

Evaluating Differences in Dam Counts

And Their Effects on Abundance Estimates

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1 Introduction

The **D**am **A**dult **B**ranch **O**ccupancy **M**odel (DABOM) has been used to estimate steelhead escapement to various locations around the Upper Columbia for nearly a decade. One of the requirements of this model is an accurate estimate of abundance (possibly with uncertainty) *somewhere* in the system. To this point, we have used dam counts at Priest Rapids Dam to generate that estimate of abundance. We have adjusted the raw counts by an estimated re-ascension rate, to account for fish that may have been counted twice.

Recently, we have called into question the assumption that the dam counts at Priest Rapids are an accurate depiction of how many steelhead are crossing that dam each day. One reason for this questioning is a comparison between the counts at Priest Rapids, and other upstream dams (i.e Rock Island, Rocky Reach and Wells) (Table 1). In recent years (2019-2022) the counts were higher at Rock Island dam, the next upstream dam, compared to Priest Rapids, which is surprising because there are no major tributaries between Priest Rapids and Rock Island. Between Rock Island and Rocky Reach some steelhead move into the Wenatchee River, and between Rocky Reach and Wells dam some move into the Entiat River, so we expect those counts to shrink as we move upstream.

It is important to acknowledge the various processes going on at and between each dam to help understand these discrepancies. First, although the tagged fish at Priest are assumed to be a representative sample of the steelhead run at large crossing Priest, the proportion of hatchery and natural origin fish may be different at different dams as fish move into different populations at different rates depending on their origin. Second, the re-ascension rate may be (and probably is) different at other dams compared to Priest. We have recently begun evaluating re-ascension rates at Rock Island and Rocky Reach, as well as Priest Rapids, but those rates are not available for all years yet.

Table 1: Total steelhead dam counts at mainstem dams on the Columbia River from June 1 of the previous year to May 31 (or the most recent day available in 2022), and the percent of those counts compared to counts at Priest Rapids Dam.

Year	Priest Rapids	Rock Island	Rocky Reach	Wells
2011	26,431 (100%)	22,129 (83.7%)	18,091 (68.4%)	12,791 (48.4%)
2012	20,806 (100%)	19,123 (91.9%)	15,418 (74.1%)	12,047 (57.9%)
2013	17,192 (100%)	15,387 (89.5%)	12,529 (72.9%)	9,741 (56.7%)
2014	15,072 (100%)	11,675 (77.5%)	9,293 (61.7%)	7,280 (48.3%)
2015	19,659 (100%)	14,883 (75.7%)	10,450 (53.2%)	7,650 (38.9%)
2016	14,303 (100%)	13,962 (97.6%)	10,871 (76%)	9,165 (64.1%)
2017	6,507 (100%)	7,182 (110.4%)	5,762 (88.6%)	4,820 (74.1%)
2018	5,804 (100%)	5,269 (90.8%)	3,951 (68.1%)	3,835 (66.1%)
2019	4,909 (100%)	5,244 (106.8%)	4,283 (87.2%)	3,912 (79.7%)
2020	3,911 (100%)	4,441 (113.6%)	3,333 (85.2%)	2,763 (70.6%)
2021	6,509 (100%)	6,734 (103.5%)	5,397 (82.9%)	4,391 (67.5%)
2022	2,810 (100%)	4,528 (161.1%)	3,989 (142%)	3,116 (110.9%)
2023	3,720 (100%)	5,665 (152.3%)	4,374 (117.6%)	2,835 (76.2%)

2 Methods

We completed the same analysis for each spawn year between 2011 and 2021. For each dam (Rock Island, Rocky Reach, and Wells), we started by examining all the tags put out at Priest Rapids that were observed at or upstream of the j^{th} dam, by origin (i). For each dam, we used these groups of tags to estimate the proportion of each origin of fish that crossed each dam ($\pi_{i,j}$).

$$\pi_{i,j} = \frac{t_{i,j}^{up}}{\sum_j t_j^{up}}$$

We then examined the number of Priest tags detected at each dam (prior to cleaning the detection data with PITcleanr), separated by origin. We inflated this number by the estimated detection probability estimated for each dam by DABOM (\hat{p}_j) to generate an estimate of the number of tags that crossed each dam. We then divided this estimate by the total number of tags, by origin, that we started with at Priest. This provides an estimate of the probability that a fish would move from Priest past the j^{th} dam, by origin i ($\psi_{i,j}$).

$$t_{i,j}^{est} = \frac{t_{i,j}^{obs}}{\hat{p}_j} \psi_{i,j} = \frac{t_{i,j}^{est}}{t_i^{PRD}}$$

Through a collaboration with the Columbia Basin Research group, a query was constructed from PIT tag detections in PTAGIS to evaluate whether each tag detected at a dam was a first-time crossing, or a re-ascension (the fish had fallen back below the dam and was crossing it again). We used this query to generate estimates of re-ascension rates for origin i at dam j ($\eta_{i,j}$). The re-ascension queries are currently available for Priest Rapids (all years), Rock Island (2016 - 2021) and Rocky Reach (2015 - 2021). For Rock Island and Rocky Reach, for years when the specific rate was not available we used the mean across the years we did have. For other dams (i.e. Wells), we used the re-ascension rate at Priest Rapids for that year.

The next step was to multiply the total dam counts at each dam (C_j) by the estimated proportion of origins ($\pi_{i,j}$) and one minus the re-ascension rate ($1 - \eta_{i,j}$), then divide each result by the appropriate movement probability ($\psi_{i,j}$). This provides an estimate of the total number of unique fish, by origin, that crossed Priest, according to the dam count at each dam ($\Gamma_{i,j}$). Using the delta method, the appropriate uncertainty was propagated through this entire process.

$$\Gamma_{i,j} = \frac{C_j * \pi_{i,j} * (1 - \eta_{i,j})}{\psi_{i,j}} \Gamma_j = \sum_i \Gamma_{i,j}$$

These estimates can be inflated by the re-ascension rate at Priest Rapids and summed across origin to compare to the recorded counts of total steelhead at Priest Rapids. They can also be used to calculate the effect of using different dam counts within DABOM on steelhead escapement estimates across the entire Upper Columbia by origin and year.

3 Results

The estimated parameters used in the overall calculations are shown in Table 2. The resulting estimates of Priest Dam count equivalents are in Table 3, and also presented visually in Figure 2. The absolute difference in estimates of unique fish crossing Priest Rapids Dam compared to using counts at Priest, split by origin, is shown in Figure 3. The relative impacts to DABOM estimates of abundance from using a different abundance estimate at Priest Rapids, compared to the original estimate, are shown in Figure 4 and Table 4. The average relative difference across an early period (2011-2015) and a late period is shown in Table 5.

Table 2: Estimated parameters used as inputs for Priest Rapids Dam count equivalents.

Year	Dam	Origin	π	η	ψ	Total Dam Count (C)
2011	Priest Rapids	H	0.712	0.050	1.000	26,431
2011	Rock Island	H	0.739	0.050	0.883	22,129
2011	Rocky Reach	H	0.801	0.050	0.769	18,091
2011	Wells	H	0.818	0.050	0.617	12,791
2011	Priest Rapids	W	0.288	0.039	1.000	26,431
2011	Rock Island	W	0.261	0.039	0.787	22,129
2011	Rocky Reach	W	0.199	0.039	0.471	18,091
2011	Wells	W	0.182	0.039	0.338	12,791
2012	Priest Rapids	H	0.763	0.052	1.000	20,806
2012	Rock Island	H	0.764	0.052	0.850	19,123
2012	Rocky Reach	H	0.824	0.052	0.732	15,418
2012	Wells	H	0.837	0.052	0.628	12,047
2012	Priest Rapids	W	0.237	0.038	1.000	20,806
2012	Rock Island	W	0.236	0.038	0.858	19,123
2012	Rocky Reach	W	0.176	0.038	0.502	15,418
2012	Wells	W	0.163	0.038	0.393	12,047
2013	Priest Rapids	H	0.809	0.064	1.000	17,192
2013	Rock Island	H	0.810	0.064	0.855	15,387
2013	Rocky Reach	H	0.864	0.064	0.741	12,529
2013	Wells	H	0.873	0.064	0.632	9,741
2013	Priest Rapids	W	0.191	0.070	1.000	17,192
2013	Rock Island	W	0.190	0.070	0.844	15,387
2013	Rocky Reach	W	0.136	0.070	0.495	12,529
2013	Wells	W	0.127	0.070	0.387	9,741
2014	Priest Rapids	H	0.650	0.080	1.000	15,072
2014	Rock Island	H	0.642	0.080	0.788	11,675
2014	Rocky Reach	H	0.689	0.080	0.650	9,293
2014	Wells	H	0.700	0.080	0.584	7,280

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Table 2: Estimated parameters used as inputs for Priest Rapids Dam count equivalents. (*continued*)

Year	Dam	Origin	π	η	ψ	Total Dam Count (C)
2014	Priest Rapids	W	0.350	0.074	1.000	15,072
2014	Rock Island	W	0.358	0.074	0.816	11,675
2014	Rocky Reach	W	0.311	0.074	0.542	9,293
2014	Wells	W	0.300	0.074	0.463	7,280
2015	Priest Rapids	H	0.660	0.074	1.000	19,659
2015	Rock Island	H	0.672	0.074	0.812	14,883
2015	Rocky Reach	H	0.702	0.013	0.604	10,450
2015	Wells	H	0.720	0.074	0.523	7,650
2015	Priest Rapids	W	0.340	0.058	1.000	19,659
2015	Rock Island	W	0.328	0.058	0.752	14,883
2015	Rocky Reach	W	0.298	0.010	0.494	10,450
2015	Wells	W	0.280	0.058	0.393	7,650
2016	Priest Rapids	H	0.657	0.055	1.000	14,303
2016	Rock Island	H	0.669	0.013	0.875	13,962
2016	Rocky Reach	H	0.713	0.012	0.757	10,871
2016	Wells	H	0.737	0.055	0.711	9,165
2016	Priest Rapids	W	0.343	0.034	1.000	14,303
2016	Rock Island	W	0.331	0.008	0.831	13,962
2016	Rocky Reach	W	0.287	0.012	0.584	10,871
2016	Wells	W	0.263	0.034	0.485	9,165
2017	Priest Rapids	H	0.770	0.057	1.000	6,507
2017	Rock Island	H	0.769	0.019	0.841	7,182
2017	Rocky Reach	H	0.802	0.017	0.750	5,762
2017	Wells	H	0.816	0.057	0.694	4,820
2017	Priest Rapids	W	0.230	0.070	1.000	6,507
2017	Rock Island	W	0.231	0.009	0.857	7,182
2017	Rocky Reach	W	0.198	0.012	0.621	5,762
2017	Wells	W	0.184	0.070	0.526	4,820
2018	Priest Rapids	H	0.657	0.081	1.000	5,804
2018	Rock Island	H	0.652	0.027	0.893	5,269
2018	Rocky Reach	H	0.701	0.027	0.770	3,951
2018	Wells	H	0.705	0.081	0.707	3,835
2018	Priest Rapids	W	0.343	0.051	1.000	5,804
2018	Rock Island	W	0.348	0.016	0.908	5,269
2018	Rocky Reach	W	0.299	0.018	0.630	3,951
2018	Wells	W	0.295	0.051	0.567	3,835
2019	Priest Rapids	H	0.699	0.048	1.000	4,909
2019	Rock Island	H	0.698	0.024	0.841	5,244
2019	Rocky Reach	H	0.725	0.032	0.777	4,283
2019	Wells	H	0.736	0.048	0.714	3,912
2019	Priest Rapids	W	0.301	0.011	1.000	4,909
2019	Rock Island	W	0.302	0.004	0.870	5,244
2019	Rocky Reach	W	0.275	0.028	0.684	4,283
2019	Wells	W	0.264	0.011	0.594	3,912
2020	Priest Rapids	H	0.468	0.066	1.000	3,911
2020	Rock Island	H	0.466	0.019	0.878	4,441

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Table 2: Estimated parameters used as inputs for Priest Rapids Dam count equivalents. (*continued*)

Year	Dam	Origin	π	η	ψ	Total Dam Count (C)
2020	Rocky Reach	H	0.516	0.016	0.775	3,333
2020	Wells	H	0.533	0.066	0.712	2,763
2020	Priest Rapids	W	0.532	0.026	1.000	3,911
2020	Rock Island	W	0.534	0.006	0.886	4,441
2020	Rocky Reach	W	0.484	0.022	0.640	3,333
2020	Wells	W	0.467	0.026	0.551	2,763
2021	Priest Rapids	H	0.653	0.031	1.000	6,509
2021	Rock Island	H	0.654	0.022	0.894	6,734
2021	Rocky Reach	H	0.717	0.014	0.780	5,397
2021	Wells	H	0.750	0.031	0.724	4,391
2021	Priest Rapids	W	0.347	0.029	1.000	6,509
2021	Rock Island	W	0.346	0.014	0.868	6,734
2021	Rocky Reach	W	0.283	0.026	0.574	5,397
2021	Wells	W	0.250	0.029	0.454	4,391

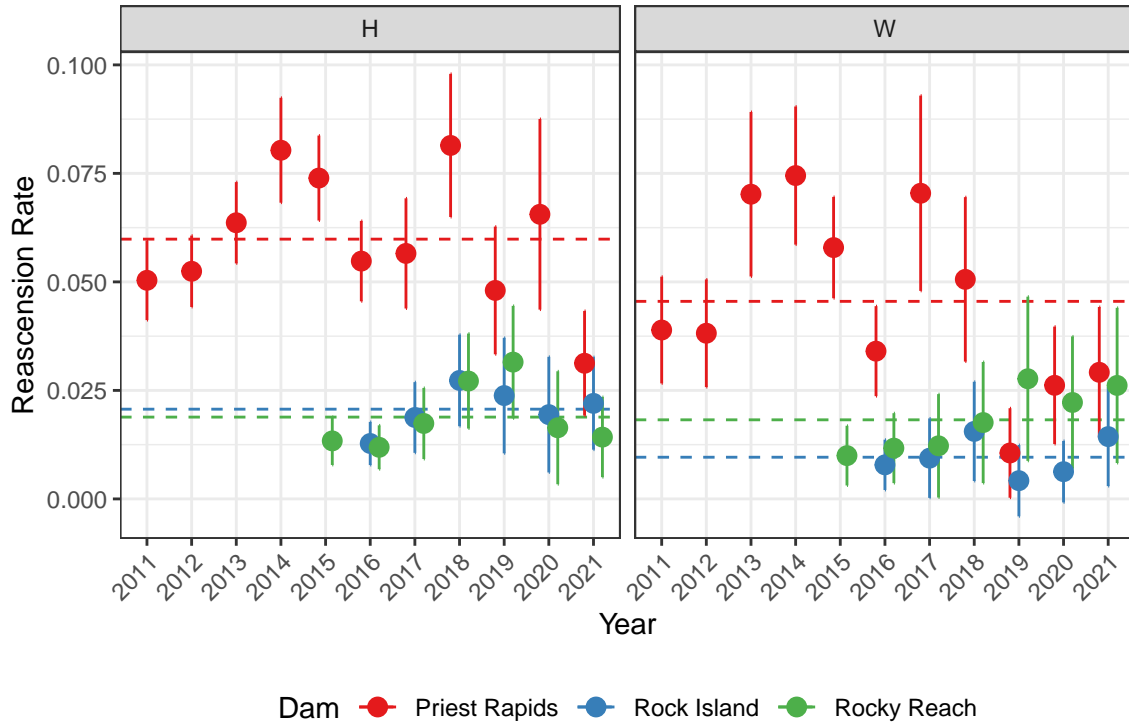


Figure 1: Estimates of re-ascension rates, colored by dam, with 95% confidence intervals, faceted by origin. Dashed lines represent mean rates across all years that are available.

Table 3: Estimates of the equivalent of total counts at Priest Rapids dam, and the relative difference compared to counts at Priest that year.

Year	Dam	Re-Ascension Available	Priest Count Equiv.	SE Count	Relative Difference (%)	SE Rel. Diff.
2011	Priest Rapids	TRUE	26,431	-	0.0	-
2011	Rock Island	FALSE	25,795	418	-2.4	1.6
2011	Rocky Reach	FALSE	26,431	487	0.0	1.8
2011	Wells	FALSE	23,792	502	-10.0	1.9
2012	Priest Rapids	TRUE	20,806	-	0.0	-
2012	Rock Island	FALSE	22,394	316	7.6	1.5
2012	Rocky Reach	FALSE	22,702	351	9.1	1.7
2012	Wells	FALSE	21,000	356	0.9	1.7
2013	Priest Rapids	TRUE	17,192	-	0.0	-
2013	Rock Island	FALSE	17,957	303	4.4	1.8
2013	Rocky Reach	FALSE	17,972	286	4.5	1.7
2013	Wells	FALSE	16,572	285	-3.6	1.7
2014	Priest Rapids	TRUE	15,072	-	0.0	-
2014	Rock Island	FALSE	14,548	268	-3.5	1.8
2014	Rocky Reach	FALSE	15,087	302	0.1	2.0
2014	Wells	FALSE	13,356	283	-11.4	1.9
2015	Priest Rapids	TRUE	19,659	-	0.0	-
2015	Rock Island	FALSE	18,724	318	-4.8	1.6
2015	Rocky Reach	TRUE	19,481	311	-0.9	1.6
2015	Wells	FALSE	15,904	283	-19.1	1.4
2016	Priest Rapids	TRUE	14,303	-	0.0	-
2016	Rock Island	TRUE	16,817	245	17.6	1.7
2016	Rocky Reach	TRUE	16,132	258	12.8	1.8
2016	Wells	FALSE	14,434	251	0.9	1.8
2017	Priest Rapids	TRUE	6,507	-	0.0	-
2017	Rock Island	TRUE	8,860	166	36.2	2.5
2017	Rocky Reach	TRUE	8,339	167	28.2	2.6
2017	Wells	FALSE	7,328	158	12.6	2.4
2018	Priest Rapids	TRUE	5,804	-	0.0	-
2018	Rock Island	TRUE	6,137	135	5.7	2.3
2018	Rocky Reach	TRUE	5,721	138	-1.4	2.4
2018	Wells	FALSE	5,788	149	-0.3	2.6
2019	Priest Rapids	TRUE	4,909	-	0.0	-
2019	Rock Island	TRUE	6,283	185	28.0	3.8
2019	Rocky Reach	TRUE	5,751	141	17.2	2.9
2019	Wells	FALSE	5,760	150	17.3	3.1
2020	Priest Rapids	TRUE	3,911	-	0.0	-
2020	Rock Island	TRUE	5,193	145	32.8	3.7
2020	Rocky Reach	TRUE	4,853	152	24.1	3.9

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Table 3: Estimates of the equivalent of total counts at Priest Rapids dam, and the relative difference compared to counts at Priest that year. *(continued)*

Year	Dam	Re-Ascension Available	Priest Count Equiv.	SE Count	Relative Difference (%)	SE Rel. Diff.
2020	Wells	FALSE	4,396	148	12.4	3.8
2021	Priest Rapids	TRUE	6,509	-	0.0	-
2021	Rock Island	TRUE	7,688	195	18.1	3.0
2021	Rocky Reach	TRUE	7,712	220	18.5	3.4
2021	Wells	FALSE	6,960	216	6.9	3.3

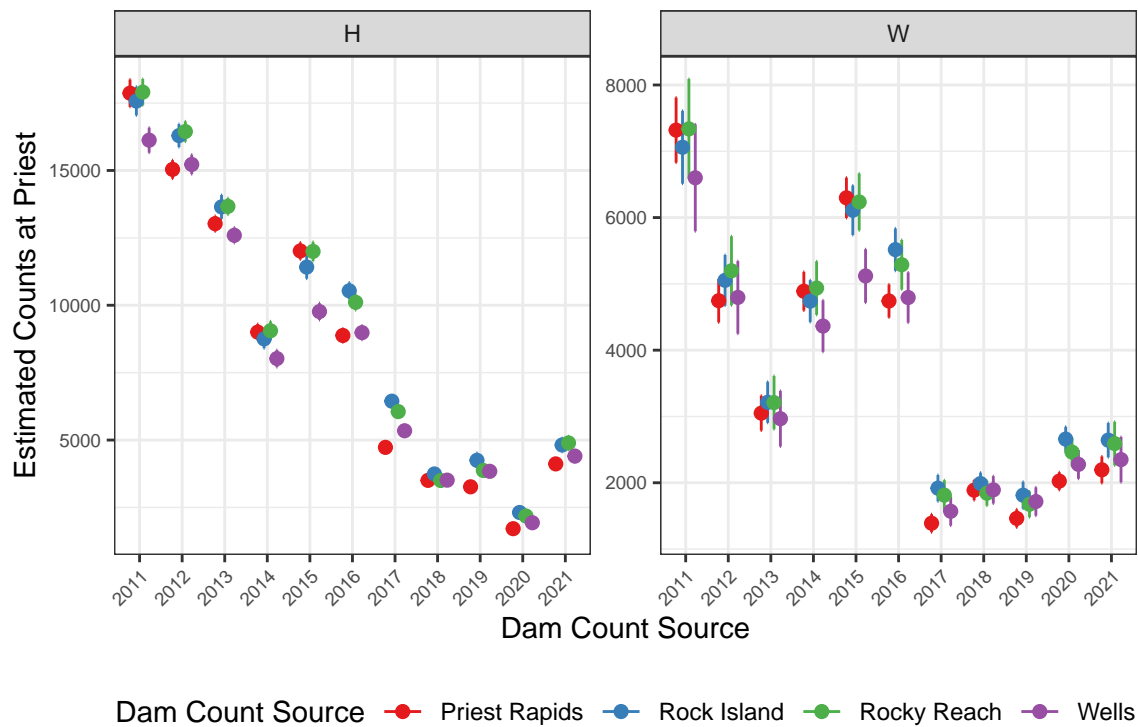


Figure 2: Estimates of unique number of fish crossing Priest Rapids dam, based on counts from different dams (colors). Facted by origin. Errorbars represent 95% confidence intervals.

Table 4: Comparison between using original estimate of escape-ment at Priest by origin with Priest equivalents from various dams. Relative difference would impact all abundance estimates from DABOM equally.

Year	Dam	Origin	Priest Equiv.	SE	Original Priest Est.	Relative Difference (%)
2011	Rock Island	H	17,575	272	17,868	-1.6
2011	Rock Island	W	7,061	281	7,319	-3.5

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Table 4: Comparison between using original estimate of escape-
ment at Priest by origin with Priest equivalents from various dams.
Relative difference would impact all abundance estimates from
DABOM equally. *(continued)*

Year	Dam	Origin	Priest Equiv.	SE	Original Priest Est.	Relative Difference (%)
2011	Rocky Reach	H	17,906	249	17,868	0.2
2011	Rocky Reach	W	7,337	384	7,319	0.2
2011	Wells	H	16,124	237	17,868	-9.8
2011	Wells	W	6,600	412	7,319	-9.8
2012	Rock Island	H	16,293	219	15,039	8.3
2012	Rock Island	W	5,053	195	4,746	6.5
2012	Rocky Reach	H	16,444	193	15,039	9.3
2012	Rocky Reach	W	5,197	266	4,746	9.5
2012	Wells	H	15,223	185	15,039	1.2
2012	Wells	W	4,796	279	4,746	1.0
2013	Rock Island	H	13,649	226	13,027	4.8
2013	Rock Island	W	3,214	158	3,050	5.4
2013	Rocky Reach	H	13,668	158	13,027	4.9
2013	Rocky Reach	W	3,209	205	3,050	5.2
2013	Wells	H	12,595	146	13,027	-3.3
2013	Wells	W	2,966	214	3,050	-2.7
2014	Rock Island	H	8,752	178	9,003	-2.8
2014	Rock Island	W	4,740	162	4,889	-3.1
2014	Rocky Reach	H	9,055	179	9,003	0.6
2014	Rocky Reach	W	4,937	206	4,889	1.0
2014	Wells	H	8,023	163	9,003	-10.9
2014	Wells	W	4,364	198	4,889	-10.7
2015	Rock Island	H	11,416	220	12,015	-5.0
2015	Rock Island	W	6,110	191	6,298	-3.0
2015	Rocky Reach	H	11,997	181	12,015	-0.1
2015	Rocky Reach	W	6,236	219	6,298	-1.0
2015	Wells	H	9,766	160	12,015	-18.7
2015	Wells	W	5,119	206	6,298	-18.7
2016	Rock Island	H	10,536	159	8,880	18.7
2016	Rock Island	W	5,516	163	4,742	16.3
2016	Rocky Reach	H	10,109	149	8,880	13.8
2016	Rocky Reach	W	5,289	191	4,742	11.5
2016	Wells	H	8,984	136	8,880	1.2
2016	Wells	W	4,794	194	4,742	1.1
2017	Rock Island	H	6,442	109	4,729	36.2
2017	Rock Island	W	1,918	102	1,390	38.1
2017	Rocky Reach	H	6,055	98	4,729	28.1
2017	Rocky Reach	W	1,813	115	1,390	30.5
2017	Wells	H	5,345	93	4,729	13.0
2017	Wells	W	1,570	110	1,390	13.0
2018	Rock Island	H	3,743	88	3,504	6.8
2018	Rock Island	W	1,988	84	1,888	5.3
2018	Rocky Reach	H	3,500	80	3,504	-0.1

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Table 4: Comparison between using original estimate of escapement at Priest by origin with Priest equivalents from various dams. Relative difference would impact all abundance estimates from DABOM equally. (*continued*)

Year	Dam	Origin	Priest Equiv.	SE	Original Priest Est.	Relative Difference (%)
2018	Rocky Reach	W	1,843	96	1,888	-2.4
2018	Wells	H	3,513	87	3,504	0.2
2018	Wells	W	1,893	106	1,888	0.2
2019	Rock Island	H	4,248	142	3,266	30.1
2019	Rock Island	W	1,812	103	1,463	23.9
2019	Rocky Reach	H	3,872	90	3,266	18.6
2019	Rocky Reach	W	1,675	100	1,463	14.5
2019	Wells	H	3,841	93	3,266	17.6
2019	Wells	W	1,717	109	1,463	17.4
2020	Rock Island	H	2,314	95	1,712	35.1
2020	Rock Island	W	2,658	95	2,025	31.3
2020	Rocky Reach	H	2,183	91	1,712	27.5
2020	Rocky Reach	W	2,462	110	2,025	21.6
2020	Wells	H	1,933	85	1,712	12.9
2020	Wells	W	2,277	111	2,025	12.5
2021	Rock Island	H	4,817	131	4,115	17.1
2021	Rock Island	W	2,643	132	2,195	20.4
2021	Rocky Reach	H	4,893	128	4,115	18.9
2021	Rocky Reach	W	2,591	168	2,195	18.0
2021	Wells	H	4,404	112	4,115	7.0
2021	Wells	W	2,349	174	2,195	7.0

Table 5: Mean relative difference (%) between escapement estimates using counts from these dams compared to Priest Rapids, by origin, separated into an early period (2011-2015) and late period (2016-2021).

Dam	Origin	Early	Late
Rock Island	H	0.74	24.00
Rock Island	W	0.45	22.55
Rocky Reach	H	2.98	17.79
Rocky Reach	W	2.99	15.63
Wells	H	-8.29	8.67
Wells	W	-8.20	8.53

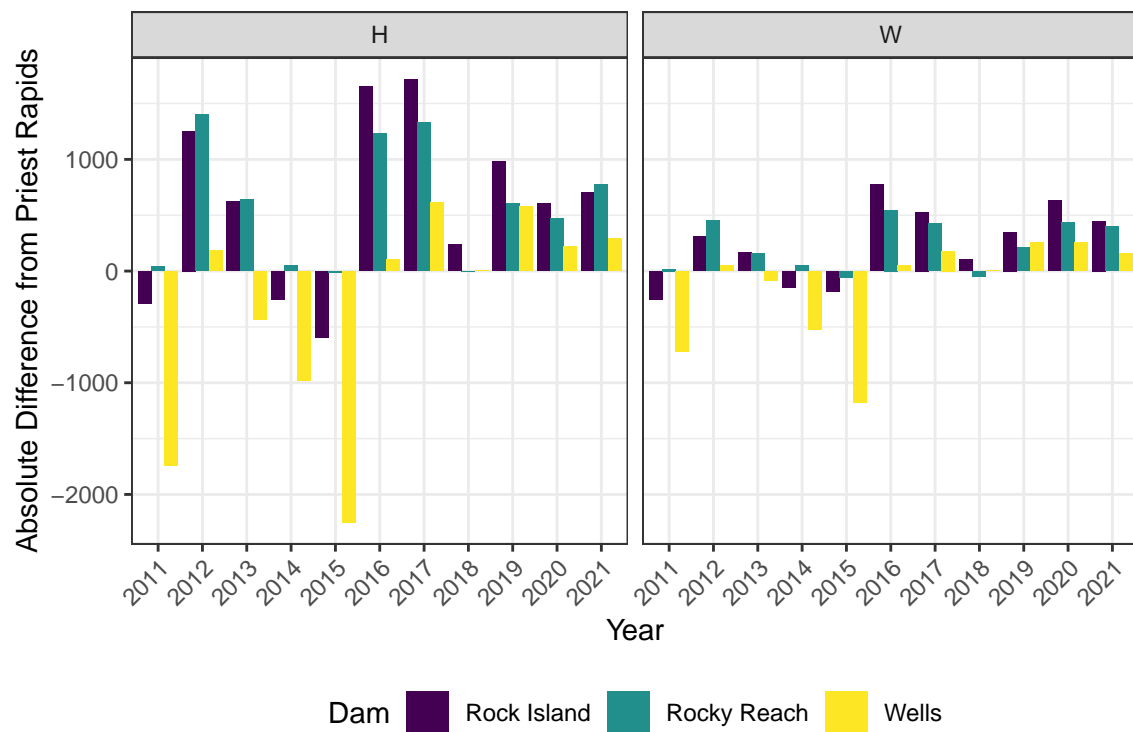


Figure 3: Absolute differences of the equivalent of total steelhead counts at Priest Rapids Dam, compared to using counts at Priest Rapids, using starting counts from different dams (colors), faceted by origin.

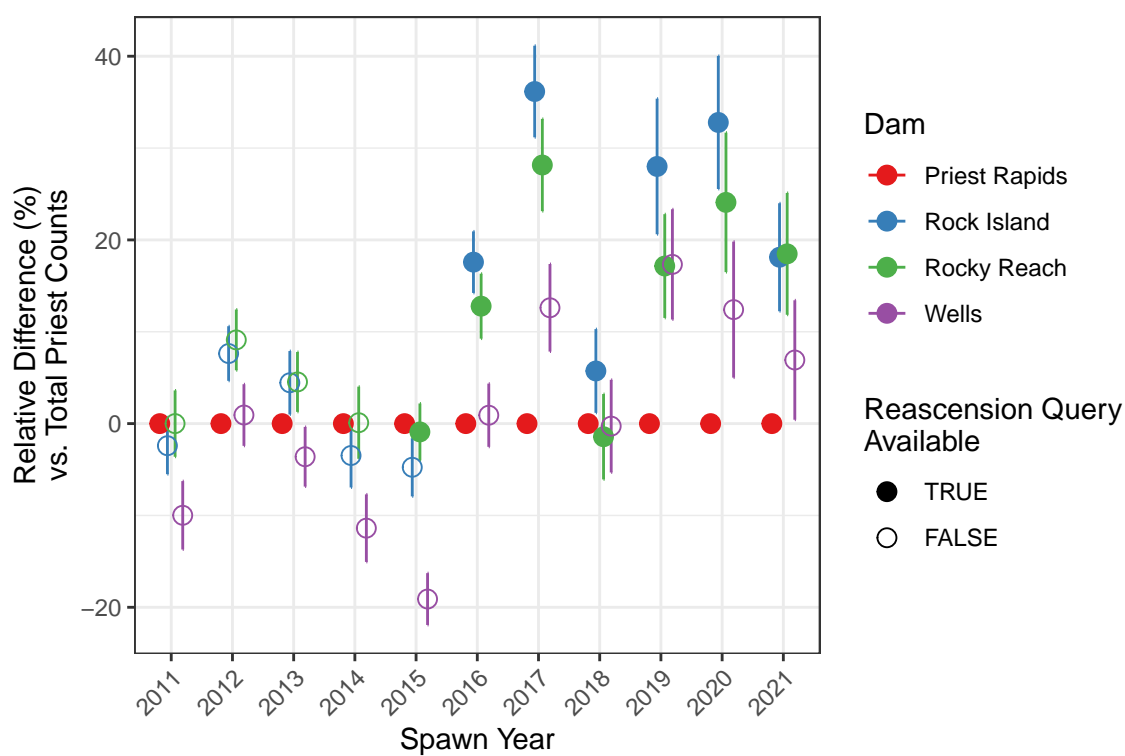


Figure 4: Relative differences of the equivalent of total steelhead counts at Priest Rapids Dam, using starting counts from different dams (colors), with 95% confidence intervals. The shape of each point depicts whether re-ascension data was available for that dam/year combination.

4 Discussion

In recent years, there appears to be some discrepancy between dam counts of steelhead at Priest Rapids dam, and those further upstream, particularly Rock Island and Rocky Reach. Focusing on Rock Island, the average differences have shifted from less than 1% in 2011-2015 to more than 20% in recent years (2016-2021). The choice of using counts at Priest Rapids or Rock Island will have a substantial impact on estimates of escapement throughout the Upper Columbia.

It is unclear exactly what has caused this shift in recent years. Although the counts for spawn year 2022 have not been completed, they show a large exasperation of this problem, with the raw counts being 60% higher at Rock Island compared to Priest Rapids, and nearly 40% higher at Rocky Reach, despite the loss of all the fish that turned up the Wenatchee between Rock Island and Rocky Reach.

Counts at Rock Island and Rocky Reach dams are overseen by Chelan County Public Utility District (PUD), while Grant County PUD is in charge of counts at Priest Rapids Dam, and Douglas County PUD runs the counts at Wells Dam. There is a lot of consistency between Rock Island and Rocky Reach estimates (Figures 2 and 4), suggesting operations at each dam may explain at least part of the differences between estimates.

While escapement estimates can be generated by any of these dam counts using the DABOM model, clearly the choice of dam to use will make a substantial impact (up to a 35% difference (Table 4). In addition, there may be other analyses that rely solely on counts from an individual dam, or a combination of counts from multiple dams. This evaluation has shown there is not consistency of counts between these dams in recent years, calling into question the results from any of those types of analyses.