Movement Patterns of Bulltrout at the Imnaha Weir in 2017

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Objectives

1. Estimate the detection probability of each mainstem Imnaha River node, the total number of tags at each node and the conversion rates of tagged fish moving upstream.
2. Estimate the proportion of fish passing the Imnaha River weir through the two available passage routes; weir panels and trap.
3. Estimate the proportion of fish successfully passing the Imanah River weir as a function of time spent below the weir.
4. For both weir passage routes estimate the number of attempts, the probability of success, the amount of time to pass and the fallback rate.
5. Provide a descriptive summary of migration patterns and detection histories of fish that remained downstream of the weir.

Methods and Results

Objective 1 - Detection Efficiencies, Total Tags and Conversion Rates

Using previously tagged fish (i.e., excluded fish tagged at IMNAHW in 2017) and removing individuals trapped and released at the "intake" the season wide detection efficiencies of tagged bulltrout averaged 0.54 at instream nodes and 0.99 at the two ladder antennas (Table 1). Season wide estimates include detections of roaming fish that have multiple chances of being seen at the node during the season. Using individual IR4 node detection estimates, the probability of being seen at the IR4 site on either node was 0.92, suggesting 8% of the available tags migrated past undetected.

Conversion rates between instream detection sites indicate that a small numbers of tagged bulltrout drop-out and fail to complete the full upstream migration through the Imanha River. Moving upstream the estimated dropout rates bewteen instream array sites was approximately 7% between IR2 and IR3, 13% between IR3 and IR4, and 16% between IR4 and IR5 (Table 1). However, the reported conversion rate between IR4 and IR5 is a minimum estimate because it does not include fish released at the intake (n = 25). If tags released at the intake were included the conversion from IR4 to upstream of the weir would be approximately 100%. The estimated conversion rate between downstream and upstream ladder antennas was approximately 100%, but only 32% for tags detected at the upstream ladder antenna converting to the trap.

Table 1: Summary of unique tags observed and the estimated number of tags reaching each detection node in Imanaha River.

Node	Unique_tags	det_eff	N_tags	Conversion	Dropout_km
IR1	85	0.5	169	NA	NA
IR2	77	0.44	174	1.03	1.67
IR3B0	36	0.22	161	0.93	-0.42
IR3A0	51	0.31	163	1.01	NA
IR4B0	98	0.7	141	0.87	-0.51

Node	Unique_tags	det_eff	N_tags	Conversion	Dropout_km
IR4A0	110	0.75	147	1.04	NA
IMLB0	74	0.99	75	0.51	NA
IMLA0	73	1	73	0.97	NA
IMNAHW	23	1	23	0.32	NA
IR5B0	109	0.88	123	0.84	NA
IR5A0	120	NA	NA	NA	NaN

Objective 2 - Passage Route Proportions

Using only unique tag detections at IR4A0 of fish known to successfully pass the weir we estimate 16% use the ladder and trap passage route (Table 2).

Table 2: Estimated passage route proportions for bulltrout successfully migrating past the Imanah River weir.

IR4A0	IMNAHW	p_Trap	p_Panel
147	23	0.16	0.84

Objective 3 - Passage Proportion by Time

A Kaplan-Meier function was used to estimate the probability of bulltrout remaining downstream of the weir as a function of time to pass (days) and the arrival period at IR4. To estimate the function the observation dataset was queried for the minimum observation date of tags observed at IR4 and IR5 (excluding 2017 IMNAHW tags and fish released at the "intake") when the weir panels were closed. The time variable was calculated as the difference between minimum observation dates at the two sites. For unique tags seen only at IR4, a right censored time variable was created as the number of days between the minimum and maximum observation dates at IR4. Right censoring allows us to include all individuals in the analysis without assuming a particular outcome. Individuals were then broken into early and late arrival groups based on their minimum observation date at IR4 with a July 15th cut-off.

Arrival timing was a significant covariate in the passage model (Figure 1). Early arriving fish tended to spend more time below the weir with only 25% of the tags passing within 5 days and approximately 40% passing within 10 days. As compared to approximately 63% of late arriving fish passing within 5 days and 80% passing within 10 days. At the end of the season the passage model estimates 98% of the early arriving fish past the weir and 96% of the late arriving fish past the weir.

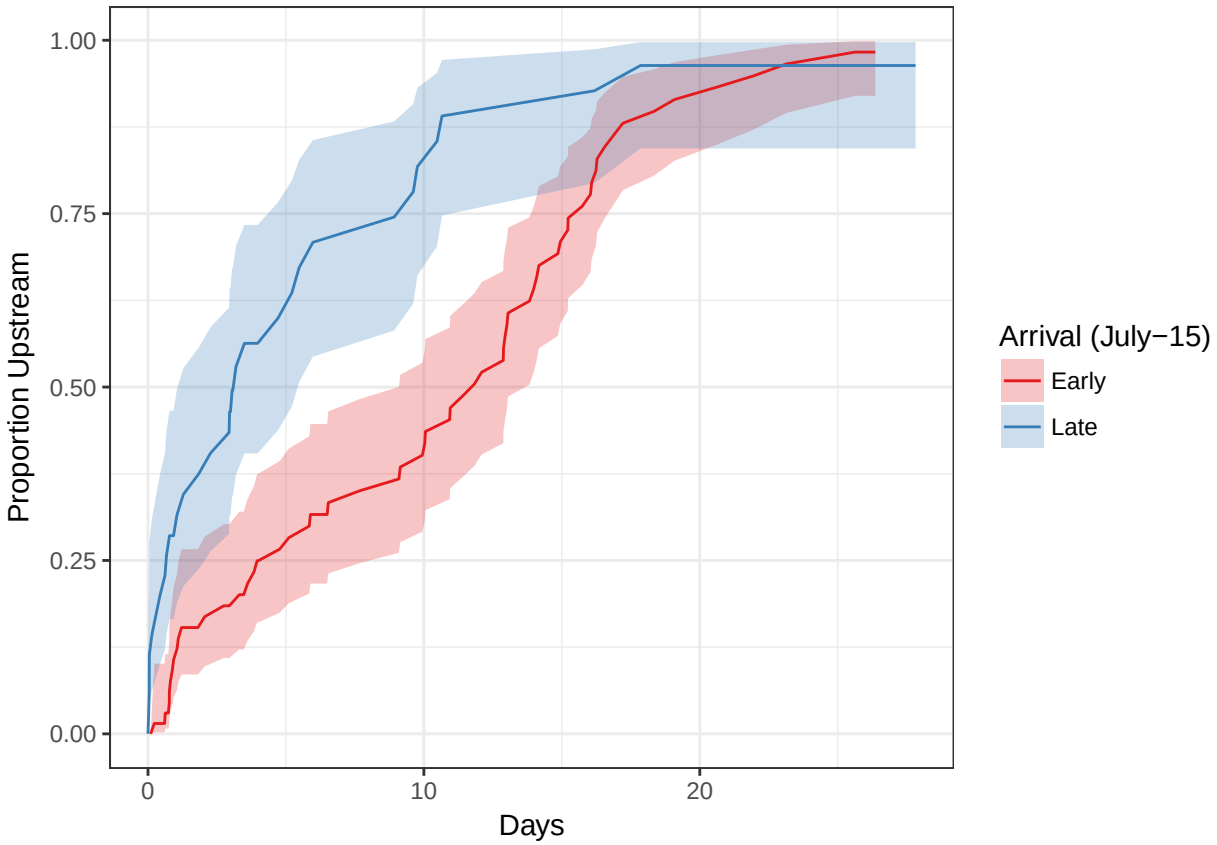

Figure 1: Estimated proportion of individual tags successfullly migrating upstream of the Imnaha weir as a function of days from the minimum observation date at IR4.

Objective 4 - Successful Weir Passage

Ladder and Trap Passage

The number of passage attempts and the probability of successfully climbing the ladder and being trapped on a single attempt was modeled using a geometric probability distribution. Attempts were defined as each upstream movement from any downstream node to IMLB0. The model was populated with 23 unique tags caught during the weir closure, and it estimated a 0.58 probabilty of being trapped on a single attempt. The expected number of attempts to climb the ladder and become trapped was estimated at 1.74, with 95% of all fish being successfully trapped between 1 and 4 attempts (Figure 2).

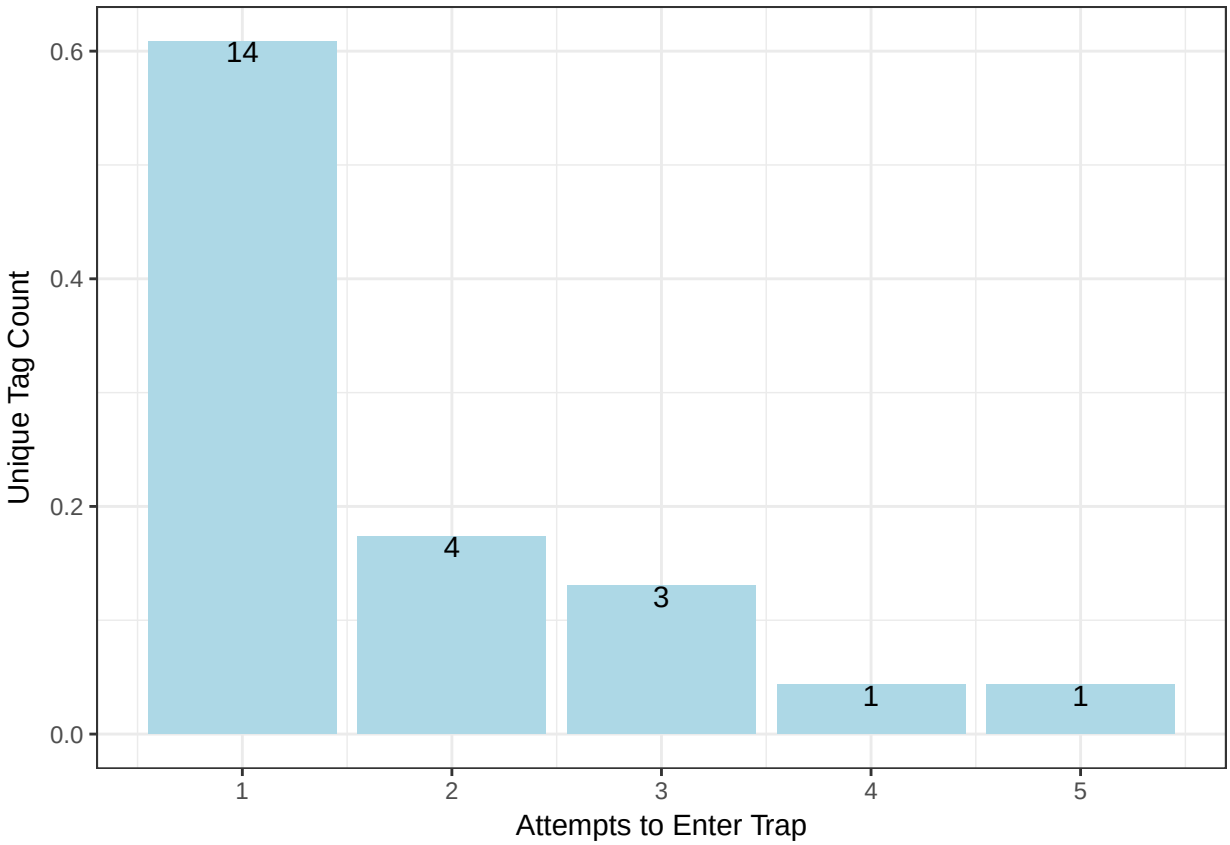

Figure 2: Number of attempts made by successfully trapped individuals to climb the ladder.

Using the same 23 tags, an exponential probabilty distribution was used to model the amount of time required to successfully become trapped. The amount of time to pass before being trapped was calculated as the difference between the minimum observation time at IMNAHW and the minimum observation time at IMLB0 (time includes additional wait and processing time after being trapped). The model estimated the expected number of days from the first observation at IMLB0 to when an individual was trapped at 3.45 with 95% of all fish being caught between (0.09) and (12.73) days (Figure 3).

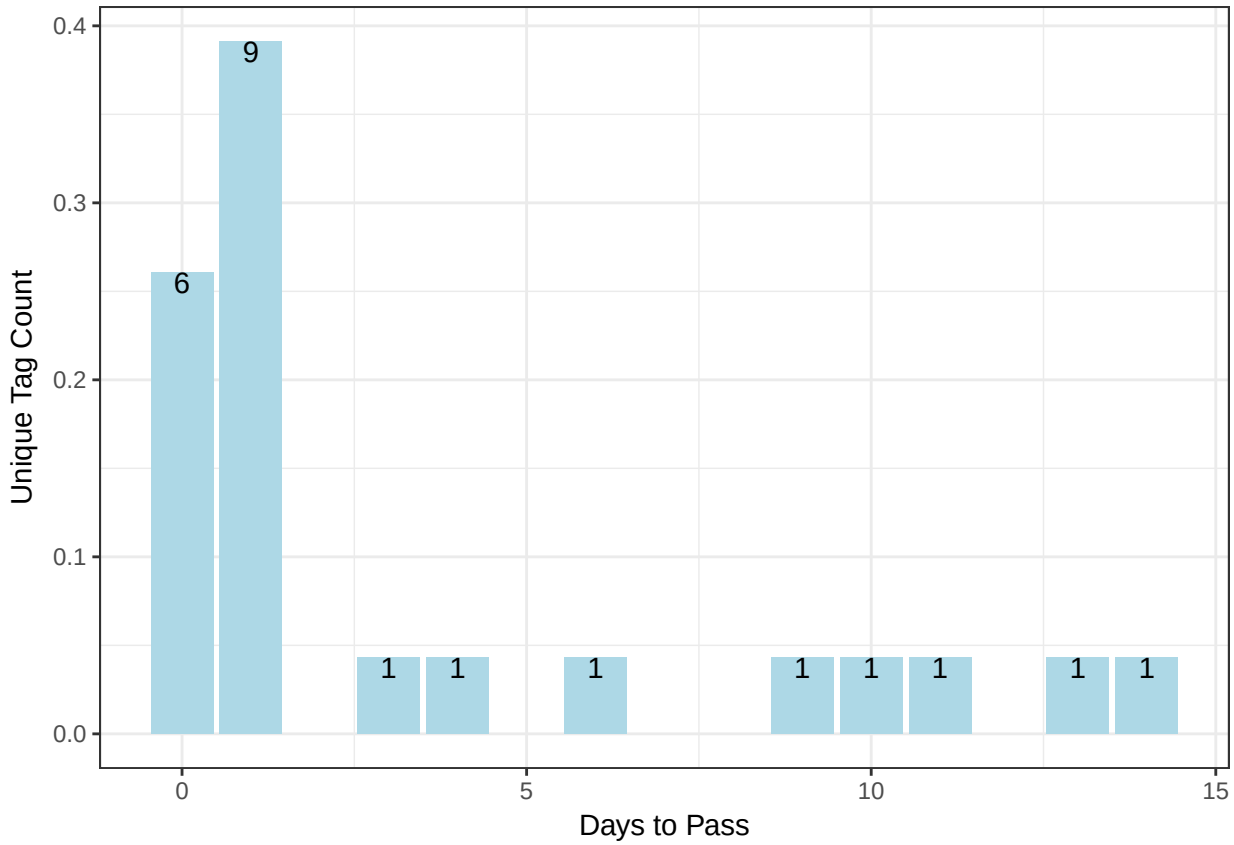

Figure 3: Number of days (rounded) from the first attempt to climb the ladder and successfully be trapped.

Weir Panel Passage

Passage attempts for fish successfully passing the weir through the panels during closure and reaching IR5 was estimated similary to fish climbing the ladder. Attempts to pass through the panels were defined as each upstream movement from any downstream node to IR4A0, thus assuming a detection at IR4A0 was an actual attempt to pass the weir. The model was populated with 68 unique tags and estimated a 0.22 probabilty of passing through the panels on a single attempt. The expected number of attempts to pass the panels was estimated at 4.51, with 95% of all fish successfully passing after 1 to 14 attempts (Figure 4).

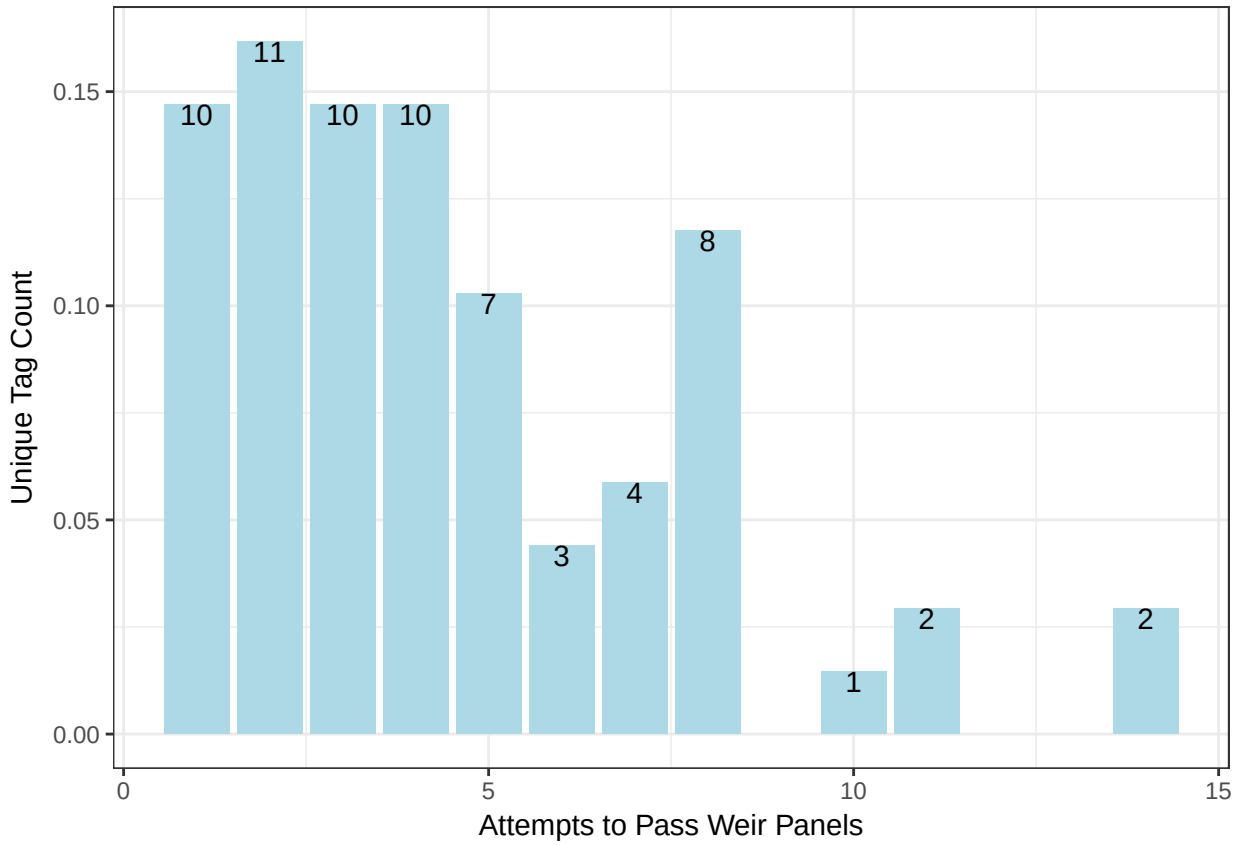

Figure 4: Number of attempts made by individuals that successfully reached IR5 by passing through weir panels.

Using the same 68 tags, the amount of time required to successfully pass through the panels and reach IR5 was modeled with an exponential distribution. The amount of time to pass was calculated as the difference between the minimum observation time at IR5 and the minimum observation time at IR4A0. The model estimated the expected number of days from the first observation at IR4A0 to when an individual reached IR5 at 8.71 (Figure 3).

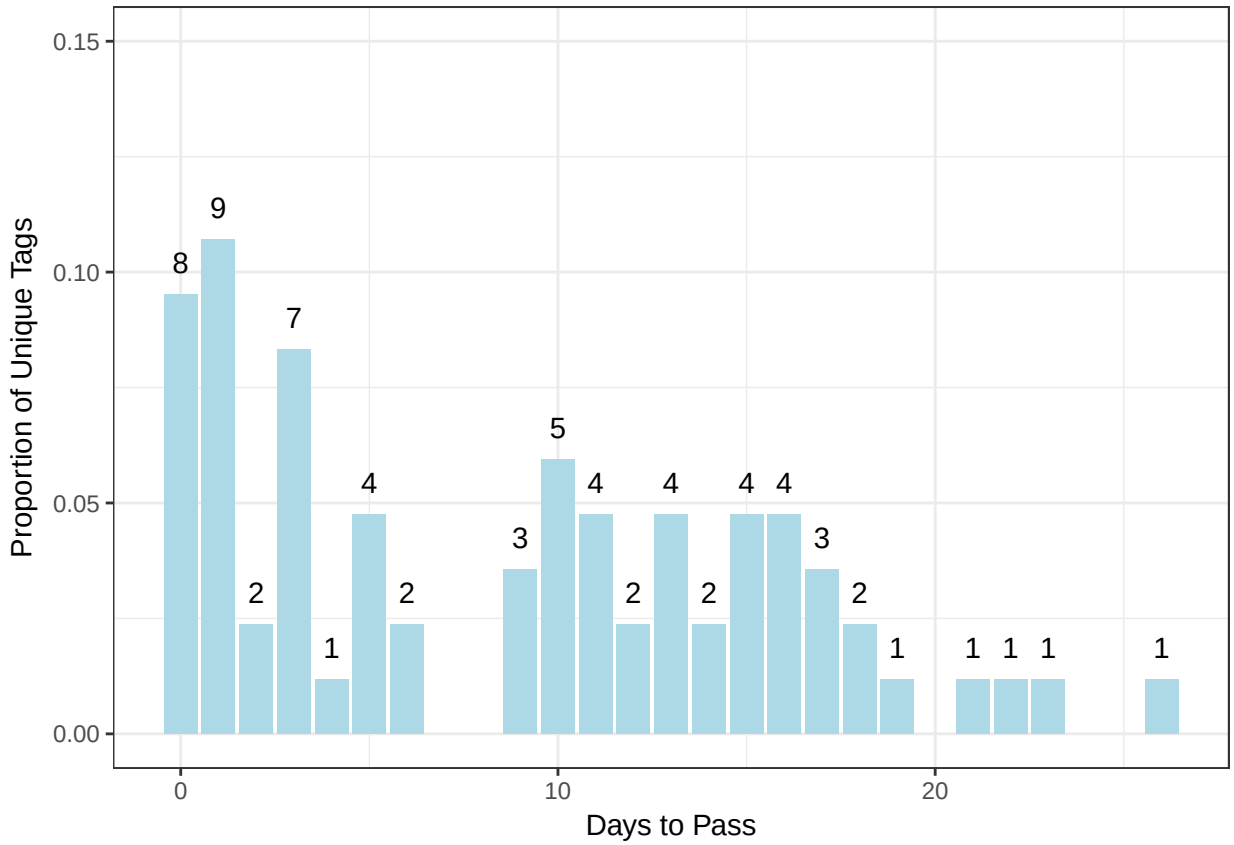

Figure 5: Number of days (rounded) from the first attempt to pass the weir through the weir panels.

Fallback Rates

Unique tags observed successfully passing the Imnaha weir during trap closure were evaluated for rates of fallback. Five groups of fish were evaluated based on the individual's passage route (panel or trap), location of release (intake or tube) and date of passage; passage date was split into early and late groups using a July 15th cut-off. Generally, fallback rates were low for the five groups and averaged 9% for all fish (Table 3). However, fish released at the intake during the early period experienced a considerably higher fallback rate of 24%.

Table 3: Unique tag detections of fish observed passing the Imnaha weir through the trap and weir panels and their rate of fallback. Fallback rates were stratified into early and late arrival periods using a cut-off of July 15th.

Route	Release_Location	Arrival	Upstream	Fallback	Rate
Panel	NA	Early	13	NA	NA
Trap	Intake	Early	25	6	0.24
Trap	Tube	Early	29	1	0.03
Panel	NA	Late	67	2	0.03
Trap	Tube	Late	39	2	0.05

Objective 5 - Unsuccessful Weir Passage

Seventeen unique tags at IR4 were never seen in the trap or at IR5. Of the seventeen tags, 1 was observed in early spring prior to the trap closing, 10 were seen at ladder antennas after being detected at IR4 and 1 was observed at IR1 during the trap closure (Figure 6, Table 5). Assumming the tag detections represent all

bulltrout below the weir, 11% of the fish probably left the area just a few days after reaching the weir and approximately 60% of fish would have passed above the weir if they were trapped after reaching IMLA0.

Additionally, using the maximum observation date of unique tags at IR4, only 8 tags were observed at IR4 after July 15th and only 3 were observed close to August 11th when panels were raised (Figure 6). Suggesting few fish were holding directly downstream of the weir and potentially unable to pass before the weir panels were opened.

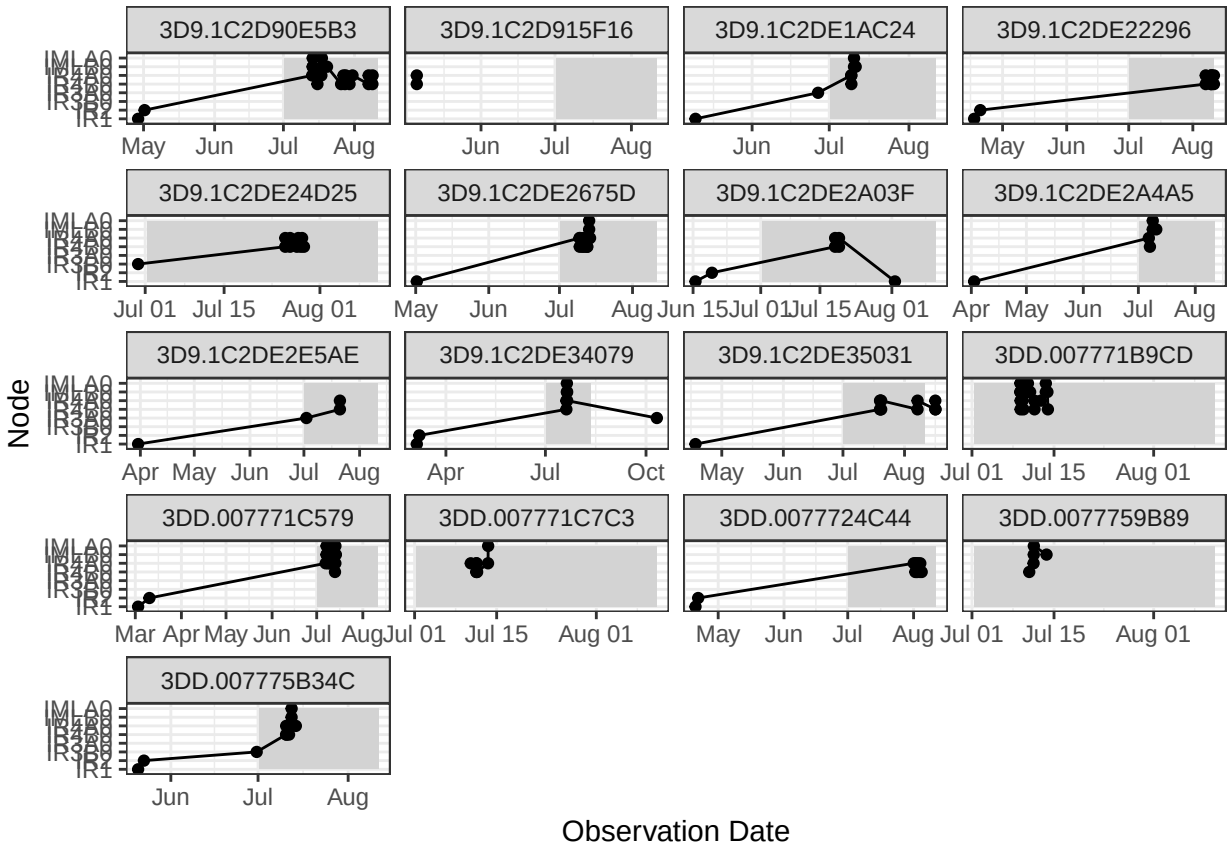

Figure 6: Migration patterns for unique tags observed at IR4 but not subsequently observed in the Imnaha River trap or IR5 (n = 17). The grey shading indicates the weir panel closure period.

Table 4: PIT-tag observations of fish at IR4 that did not successfull pass the weir and were seen at a later date at other sites.

SiteID	n
IR1	1
IR3	1
IR4	17
IML	10

Appendix

Dataset Development

The complete bulltrout PIT-tag observation dataset was developed by combining two PTAGIS queries. First, a tagging detail query was run on October, 16 for all bulltrout tagged in the Imnaha or Hell Canyon subbasins. The tagging detail query returned 3669 unique tags released at 10 sites (Table 6, Table 7). Next, the unique tag IDs were imported into a complete tag history query to return every detection observation

of the 3669 imported tag IDs. The complete tag history query was also run on October, 16 and returned 51012 tag observations.

Once the complete tag histories were downloaded from PTAGIS all observations were automatically processed with a computer program and trap operational data was added. Automatic processing of observations was completed using a function written in the R statistical programming language. The function completes five tasks. First, it assigns an observation node (i.e., a single spanning array of antennas or a single tag detection location [IMNAHW]) to each record based on the combination of "Event Site Code Value", "Antenna ID" and "Antenna Group Configuration Value" fields. Next, the function cycles through chronologically ordered observations of each tag ID to determine if the current observation was upstream or downstream from the last observation. After assigning upstream and downstream movements an overall migration path is assigned to all records to identify fish generally moving upstream towards the spawning grounds, or downstream as a potential post-spawned individual. Then, observations of a single tag in two seperate stream paths are identifited as invalid (e.g., a tag detected at BSC and IR3 is invalid). Last, to remove redundant information, observations are truncated to only those detections after a specified date (e.g., this analysis used only observations after January 1, 2017), and to the single record with the minimum observation date at each node for an individual upstream/downstream movement. Finally, trapping metadata was appended to each observation which included the operational status of the Imnaha River weir (i.e., open, closed, 2-panels open, 3-panels open, 4-panels open) and the release location (i.e., tube or intake) of an individual trapped at the Imnaha River weir. After processing the complete tag history file 2361 observations of 237 unique tags remained at mainstem Imnaha River sites (Table 8).

Table 6: All new tags released from 2005-2017 at Imnaha and Hells Canyon subbasin release sites formed the valid tag list.

Release_Year	n
2005	242
2006	461
2007	512
2008	519
2009	243
2010	59
2011	351
2012	130
2013	188
2014	219
2015	287
2016	341
2017	117
Total	3669

Table 7: Valid tags were released from 10 unique release sites within the Imnaha and Hells Canyon subbasins.

Release_Site	n
BSHEEC	932
CANALC	26
IMNAHW	618
IMNTRP	258
LICK2C	336
LSHEEC	44
MCCULC	685
REDMOC	7
SALTC	63
SNAKE4	700

Release_Site	n
Total	3669

Table 8: Unique tag observations at each detection site in the Imnaha River. Tag observations include upstream and downstream migrating fish, individual tagged at the Imanha weir in 2017 and observations of all fish released through the tube or at the intake.

SiteID	n
IR1	97
IR2	91
IR3	79
IR4	141
IML	88
IMNAHW	95
IR5	179
Total	237

Exploratory Data Analysis

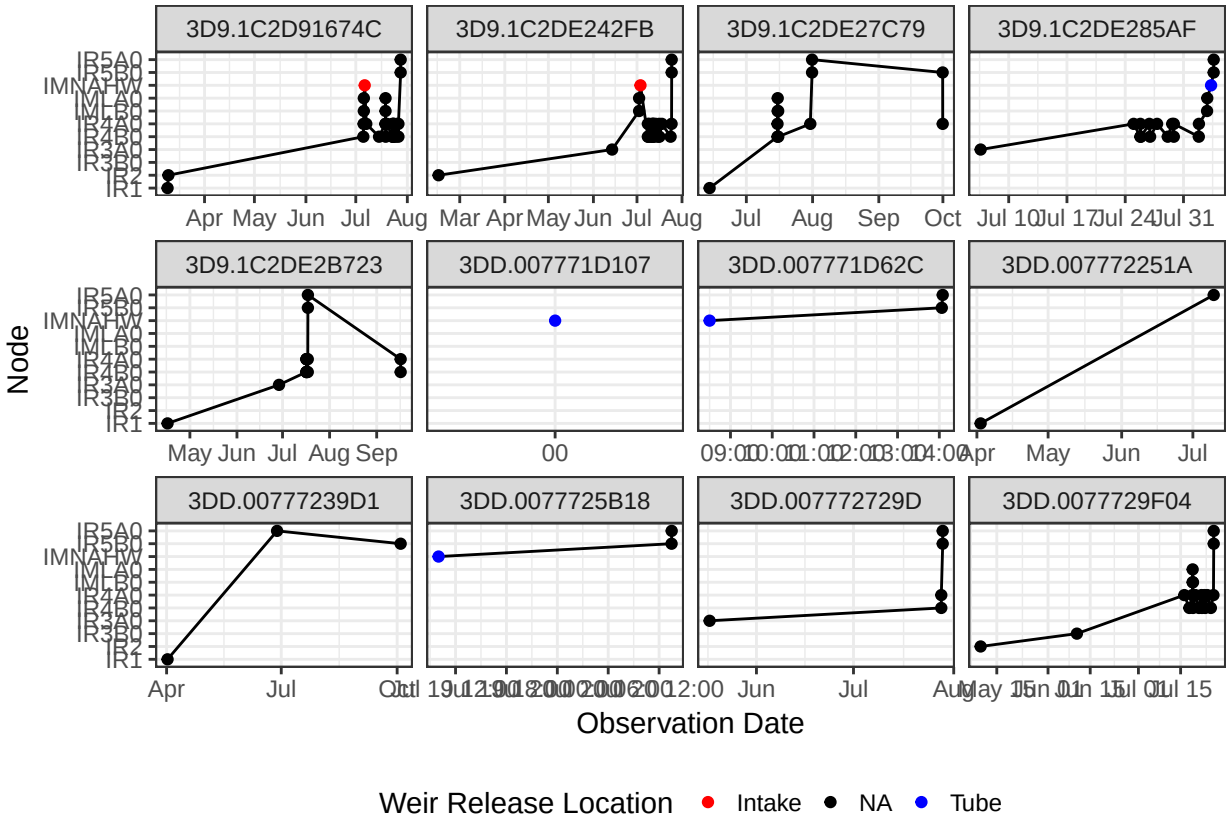

Figure 7: Migration pattern of 12 randomly selected tagged bulltrout moving through through the Imnaha River.

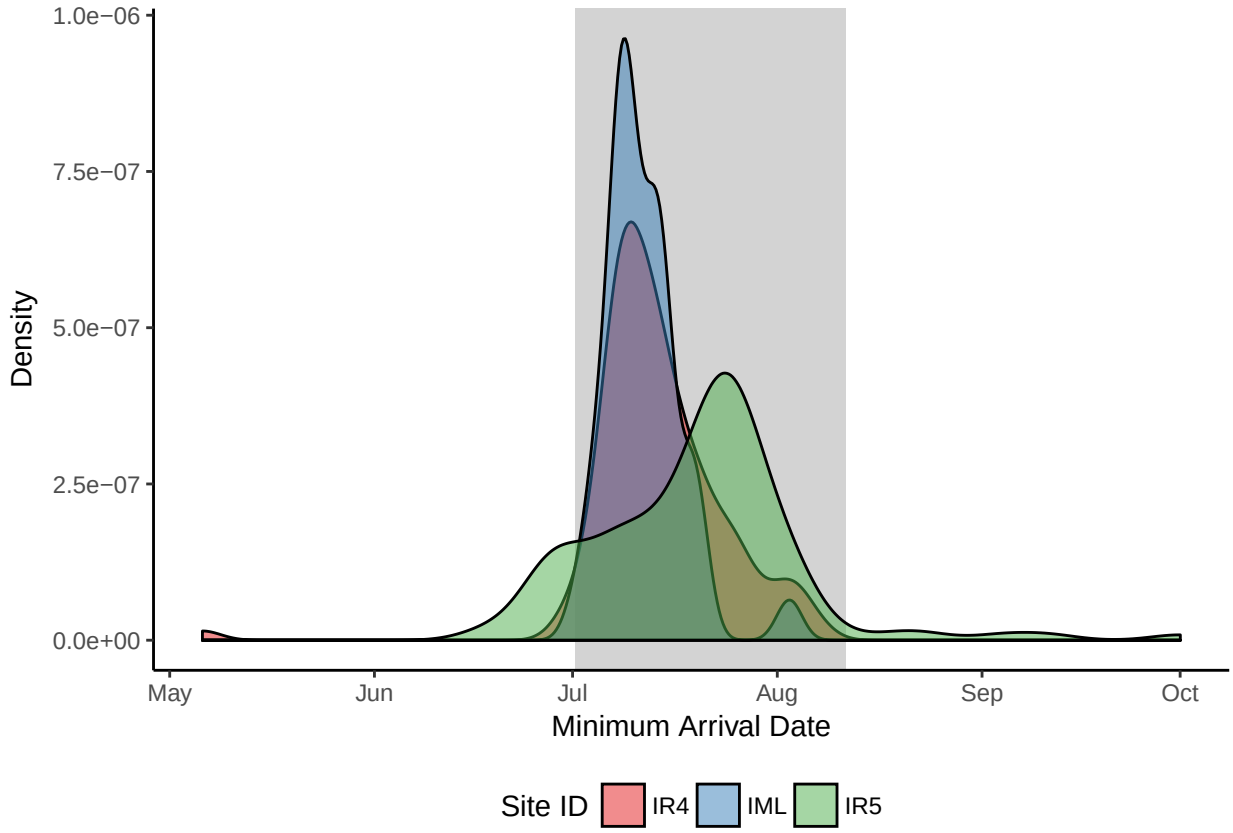

Figure 8: Minimum arrival time of the first observation of fish moving upstream past three Imnaha weir detection sites. The grey shaded rectangle indicates the period of time the weir was closed and blocking passage of Chinook Salmon.

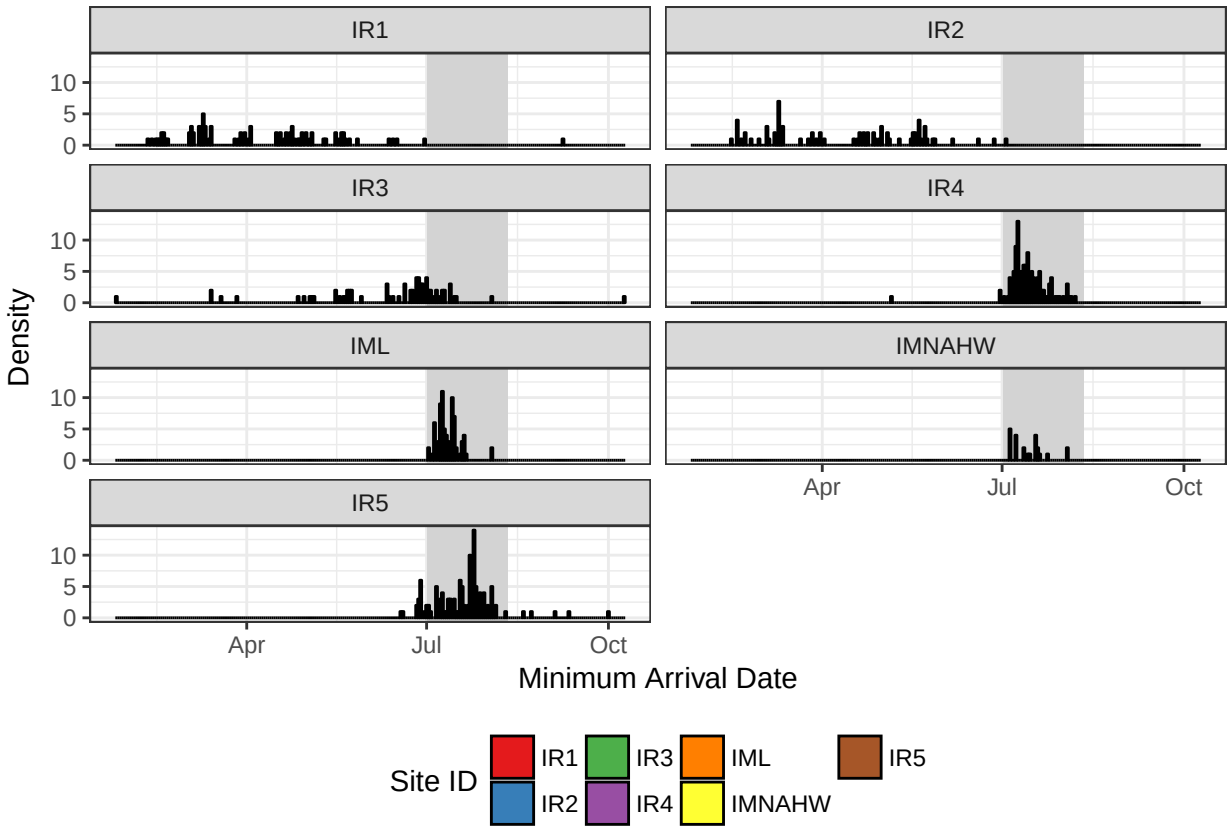

Figure 9: Minimum arrival time of the first observation of fish moving upstream at all Imnaha River detection sites. The grey shaded rectangle indicates the period of time the weir was closed and blocking passage of Chinook Salmon.

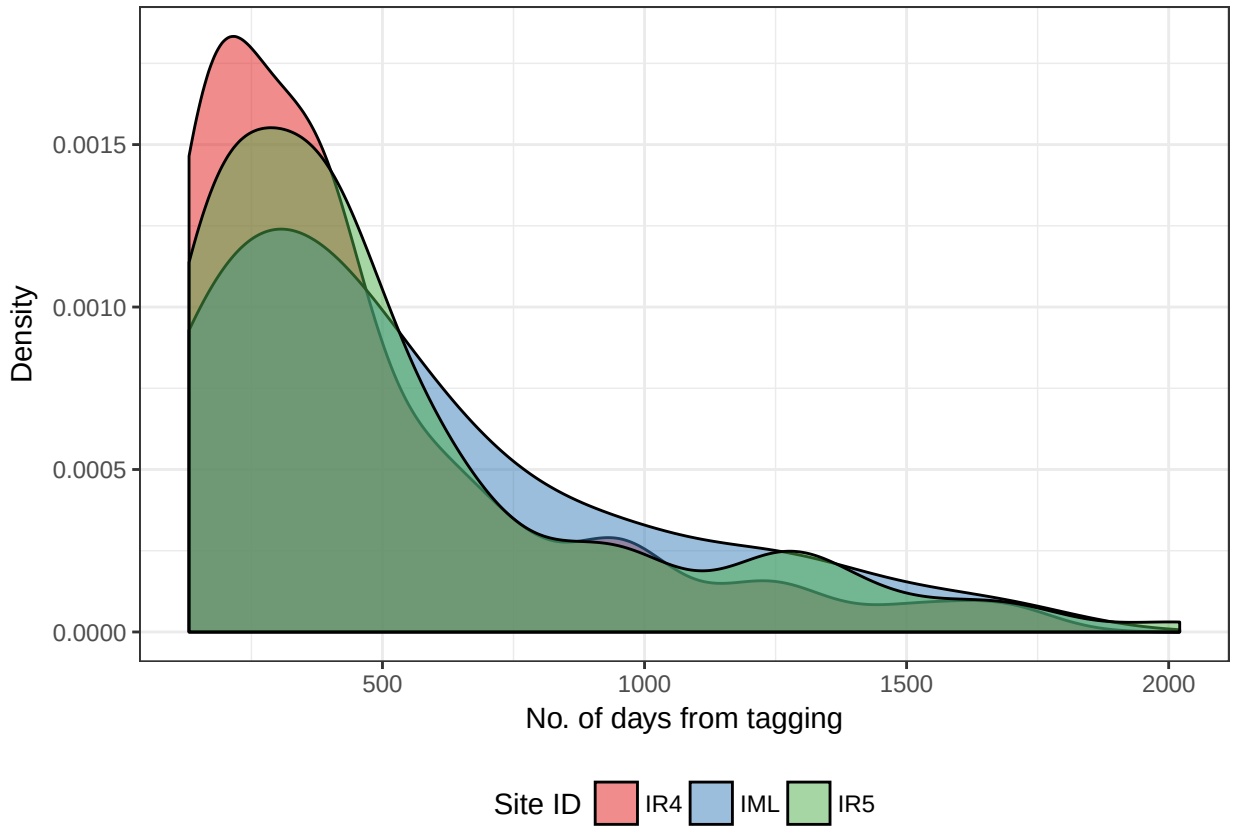

Figure 10: The distribution of the number of days from initial tagging for upstream migrating fish observed at three Imanha weir detection sites.

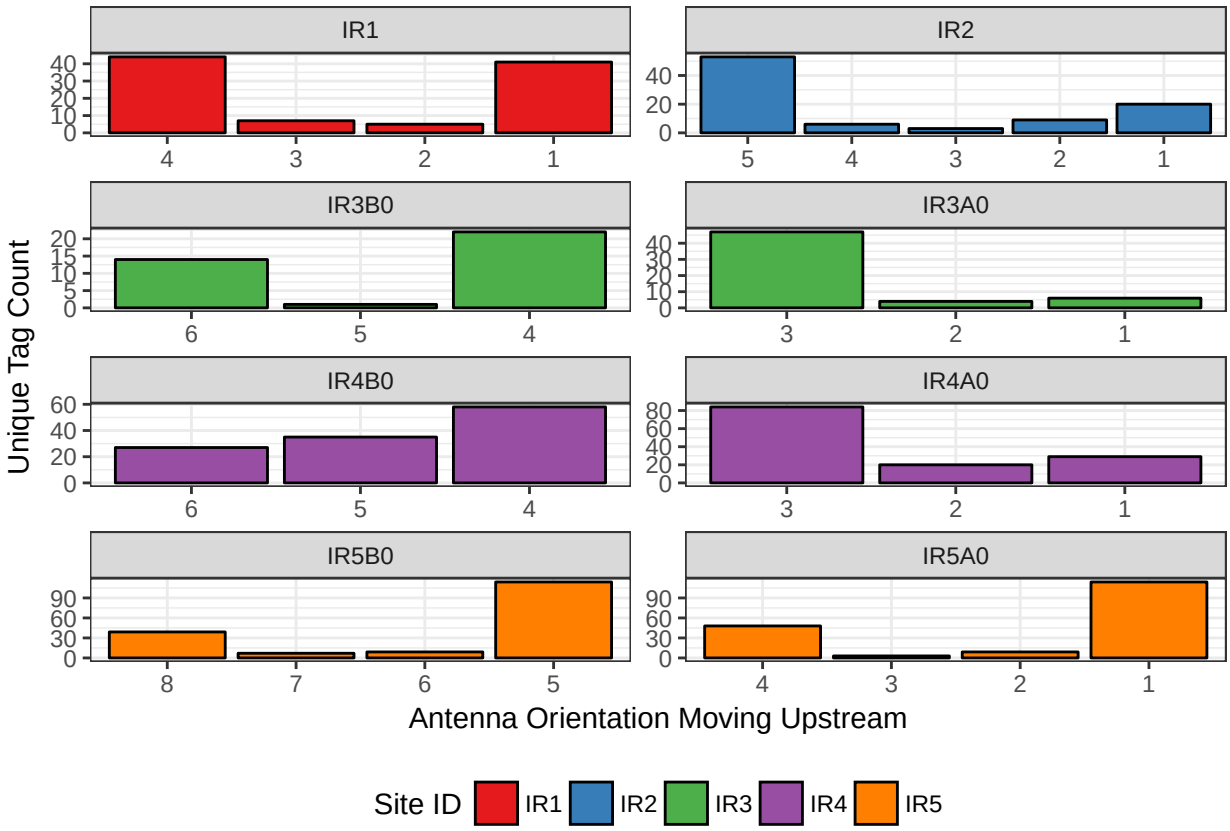

Figure 11: Unique tag count on each instream node antenna. Antennas are arranged from the left to right stream bank for an upstream moving fish.

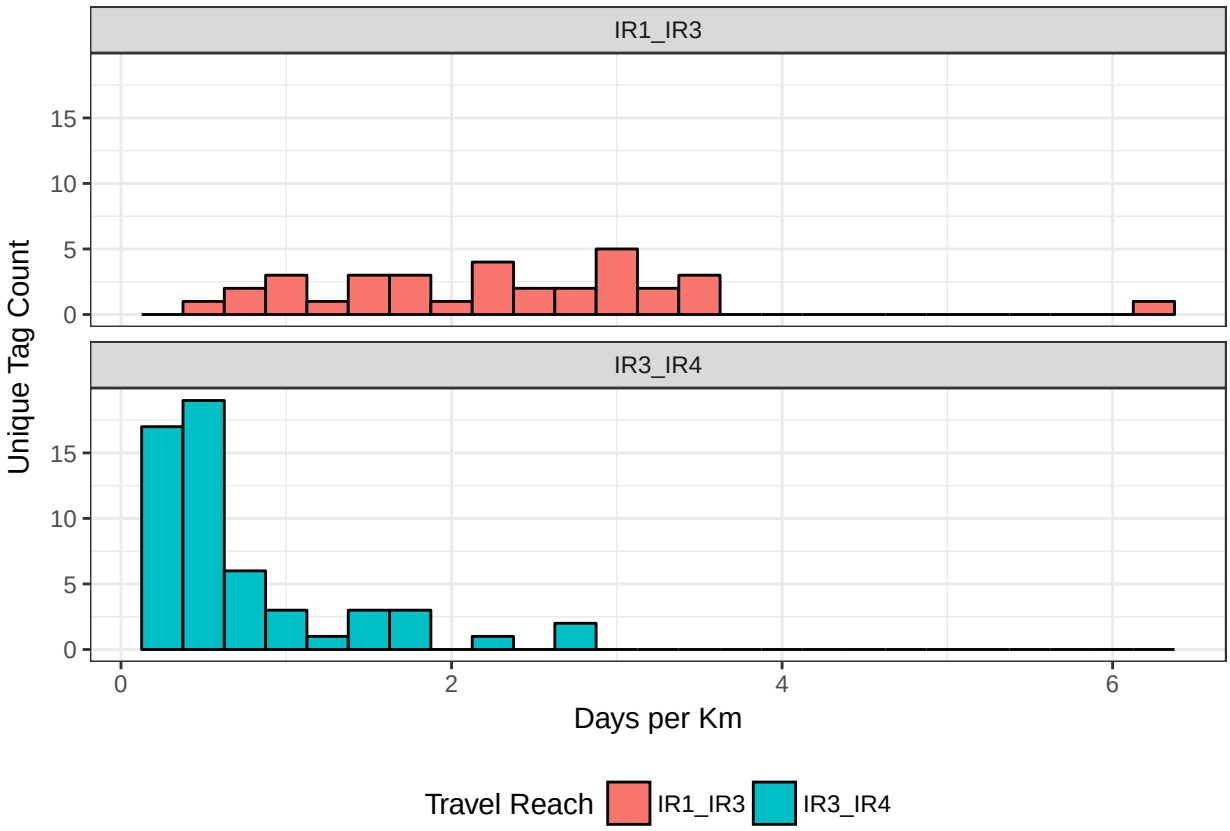

Figure 12: Travel time distributions for fish migrating upstream between two stream reaches; IR1 to IR3 and IR3 to IR4.

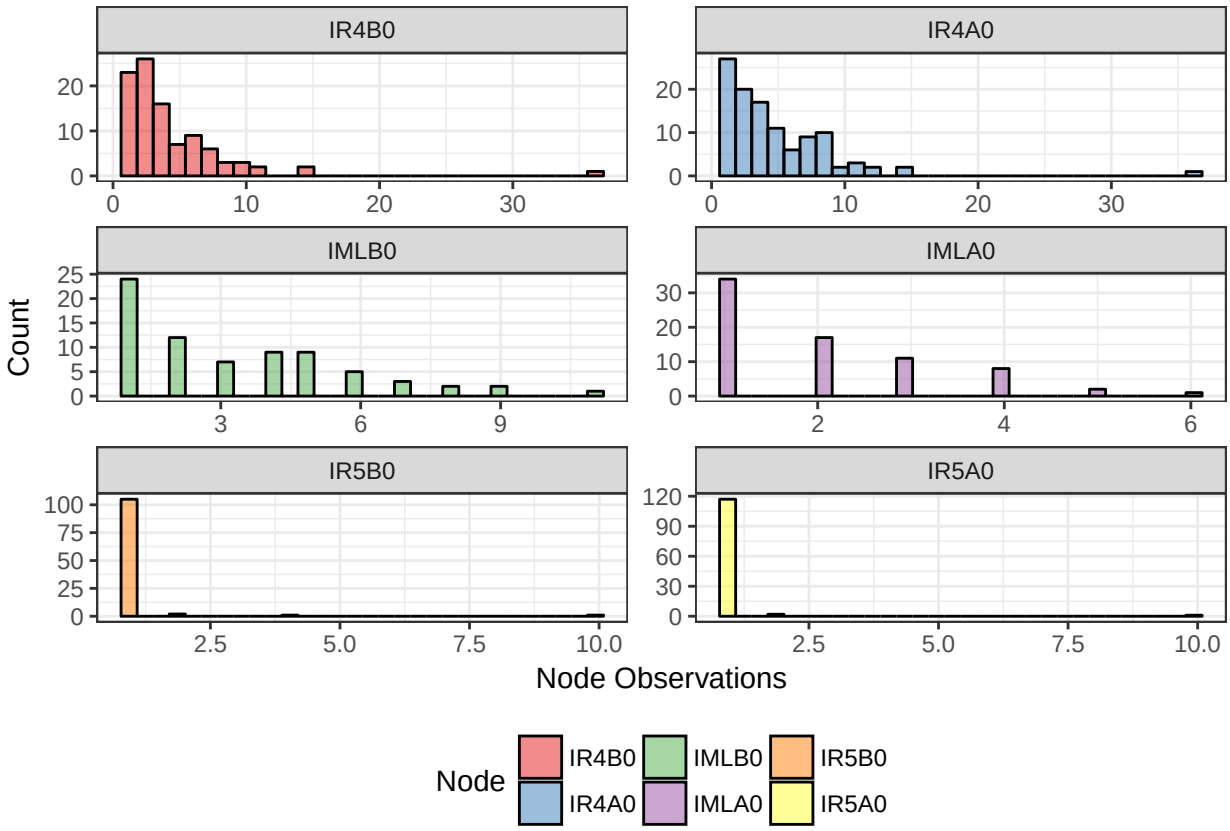

Figure 13: The number of times a fish is observed passing Imnaha weir node sites during upstream migration. The passage count is defined as the first observation within a deteciton series of fish moving upstream or temporaily downstream during their overall upstream migration.

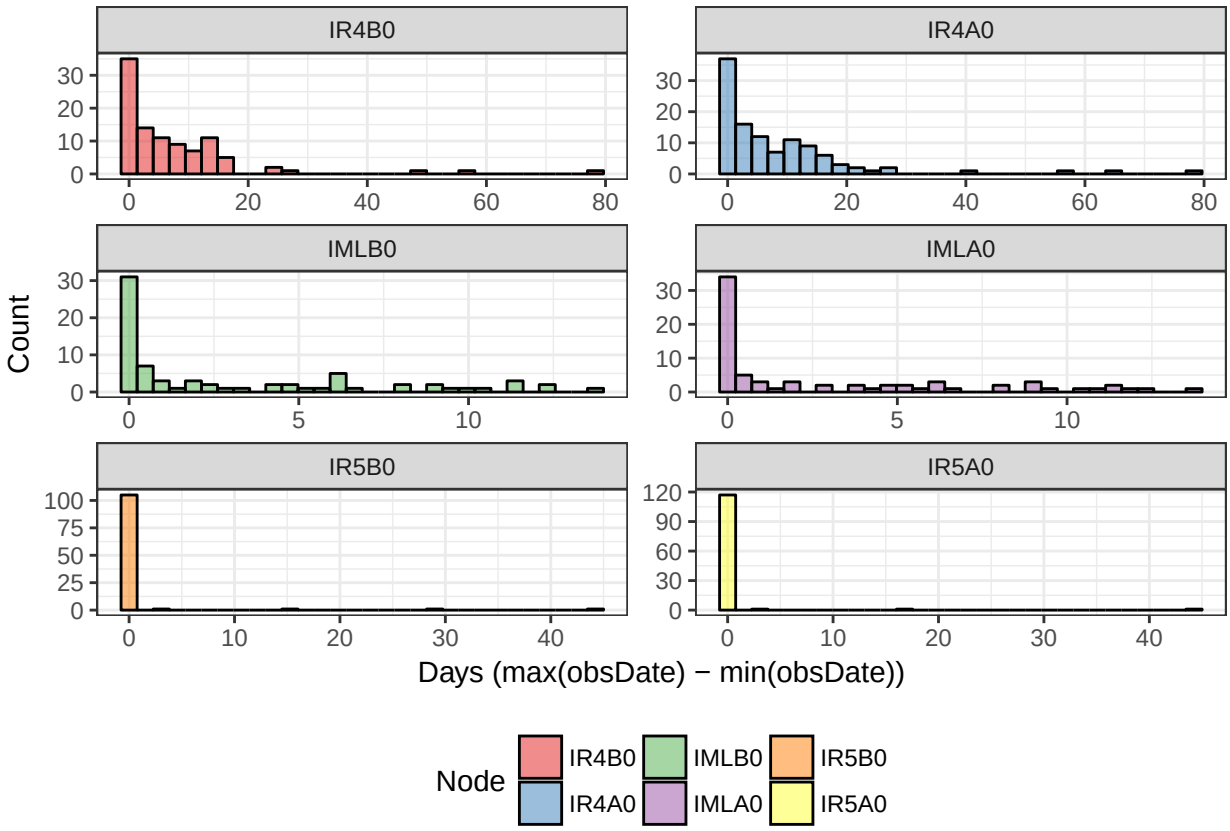

Figure 14: The number of days between the first and last observation of fish at each Imanaha weir node during their upstream migration.