grande Ronde River | mainstem, upstream of LGR | 0.18 (0.0000000000011 - 1) |
| Grande Ronde | Grande Ronde River | mainstem, upstream of LGR | 0.00017 (0.0000000000000095 - 0.00089) |
| Imnaha River | Grande Ronde River | mainstem, upstream of LGR | 0.45 (0.000000000000000000021 - 1) |
| Tucannon River | Grande Ronde River | loss | 1 (0.99 - 1) |
| Asotin Creek | Grande Ronde River | loss | 1 (0.99 - 1) |
| Clearwater River | Grande Ronde River | loss | 0.79 (0.000013 - 1) |
| Salmon River | Grande Ronde River | loss | 0.82 (0.0016 - 1) |
| Grande Ronde | Grande Ronde River | loss | 1 ( 1 - 1) |
| Imnaha River | Grande Ronde River | loss | 0.55 (0 - 1) |
| Tucannon River | Imnaha River Mouth | mainstem, upstream of LGR | 0.019 (0.000000000044 - 0.089) |
| Asotin Creek | Imnaha River Mouth | mainstem, upstream of LGR | 0.38 (0.0000000038 - 1) |
| Clearwater River | Imnaha River Mouth | mainstem, upstream of LGR | 0.38 (0.00000000071 - 1) |
| Salmon River | Imnaha River Mouth | mainstem, upstream of LGR | 0.88 (0.33 - 1) |
| Grande Ronde | Imnaha River Mouth | mainstem, upstream of LGR | 0.017 (0.0000000000062 - 0.085) |
| Imnaha River | Imnaha River Mouth | mainstem, upstream of LGR | 0.00064 (0.000046 - 0.0018) |
| Tucannon River | Imnaha River Mouth | loss | 0.98 (0.91 - 1) |
| Asotin Creek | Imnaha River Mouth | loss | 0.62 (0.00000034 - 1) |
| Clearwater River | Imnaha River Mouth | loss | 0.62 (0.00000013 - 1) |
| Salmon River | Imnaha River Mouth | loss | 0.12 (0.00000000058 - 0.67) |
| Grande Ronde | Imnaha River Mouth | loss | 0.98 (0.91 - 1) |
| Imnaha River | Imnaha River Mouth | loss | 1 ( 1 - 1) |

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