

Run Size Forecast for Yakima River Adult Spring Chinook, 2024

Preliminary¹

Prepared by:
Bill Bosch and Ukesh Koju
Yakima Klickitat Fisheries Project
Yakama Nation Fisheries Resource Management
760 Pence Road
Yakima, Washington 98908

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¹ Some updates to 2023 age-at-return data are still pending. An updated forecast may be generated in February, 2024, but is not expected to differ substantially from this report.

Summary

In 2023 the forecast was for a return of 5,550 adult (age-4 and age-5) spring Chinook to the mouth of the Yakima River. The actual return in 2023 was estimated to be 2,670 adult spring Chinook (48% of forecast). Throughout the Columbia Basin, preseason forecasts are generally based on examination of brood cohort relationships projecting age-4 returns using the return survival of age-3 fish in a given brood, and similarly projecting age-5 returns from age-4 returns. However, over the past 1-3 decades high age-3 jack return abundance has not always been a reliable predictor of age-4 return abundance. Therefore, biologists and scientists throughout the region have been exploring other forecast methods to see if parameters such as NOAA ocean ecosystem indicators², jack size, or other variables can help explain and correct for ocean conditions or other factors that might affect the reliability of jacks as a predictor.

To produce the 2010-2023 Yakima River forecasts, we evaluated output from several different methods all of which used jack abundance in some combination with traditional cohort relationships, NOAA ocean ecosystem indicators, or jack size. These methods produced preliminary forecasts for 2024 age-4 and age-5 adult returns ranging from 2,400 to 9,300 spring Chinook. We have also been evaluating methods which use jack abundance or Prosser smolt estimates, juvenile survival estimates for natural- and hatchery-origin fish from Roza to McNary Dams, and NOAA ocean ecosystem indicator data as input variables to forecast combined age-4 and age-5 adult returns. These data are only available dating back to the 1997 brood year (1999 migration year), but were used to produce Yakima River forecasts for 10 of the 12 years between 2012 and 2023 and resulted in relatively good forecasts for 7 of these 10 years (range of absolute error 0.7% to 16.5%); in 4 of these 7 years the model forecast was adjusted by average error in the model. This method produced a raw forecast of 4,230 adult spring Chinook for 2024. This year, we also began to explore the potential of time series models to yield better forecasts (Appendix A).

In spite of its relatively good forecasting performance in some recent years, annual variability in freshwater and marine conditions causes uncertainty in output from the model using abundance, freshwater, and marine survival indices. In addition, a moderate-to-strong El Nino is forecast into the spring of 2024³, NOAA's ocean indicator data set indicates average ocean conditions experienced by spring Chinook returning in 2024, and jack returns to the Columbia Basin in 2023 were only 66% of the recent 10-year average. Therefore, we continue to be conservative in issuing a forecast using this method. The model selected for this year's forecast uses jack counts, juvenile freshwater survival indices, and NOAA ocean ecosystem indicators as inputs, adjusts the output by actual (compared to predicted) model performance, and produces a 2024 forecast of 2,370 adult spring Chinook. This result is very consistent with the average of 2,600 adults predicted from a variety of time series models (Appendix A). The 2024 forecast is 880 wild/natural and 1,490 hatchery-origin adult (age-4 and age-5) spring Chinook returns to the Yakima Basin (Table 1). Hatchery-origin returns are from the Cle Elum Supplementation and Research Facility (CESRF) in the Upper Yakima River which has been in operation since 1997.

² see <https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern>

³ see https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf
2024 Yakima River Spring Chinook Forecast, November 28, 2023

Table 1. Forecasted return of adult Spring Chinook to the Yakima River mouth in 2024 by age and stock.

Stock	Age-4	Age-5	Total Adults
Upper Yakima Natural	470	20	490
Upper Yakima CESRF	1,490	0	1,490
Naches/American Wild	230	160	390
Total Run	2,190	180	2,370
Total Wild/Natural	700	180	880
Total CESRF	1,490	0	1,490

The total 2024 forecasted return of 2,370 adult spring Chinook is similar to the actual 2023 adult return and 50% of the recent 10-year (2014-2023) average adult return of 4,740 spring Chinook.

Review of 2023 Yakima River spring Chinook return

The estimated spring Chinook return to the Yakima River mouth in 2023 was 2,670 (1,360 CESRF) adults and 660 (560 CESRF) jacks for a total return of 3,330 spring Chinook (Table 2). The final Prosser Dam counts were estimated to be: 2,650 adults (1,360 CESRF), and 680 jacks (560 CESRF) for a total count of 3,330 spring Chinook (Table 3). After reviewing Prosser and Roza counts, the estimated harvest between the two dams, and estimated spawning in the upper Yakima below Roza Dam, the final Prosser Dam counts were adjusted post-season to account for size and age differences and for fish that were assumed to have passed upstream (uncounted) during the course of the season. The final Roza Dam counts were: 2,230 adults (1,250 CESRF), and 630 jacks (560 CESRF) for a total count of 2,860 spring Chinook (Table 4). Age information from all available sampling data is used to reconstruct the river mouth run components, and to produce brood cohort tables for the forecast. Since age data from scale samples do not always agree with jack counts based on video or physical observations, adjustments are typically made during run reconstruction resulting in slight discrepancies between adult and jack river mouth run size estimates compared to Prosser Dam and harvest below Prosser Dam estimates, and between Prosser and Roza Dam estimates. The reader may also notice some discrepancies in CESRF and wild/natural count estimates throughout this report due to inherent inaccuracies involved with video-based mark sampling.

Harvest was estimated at 200 adults and no jacks. Harvest consisted of approximately 90 and 110 wild/natural and CESRF adults, respectively, with no fish harvested in fisheries below Prosser Dam (Table 5). Effort in Yakima River tribal fisheries has decreased in recent years with the low returns.

Estimated escapements were: 2,115 spring Chinook (540 jacks; approximately 71% of the total escapement was estimated to be returns from the CESRF) into the upper Yakima River subbasin (Tables 2 and 6), and 240 spring Chinook into the Naches River and its associated subbasins (Table 2). A total of about 340 redds were counted in the upper Yakima River subbasin and 60 redds were counted in the Naches River and its associated subbasins (Table 7).

Forecast for 2024 Yakima River spring Chinook return

Age-4:age-3 and age-5:age-4 cohort ratios and regression relationships for wild/natural fish in the upper Yakima and Naches subbasins independently and for the aggregate Yakima River return were reviewed for all brood years dating back to 1982 (Tables 8-10). Similar relationships were analyzed for CESRF brood returns since 1997 (Table 11). Since most Yakima River spring Chinook return at age-4, the survival of age-3 fish (jacks) in the previous year are the primary driver in these forecasting techniques. Similar to many recent years, a regression of jack counts and survival indices for adult return years 2001-2023 was used to produce the 2024 Yakima River forecast for both natural- and hatchery-origin fish (Tables 12 and 13). This method was adjusted by actual (relative to modeled) performance and results in a conservative forecast at the lower end of values for all forecast methods evaluated (Table 14). Age and stock specific regressions were then used to apportion the aggregate natural-origin forecast into its component parts. This method projects returns for 2024 spring Chinook to the Yakima River mouth of: 2,190 age-4 and 180 age-5 fish for a total projected return of 2,370 adult spring Chinook. The forecast includes 880 wild/natural (37%) and 1,490 CESRF-origin (63%) adult (age-4 and age-5) spring Chinook returns to the Yakima Basin in 2024.

This method is similar to that used to produce Yakima River forecasts for 10 of the past 12 years and resulted in relatively good forecasts in 7 of those 10 years (range of absolute error 0.7% to 16.5%; Table 15). Note also that a variety of factors can affect the Yakima River mouth return rate of CESRF fish relative to their natural counterparts. These factors include: year-to-year variances in release numbers (Table 16), mark-selective fisheries in the lower Columbia River which target adipose-fin-clipped fish (all CESRF fish are adipose-clipped), variances in freshwater and ocean survival, and climate change impacts such as the thermal barriers in the lower Yakima River observed in large portions of the spring Chinook return timing since 2015.

Acknowledgements

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Table 2. Yakima River Spring Chinook Run (CESRF and wild/natural, Adults and Jacks combined) Reconstruction, 1995-Present.

Year	River Mouth Run Size ¹			Harvest		Harvest		Spawners			Est. Escapement		Redd Counts	
	Adults	Jacks	Total	Below Prosser	Prosser Count	Above Prosser	Below Roza ²	Roza Count	Roza Removals ³	Upper Y.R. ⁴	Naches ⁵	Upper Y.R.	Naches	
1995	526	140	666	0	666	79	9	355	0	355	223	114	104	
1996	3,060	119	3,179	100	3,079	375	26	1,631	0	1,631	1,047	801	184	
1997	3,092	81	3,173	0	3,173	575	20	1,445	261	1,184	1,133	413	339	
1998	1,771	132	1,903	0	1,903	188	3	795	408	387	917	147	330	
1999	1,513	1,268	2,781	8	2,773	596	55	1,704	738	966	418	212	186	
2000	17,519	1,582	19,101	90	19,011	2,368	204	12,327	667	11,660	4,112	3,770	888	
2001	21,225	2,040	23,265	1,793	21,472	2,838	289	12,516	718	11,798	5,829	3,226	1,192	
2002	14,616	483	15,099	328	14,771	2,780	29	8,922	878	8,044	3,041	2,816	943	
2003	4,868	2,089	6,957	59	6,898	381	83	3,842	584	3,258	2,592	868	935	
2004	13,974	1,315	15,289	135	15,154	1,544	90	11,005	718	10,287	2,515	3,414	719	
2005	8,059	699	8,758	34	8,724	440	28	6,352	667	5,685	1,904	2,009	574	
2006	5,951	363	6,314	0	6,314	600	14	4,028	664	3,364	1,672	1,245	447	
2007	2,968	1,335	4,303	10	4,293	269	13	3,025	716	2,309	986	722	313	
2008	6,615	1,983	8,598	539	8,059	993	9	5,478	1,144	4,334	1,578	1,372	495	
2009	7,441	4,679	12,120	1,517	10,603	836	18	8,633	1,595	7,038	1,117	1,575	482	
2010	11,027	2,114	13,142	156	12,986	1,585	9	9,900	1,526	8,374	1,491	2,668	552	
2011	13,398	4,561	17,960	909	17,051	3,471	0	10,520	1,936	8,584	3,060	1,898	580	
2012	11,083	970	12,053	1,331	10,722	1,989	7	6,826	1,350	5,476	1,900	1,468	811	
2013	7,101	3,144	10,245	1,191	9,054	1,462	171	6,053	1,240	4,813	1,369	648	376	
2014	8,850	2,472	11,322	221	11,101	1,950	23	7,997	1,269	6,728	1,130	1,149	379	
2015	8,795	556	9,351	83	9,268	732	0	6,433	967	5,466	2,103	1,321	614	
2016	5,517	1,399	6,916	24	6,892	420	42	5,098	859	4,239	1,332	611	366	
2017	5,462	1,701	7,163	122	7,041	1,150	25	4,193	876	3,317	1,673	539	293	
2018	3,156	448	3,605	251	3,353	297	18	2,404	605	1,799	634	348	128	
2019	1,757	466	2,222	0	2,222	40	17	2,007	516	1,491	158	235	31	
2020	2,833	529	3,362	24	3,338	44	24	2,211	571	1,640	1,059	237	146	
2021	2,924	998	3,922	0	3,922	16	37	3,274	548	2,726	594	256	188	
2022	5,431	724	6,155	0	6,155	471	26	4,410	861	3,549	1,249	494	330	
2023	2,671	663	3,334	0	3,334	196	38	2,862	747	2,115	238	335	61	

1. River Mouth run size is the greater of the Prosser count plus lower river harvest or estimated escapement plus all known harvest and removals.
2. Estimated as the average number of fish per redd in the upper Yakima times the number of redds between the Naches confluence and Roza Dam.
3. Roza removals include harvest above Roza, hatchery removals, and/or natural broodstock removals.
4. Estimated escapement into the upper Yakima River is the Roza count less harvest or broodstock removals above Roza Dam except in 1991 when Upper Yakima River escapement is estimated as the (Prosser count - harvest above Prosser - Roza subtractions) times the proportion of redds counted in the upper Yakima.
5. Naches River escapement is estimated as the Prosser count less harvest above Prosser and the Roza counts, except in 1983 and 1990 when it is estimated as the upper Yakima fish/redd times the Naches redd count.

Table 3. Estimated Spring Chinook counts at Prosser Dam, 1991-Present.

Year	Adults		Jacks			Total Passage			Actual	Forecast	
	CESRF	Wild/Nat. ²	Total	CESRF	Wild/Nat. ²	Total	Total	Wild/Nat. ²	CESRF	CESRF	
									Percent	Percent	
1991			2,750			129	2,879				
1992			4,282			133	4,415				
1993			3,795			80	3,875				
1994			1,283			19	1,302				
1995			528			138	666				
1996			2,946			133	3,079				
1997			3,126			47	3,173				
1998			1,771			132	1,903				
1999			1,795			978	2,773				
2000	41 ¹	17,381	17,422	741	848	1,589	19,011	18,229			
2001	7,803	11,960	19,763	1,087	622	1,709	21,472	12,582	8,890	41.4%	38.3%
2002	7,393	6,661	14,054	369	348	717	14,771	7,009	7,762	52.5%	56.6%
2003	1,257	3,742	4,999	989	910	1,899	6,898	4,652	2,246	32.6%	20.6%
2004	4,195	10,218	14,413	170	571	741	15,154	10,789	4,365	28.8%	41.2%
2005	737	7,160	7,897	540	287	827	8,724	7,447	1,277	14.6%	17.7%
2006	2,448	3,563	6,012	151	151	302	6,314	3,714	2,599	41.2%	31.3%
2007	823	2,044	2,867	866	560	1,426	4,293	2,604	1,689	39.3%	15.9%
2008	3,264	3,127	6,391	1,169	499	1,668	8,059	3,626	4,433	55.0%	48.3%
2009	3,039	3,590	6,629	3,183	791	3,974	10,603	4,381	6,222	58.7%	55.7%
2010	6,601	4,327	10,928	1,491	567	2,058	12,986	4,894	8,092	62.3%	71.9%
2011	5,705	7,043	12,748	2,770	1,533	4,303	17,051	8,576	8,475	49.7%	39.9%
2012	4,715	5,206	9,921	475	326	801	10,722	5,532	5,190	48.4%	47.2%
2013	2,665	3,841	6,506	1,461	1,087	2,548	9,054	4,928	4,126	45.6%	44.2%
2014	3,643	5,061	8,704	1,430	967	2,397	11,101	6,028	5,073	45.7%	36.8%
2015	2,690	6,035	8,725	241	302	543	9,268	6,337	2,931	31.6%	42.3%
2016	1,741	3,639	5,380	957	555	1,512	6,892	4,194	2,698	39.1%	32.8%
2017	2,159	3,181	5,340	1,209	492	1,701	7,041	3,673	3,368	47.8%	43.7%
2018	1,536	1,436	2,972	309	72	381	3,353	1,508	1,845	55.0%	31.5%
2019	1,000	798	1,798	326	98	424	2,222	896	1,326	59.7%	57.9%
2020	1,091	1,778	2,869	390	79	469	3,338	1,857	1,481	44.4%	48.8%
2021	1,291	1,666	2,957	769	196	965	3,922	1,862	2,060	52.5%	45.7%
2022	2,281	3,278	5,559	419	177	596	6,155	3,455	2,700	43.9%	60.7%
2023	1,360	1,289	2,649	562	123	685	3,334	1,412	1,922	57.6%	35.9%

1. There were no CESRF adults returning in 2000. These are marked fish, presumably out-of-basin strays.
2. All fish prior to 2000 are assumed to be wild.

Table 4. Estimated Spring Chinook counts at Roza Dam, 1982-Present.
(total counts including fish collected and removed for broodstock)

Year	Adults			Jacks			Total Passage
	CESRF	Wild/Nat. ¹	Total	CESRF	Wild/Nat. ¹	Total	
1982			1,057			89	1,146
1983			860			147	1,007
1984			1,371			248	1,619
1985			2,189			239	2,428
1986			2,979			288	3,267
1987			1,854			74	1,928
1988			1,467			108	1,575
1989			2,375			141	2,515
1990			2,007			40	2,047
1991			No counts available				
1992			2,965			62	3,027
1993			1,795			74	1,869
1994			554			9	563
1995			280			75	355
1996			1,576			55	1,631
1997			1,396			49	1,445
1998			740			55	795
1999			879			825	1,704
2000		11,109	11,109	688	530	1,218	12,327
2001	6,180	5,010	11,190	990	336	1,326	12,516
2002	6,298	2,405	8,703	86	133	219	8,922
2003	1,151	784	1,935	1,133	774	1,907	3,842
2004	2,985	7,093	10,078	216	711	927	11,005
2005	726	4,876	5,602	540	210	750	6,352
2006	1,851	1,906	3,757	127	144	271	4,028
2007	899	1,101	2,000	833	192	1,025	3,025
2008	2,678	1,419	4,097	1,123	258	1,381	5,478
2009	2,860	2,294	5,154	2,743	736	3,479	8,633
2010	5,509	2,752	8,261	1,206	433	1,639	9,900
2011	4,280	3,444	7,724	1,845	951	2,796	10,520
2012	3,552	2,704	6,256	350	220	570	6,826
2013	2,112	2,074	4,186	1,157	710	1,867	6,053
2014	2,774	3,445	6,219	1,055	723	1,778	7,997
2015	2,260	3,775	6,035	211	187	398	6,433
2016	1,564	2,431	3,995	822	281	1,103	5,098
2017	1,651	1,492	3,143	831	219	1,050	4,193
2018	1,296	767	2,063	281	60	341	2,404
2019	985	608	1,593	319	95	414	2,007
2020	863	886	1,749	390	72	462	2,211
2021	1,291	1,018	2,309	769	196	965	3,274
2022	1,922	1,942	3,864	416	130	546	4,410
2023	1,254	973	2,227	562	73	635	2,862

1. All fish prior to 2000 are assumed to be wild.

Table 5. Spring Chinook Harvest (adults and jacks combined) in the Yakima River Basin, 1982-Present.

Year	Tribal		Non-Tribal		River Totals		Total	Harvest Rate ¹
	CESRF	Wild/Nat.	CESRF	Wild/Nat.	CESRF	Wild/Nat.		
1982	0	434	0	0	0	434	434	23.8%
1983	0	84	0	0	0	84	84	5.8%
1984	0	289	0	0	0	289	289	10.9%
1985	0	865	0	0	0	865	865	19.0%
1986	0	1,340	0	0	0	1,340	1,340	14.2%
1987	0	517	0	0	0	517	517	11.6%
1988	0	444	0	0	0	444	444	10.5%
1989	0	747	0	0	0	747	747	15.2%
1990	0	663	0	0	0	663	663	15.2%
1991	0	32	0	0	0	32	32	1.1%
1992	0	345	0	0	0	345	345	7.5%
1993	0	129	0	0	0	129	129	3.3%
1994	0	25	0	0	0	25	25	1.9%
1995	0	79	0	0	0	79	79	11.9%
1996	0	475	0	0	0	475	475	14.9%
1997	0	575	0	0	0	575	575	18.1%
1998	0	188	0	0	0	188	188	9.9%
1999	0	604	0	0	0	604	604	21.7%
2000	53	2,305	0	100	53	2,405	2,458	12.9%
2001	572	2,034	1,252	772	1,825	2,806	4,630	19.9%
2002	1,373	1,207	492	36 ²	1,865	1,243	3,108	20.6%
2003	134	306	0	0	134	306	440	6.3%
2004	289	712	569	109 ²	858	820	1,679	11.0%
2005	46	428	0	0	46	428	474	5.4%
2006	246	354	0	0	246	354	600	9.5%
2007	123	156	0	0	123	156	279	6.5%
2008	521	414	586	11 ²	1,107	425	1,532	17.8%
2009	1,089	715	541	8 ²	1,630	723	2,353	19.4%
2010	345	194	1,154	48 ²	1,499	241	1,741	13.2%
2011	1,361	1,261	1,579	179 ²	2,940	1,440	4,380	24.4%
2012	1,220	1,302	735	63 ²	1,955	1,364	3,320	27.5%
2013	846	975	786	46 ²	1,632	1,021	2,653	25.9%
2014	576	715	826	54 ²	1,402	769	2,171	19.2%
2015	121	271	385	38 ²	506	309	815	8.7%
2016	103	185	132	24 ²	235	209	444	6.4%
2017	217	201	750	104 ²	967	305	1,272	17.8%
2018	154	115	259	20 ²	413	136	548	15.2%
2019	24	16	0	0	24	16	40	1.8%
2020	26	42	0	0	26	42	68	2.0%
2021	9	7	0	0	9	7	16	0.4%
2022	61	85	300	25	361	110	471	7.7%
2023	61	58	52	25	113	83	196	5.9%

1. Harvest rate is the river total harvest as a percentage of the river mouth run size given in Table 1.
2. Estimate of post-release mortality of unmarked fish.

Table 6. Escapement (Roza Dam counts less brood stock collection and harvest above Roza) of natural- (NoR) and hatchery-origin (HoR) spring Chinook to the upper Yakima subbasin, 1982 – present.

Year	Wild/Natural (NoR)			CESRF (HoR)			Total			PHOS ¹	PNI ¹
	Adults	Jacks	Total	Adults	Jacks	Total	Adults	Jacks	Total		
1982			1,146								
1983			1,007								
1984			1,535								
1985			2,331								
1986			3,251								
1987			1,734								
1988			1,340								
1989			2,331								
1990			2,016								
1991			1,583 ²								
1992			3,009								
1993			1,869								
1994			563								
1995			355								
1996			1,631								
1997	1,141	43	1,184								
1998	369	18	387								
1999	498	468	966								
2000	10,491	481	10,972		688	688	10,491	1,169	11,660	5.9%	
2001	4,454	297	4,751	6,065	982	7,047	10,519	1,279	11,798	59.7%	62.6%
2002	1,820	89	1,909	6,064	71	6,135	7,884	160	8,044	76.3%	56.7%
2003	394	723	1,117	1,036	1,105	2,141	1,430	1,828	3,258	65.7%	60.3%
2004	6,536	671	7,207	2,876	204	3,080	9,412	875	10,287	29.9%	77.0%
2005	4,401	175	4,576	627	482	1,109	5,028	657	5,685	19.5%	83.7%
2006	1,510	121	1,631	1,622	111	1,733	3,132	232	3,364	51.5%	66.0%
2007	683	161	844	734	731	1,465	1,417	892	2,309	63.4%	61.2%
2008	988	232	1,220	2,157	957	3,114	3,145	1,189	4,334	71.9%	58.2%
2009	1,843	701	2,544	2,234	2,260	4,494	4,077	2,961	7,038	63.9%	61.0%
2010	2,436	413	2,849	4,524	1,001	5,525	6,960	1,414	8,374	66.0%	60.2%
2011	3,092	926	4,018	3,162	1,404	4,566	6,254	2,330	8,584	53.2%	65.3%
2012	2,359	191	2,550	2,661	265	2,926	5,020	456	5,476	53.4%	65.2%
2013	1,708	678	2,386	1,587	840	2,427	3,295	1,518	4,813	50.4%	66.5%
2014	3,099	685	3,784	2,150	794	2,944	5,249	1,479	6,728	43.8%	69.6%
2015	3,357	163	3,520	1,779	167	1,946	5,136	330	5,466	35.6%	73.7%
2016	2,070	266	2,336	1,198	705	1,903	3,268	971	4,239	44.9%	69.0%
2017	1,135	194	1,329	1,328	660	1,988	2,463	854	3,317	59.9%	62.5%
2018	500	33	533	1,033	233	1,266	1,533	266	1,799	70.4%	58.7%
2019	316	81	397	828	266	1,094	1,144	347	1,491	73.4%	57.7%
2020	497	56	553	746	341	1,087	1,243	397	1,640	66.3%	60.1%
2021	618	184	802	1,190	734	1,924	1,808	918	2,726	70.6%	58.6%
2022	1,575	120	1,695	1,521	333	1,854	3,096	453	3,549	52.2%	65.7%
2023	565	53	618	1,014	483	1,497	1,579	536	2,115	70.8%	58.6%
Mean ³	2,165	305	2,470	2,093	659	2,665	3,948	890	4,838	54.9%	64.3%

1. Proportionate Natural Influence equals Proportion Natural-Origin Broodstock (PNOB; 1.0 as only NoR fish are used for supplementation line brood stock) divided by PNOB plus Proportion Hatchery-Origin Spawners (PHOS).
2. This is a rough estimate since Roza counts are not available for 1991.
3. For NoR columns, mean of 1997-present values. For all other columns, mean of 2001-present values.

Table 7. Yakima Basin spring Chinook redd count summary, 1982 – present.

Year	Upper Yakima River System ¹				Naches River System				
	Mainstem ²	Cle Elum	Teaway	Total	American	Naches ²	Bumping	Little Naches	Total
1982	610	30	0	640	11	25	6	12	54
1983	387	15	0	402	36	27	11	9	83
1984	677	31	0	708	72	81	26	41	220
1985	795	153	3	951	141	168	74	44	427
1986	1,716	77	0	1,793	464	543	196	110	1,313
1987	968	75	0	1,043	222	281	133	41	677
1988	369	74	0	443	187	145	111	47	490
1989	770	192	6	968	187	200	101	53	541
1990	727	46	0	773	143	159	111	51	464
1991	568	62	0	630	170	161	84	45	460
1992	1,082	164	0	1,246	120	155	99	51	425
1993	550	105	1	656	214	189	88	63	554
1994	226	64	0	290	89	93	70	20	272
1995	105	12	0	117	46	25	27	6	104
1996	711	100	3	814	28	102	29	25	184
1997	364	56	0	420	111	108	72	48	339
1998	123	24	1	148	149	104	54	23	330
1999	199	24	1	224	27	95	39	25	186
2000	3,349	466	21	3,836	54	483	278	73	888
2001	2,910	374	21	3,305	392	436	257	107	1,192
2002	2,441	275	110	2,826	366	226	262	89	943
2003	772	87	31	890	430	228	216	61	935
2004	2,985	330	129	3,444	91	348	205	75	719
2005	1,717	287	15	2,019	140	203	163	68	574
2006	1,092	100	58	1,250	136	163	115	33	447
2007	665	51	10	726	166	60	60	27	313
2008	1,191	137	47	1,375	158	165	102	70	495
2009	1,349	197	33	1,579	92	159	163	68	482
2010	2,199	219	253	2,671	173	171	168	40	552
2011	1,663	171	64	1,898	212	145	175	48	580
2012	1,276	125	69	1,470	337	196	189	89	811
2013	552	85	34	671	170	66	85	55	376
2014	962	138	53	1,153	129	65	158	27	379
2015	1,258	39	24	1,321	239	177	152	46	614
2016	512	83	22	617	149	106	74	37	366
2017	402	118	23	543	123	84	56	30	293
2018	339	13	0	352	27	56	44	1	128
2019	185	44	9	238	21	1	2	7	31
2020	189	44	8	241	44	25	71	6	146
2021	237	18	5	260	79	59 ³	49 ³	0	187
2022	426	40	32	498	198	85	45	2	330
2023	273	65	3	341	29	12	20	0	61
Mean	933	113	25	1,072	150	150	104	42	445

¹ Yakima River redd counts include redds between the Naches River confluence and Roza Dam. In some years, water conditions preclude accurate counts in this reach and the number of redds is estimated using historical proportions for this reach.

² Including minor tributaries.

³ Surveys in the Bumping R., Rattlesnake Cr., and upper Nile watershed precluded due to fire; used recent 5-yr average.

Table 8. Brood Table for Upper Yakima wild/natural stock.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns				Returns/ Spawner
		Age-3	Age-4	Age-5	Total	
1982	1,280	324	4,016	411	4,751	3.71
1983	1,125	408	1,882	204	2,494	2.22
1984	1,715	92	1,348	139	1,578	0.92
1985	2,578	114	2,746	105	2,965	1.15
1986	3,960	171	2,574	149	2,893	0.73
1987	2,003	53	1,571	109	1,733	0.87
1988	1,400	53	3,138	132	3,323	2.37
1989	2,466	68	1,779	9	1,856	0.75
1990	2,298	79	566	0	645	0.28
1991	1,713	9	326	22	358	0.21
1992	3,048	87	1,861	95	2,043	0.67
1993	1,925	66	1,606	57	1,729	0.90
1994	573	60	737	92	890	1.55
1995	364	59	1,036	129	1,224	3.36
1996	1,657	1,059	12,882	630	14,571	8.79
1997	1,204	621	5,839	155	6,615	5.49
1998	390	434	2,803	145	3,381	8.68
1999	1,021 ¹	164	722	45	930	0.91
2000	11,864	856	7,689	127	8,672	0.73
2001	12,087	775	5,074	222	6,071	0.50
2002	8,073	224	1,875	148	2,247	0.28
2003	3,341 ¹	158	1,036	63	1,257	0.38
2004	10,377	207	1,547	75	1,828	0.18
2005	5,713	293	2,630	14	2,936	0.51
2006	3,378	868	2,887	133	3,888	1.15
2007	2,322	456	3,976	65	4,498	1.94
2008	4,343	1,135	3,410	123	4,668	1.07
2009	7,056 ¹	283	2,572	109	2,964	0.42
2010	8,383	923	3,854	59	4,836	0.58
2011	8,584	832	3,908	144	4,883	0.57
2012	5,483	197	2,445	20	2,662	0.49
2013	4,984	299	1,622	36	1,957	0.39
2014	6,751	241	814	12	1,067	0.16
2015	5,466	66	620	14	701	0.13
2016	4,281	99	905	52	1,056	0.25
2017	3,342	75	994	14 ²	1,082	0.32
2018	1,817	201	2,012	0 ²	2,213 ²	1.22 ²
2019	1,508	136	1,067 ²			
2020	1,664	80 ²				
2021	2,763					
2022	3,574					
2023	2,153 ²					

1. Approximately 45-50% of these fish were jacks.
2. Preliminary.

Table 9. Brood Table for Naches/American wild stock.

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns					Returns/ Spawner
		Age-3	Age-4	Age-5	Age-6	Total	
1982	108	127	1,274	601	0	2,002	18.54
1983	232	190	1,257	1,257	8	2,713	11.68
1984	570	164	1,109	1,080	0	2,354	4.13
1985	1,020	213	667	931	0	1,811	1.77
1986	4,123	103	670	852	31	1,657	0.40
1987	1,729	39	231	400	0	669	0.39
1988	2,167	51	815	1,557	11	2,434	1.12
1989	1,517	39	332	371	0	741	0.49
1990	1,380	40	326	168	0	533	0.39
1991	1,121	10	32	144	127	314	0.28
1992	1,188	52	1,034	661	0	1,747	1.47
1993	1,865	53	603	817	17	1,489	0.80
1994	704	21	160	167	0	348	0.49
1995	223	73	201	498	0	771	3.46
1996	1,047	209	4,010	2,359	0	6,579	6.29
1997	1,133	220	4,644	1,377	0	6,241	5.51
1998	917	364	2,167	2,316	12	4,859	5.30
1999	418 ¹	185	369	279	0	833	1.99
2000	4,112	131	2,286	346	0	2,762	0.67
2001	5,829	144	1,598	785	0	2,526	0.43
2002	3,041	78	975	443	0	1,496	0.49
2003	2,592	75	387	1,028	0	1,489	0.57
2004	2,515	227	514	232	0	973	0.39
2005	1,904	246	845	268	0	1,359	0.71
2006	1,672	237	1,120	759	0	2,117	1.27
2007	986	182	2,239	1,033	0	3,454	3.50
2008	1,578	653	1,262	803	0	2,718	1.72
2009	1,117	144	542	116	0	802	0.72
2010	1,491	381	972	412	0	1,766	1.18
2011	3,060	208	1,693	559	0	2,459	0.80
2012	1,900	105	662	540	0	1,307	0.69
2013	1,369	186	1,046	226	0	1,459	1.07
2014	1,130	245	439	49	0	733	0.65
2015	2,103	33	96	355	0	484	0.23
2016	1,332	18	688	169	0	875	0.66
2017	1,673	46	372	418	0	837	0.50
2018	634	64	811	80 ²		955 ²	1.51 ²
2019	158	66	156 ²				
2020	1,059	23 ²					
2021	594						
2022	1,249						
2023	238 ²						

1. Approximately 48% of these fish were jacks.
2. Preliminary.

Table 10. Brood Table for Yakima River aggregate (wild/natural).

Brood Year	Estimated Spawners	Estimated Yakima R. Mouth Returns					Returns/ Spawner
		Age-3	Age-4	Age-5	Age-6	Total	
1982	1,388	451	5,290	1,012	0	6,753	4.86
1983	1,357	598	3,138	1,461	8	5,206	3.84
1984	2,285	256	2,457	1,219	0	3,932	1.72
1985	3,598	327	3,412	1,037	0	4,776	1.33
1986	8,083	274	3,244	1,000	31	4,550	0.56
1987	3,732	92	1,802	508	0	2,402	0.64
1988	3,567	104	3,953	1,689	11	5,757	1.61
1989	3,983	107	2,111	379	0	2,597	0.65
1990	3,678	119	892	168	0	1,178	0.32
1991	2,834	20	358	166	127	672	0.24
1992	4,236	140	2,894	756	0	3,790	0.89
1993	3,790	119	2,209	874	17	3,218	0.85
1994	1,277	81	897	260	0	1,238	0.97
1995	587	132	1,236	627	0	1,995	3.40
1996	2,704	1,268	16,892	2,989	0	21,150	7.82
1997	2,337	841	10,482	1,532	0	12,855	5.50
1998	1,307	798	4,970	2,460	12	8,240	6.30
1999	1,439 ¹	349	1,091	324	0	1,764	1.23
2000	15,976	987	9,975	472	0	11,434	0.72
2001	17,916	919	6,671	1,007	0	8,597	0.48
2002	11,113	302	2,849	592	0	3,743	0.34
2003	5,933 ²	233	1,423	1,091	0	2,746	0.46
2004	12,893	434	2,061	307	0	2,802	0.22
2005	7,617	539	3,475	281	0	4,295	0.56
2006	5,050	1,105	4,007	892	0	6,004	1.19
2007	3,308 ²	638	6,216	1,098	0	7,952	2.40
2008	5,922	1,787	4,672	926	0	7,385	1.25
2009	8,172	426	3,115	225	0	3,766	0.46
2010	9,875	1,303	4,826	472	0	6,602	0.67
2011	11,644	1,040	5,601	703	0	7,343	0.63
2012	7,383	302	3,107	560	0	3,969	0.54
2013	6,352	485	2,668	262	0	3,415	0.54
2014	7,882	486	1,253	61	0	1,800	0.23
2015	7,569	100	716	369	0	1,185	0.16
2016	5,613	117	1,593	222	0	1,931	0.34
2017	5,015	121	1,366	432	0	1,919	0.38
2018	2,451	265	2,822	80 ³		3,168 ³	1.29 ³
2019	1,666	202	1,222 ³				
2020	2,723	103 ³					
2021	3,358						
2022	4,823						
2023	2,391 ³						

1. Approximately 48% of these fish were jacks.
2. Approximately 36% of these fish were jacks.
3. Preliminary.

Table 11. Brood Table for Cle Elum SRF Spring Chinook.

Brood Year	Estimated Spawners ¹	Estimated Yakima R. Mouth Returns				Returns/ Spawner
		Age-3	Age-4	Age-5	Total	
1997	261	741	7,753	176	8,670	33.22
1998	408	1,242	7,939	602	9,782	23.98
1999	738 ²	134	714	16	864	1.17
2000	567	1,103	3,647	70	4,819	8.50
2001	595	396	845	9	1,251	2.10
2002	629	345	1,886	69	2,300	3.66
2003	441	121	800	12	932	2.11
2004	597	805	3,101	116	4,022	6.74
2005	510	1,305	3,052	21	4,378	8.58
2006	419	3,038	5,812	264	9,114	21.75
2007	449	1,277	5,174	108	6,558	14.61
2008	457	2,344	4,567	65	6,976	15.27
2009	486	461	2,663	58	3,181	6.55
2010	336	1,495	3,183	30	4,707	14.01
2011	377	1,233	2,340	34	3,607	9.57
2012	374	221	1,492	10	1,723	4.61
2013	398	802	1,993	0	2,795	7.02
2014	384	1,008	1,447	7	2,463	6.41
2015	442	314	877	0	1,191	2.70
2016	376	287	771	41	1,099	2.92
2017	382	349	1,188	0	1,537	4.02
2018	294	546	1,701	0 ³	2,248 ³	7.65 ³
2019	306	450	1,107 ³			
2020	405	481 ³				
2021	412					
2022	377					
2023	428 ³					

1. These are the total number of natural fish collected at Roza Dam and taken to the CESRF for production brood stock.

2. 357 or 48% of these fish were jacks.

3. Preliminary.

Table 12. Juvenile Survival Based Regression Data - Wild/Natural Return.

JuvMigrYear	AdltRtnYr	Age4/5Adlts	Age-3 Yr-1	Roza- McNSurv	NOAAOcn	Predicted Age4/5Adlts
1999	2001	13,472	841	0.7390	7.4	8,720
2000	2002	6,501	798	0.4980	8.9	6,592
2001	2003	3,552	349	0.1330	8.8	3,137
2002	2004	10,299	987	0.3420	7.1	6,118
2003	2005	7,144	919	0.3095	15.8	4,125
2004	2006	3,856	302	0.3749	19.1	2,895
2005	2007	2,014	233	0.1946	20.2	1,242
2006	2008	3,152	434	0.5126	12.6	5,361
2007	2009	3,782	539	0.1833	11.3	3,372
2008	2010	4,289	1,105	0.3957	3.4	7,417
2009	2011	7,108	638	0.4843	10	6,003
2010	2012	5,769	1,787	0.5402	14.6	7,577
2011	2013	4,041	426	0.3109	8.4	4,656
2012	2014	5,051	1,303	0.2406	7.1	5,933
2013	2015	6,072	1,040	0.5782	9.6	7,476
2014	2016	3,810	302	0.4014	14.9	3,879
2015	2017	3,227	485	0.4196	21.2	3,152
2016	2018	1,515	486	0.5666	20.6	4,346
2017	2019	777	100	0.1106	19.1	597
2018	2020	1,962	117	0.1179	14	1,639
2019	2021	1,588	121	0.3190	18.1	2,353
2020	2022	3,254	265	0.2220	13.9	2,685
2021	2023	1,302	202	0.2651	6.6	4,262
2022	2024		103	0.0350	11.2	1,532
					Adjusted	883

<i>Regression Statistics</i>	
Multiple R	0.7344942
R Square	0.5394817
Adjusted R Square	0.4667683
Standard Error	2190.3974
Observations	23

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	3199.53	1846.636	1.7326267	0.09936372
X Variable 1	1.7654352	1.339729	1.3177551	0.20325454
X Variable 2	7344.182	3197.576	2.2967968	0.03316955
X Variable 3	-188.019	98.41659	-1.9104397	0.07128741

Table 13. Juvenile Survival Based Regression Data – Hatchery-Origin Return.

JuvMigrYear	AdltRtnYr	Age4/5Adlts	Age-3Yr-1	Roza-McNSurv	NOAAOcn	Predicted Age4/5Adlts
1999	2001	7,753	741	0.5913	7.4	4,817
2000	2002	8,115	1,242	0.2793	8.9	4,013
2001	2003	1,316	134	0.1751	8.8	2,194
2002	2004	3,663	1,103	0.2628	7.1	4,043
2003	2005	915	396	0.2458	15.8	1,744
2004	2006	2,094	397	0.2041	19.1	1,079
2005	2007	953	130	0.1180	20.2	231
2006	2008	3,463	901	0.2505	12.6	2,899
2007	2009	3,660	1,444	0.4061	11.3	4,405
2008	2010	6,739	3,574	0.2599	3.4	7,777
2009	2011	6,291	1,476	0.2035	10	3,851
2010	2012	5,314	2,774	0.3203	14.6	5,280
2011	2013	3,060	543	0.3310	8.4	3,392
2012	2014	3,800	1,840	0.1526	7.1	4,562
2013	2015	2,723	1,432	0.2642	9.6	4,093
2014	2016	1,708	254	0.2661	14.9	1,777
2015	2017	2,235	913	0.2432	21.2	1,578
2016	2018	1,641	1,215	0.2162	20.6	1,952
2017	2019	979	349	0.2162	19.1	1,065
2018	2020	871	349	0.2141	14	1,832
2019	2021	1,337	408	0.5980	18.1	2,787
2020	2022	2,177	733	0.5580	13.9	3,688
2021	2023	1,369	522	0.1970	6.6	3,114
2022	2024		560	0.2580	11.2	2,702
					Adjusted	1,492

<i>Regression Statistics</i>	
Multiple R	0.754371
R Square	0.569076
Adjusted R Square	0.501035
Standard Error	1588.753
Observations	23

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	2674.147	1461.23	1.830066	0.082975
X Variable 1	1.288014	0.442828	2.908607	0.009007
X Variable 2	3913.673	2571.036	1.522217	0.144425
X Variable 3	-152.083	71.66681	-2.12209	0.047199

Table 14. Summary of 2024 Yakima River Spring Chinook forecast values using various methods or models.

Projection	Method or Model
3,440	Average Adult per Jack Return Rate for adult return years 2000-2023
4,410	Regression of age3:age4 and age4:age5 cohort returns for brood years 1982-2019
7,740	Regression of jacks and jack post-eye length to adult returns for adult return years 2001-2023
9,260	Regression of jacks, jack post-eye length, and ocean chinook juvenile abundance indices to adult returns for adult return years 2001-2023
5,240	Regression of adult returns to jack returns for jack return years 1982-2022
6,210	Regression of adult returns to adult spawners, jacks, and jack mideye length for jack return years 1986-2022
3,040	Average return rates of age4:age3 and age5:age4 fish for most recent 10 brood years
2,370	Regression of adult returns to jacks, and freshwater survival and ocean survival indices for adult return years 2001-2023 (adjusted by average error)
5,270	Regression of adult returns to smolts at Prosser, and freshwater survival and ocean survival indices for adult return years 2001-2023
5,220	Average of above predictors
4,800	Geometric mean of above predictors

Table 15. Forecasted and actual returns of age-4 and age-5 spring Chinook, forecast error, and forecast method for forecast years 2012-2023.

Year	Forecast	Actual	Error	Method
2012	12,040	11,080	8.7%	Smolts+FreshWaterSurv.+OCN surv. adjusted by avg error
2013	7,330	7,100	3.2%	Smolts+FreshWaterSurv.+OCN surv. unadjusted
2014	9,110	8,850	2.9%	Smolts+FreshWaterSurv.+OCN surv. unadjusted
2015	9,320	8,790	6.0%	Average adult per jack return rate for 6 of past 7 'high jack' count years (2007-2013, not 2012)
2016	4,610	5,520	-16.5%	Regression of adult returns to adult spawners, jacks, and jack mideye length
2017	6,320	5,460	15.8%	Jacks+FreshWaterSurv.+OCN surv. unadjusted
2018	6,340	3,160	100.6%	Smolts+FreshWaterSurv.+OCN surv. unadjusted
2019	2,970	1,760	68.8%	Jacks+FreshWaterSurv.+OCN surv. unadjusted
2020	2,810	2,830	-0.7%	Jacks+FreshWaterSurv.+OCN surv. adjusted by 2019 error
2021	3,170	2,920	8.6%	Jacks+FreshWaterSurv.+OCN surv. adjusted by avg error
2022	4,680	5,430	-13.8%	Jacks+FreshWaterSurv.+OCN surv. adjusted by avg error
2023	5,550	2,670	107.9%	Jacks+FreshWaterSurv.+OCN surv. adjusted by avg error
2024	2,370			Jacks+FreshWaterSurv.+OCN surv. adjusted by avg error

Table 16. CESRF Smolt Releases by Brood Year¹

Brood Year	Migration Year	Total Release	Return Year for:		
			Age-3 (jack)	Age-4	Age-5
1997	1999	386,048	2000	2001	2002
1998	2000	589,683	2001	2002	2003
1999	2001	758,789	2002	2003	2004
2000	2002	834,285	2003	2004	2005
2001 ²	2003	370,236	2004	2005	2006
2002	2004	836,904	2005	2006	2007
2003	2005	824,692	2006	2007	2008
2004	2006	785,448	2007	2008	2009
2005	2007	860,002	2008	2009	2010
2006	2008	642,795	2009	2010	2011
2007	2009	771,265	2010	2011	2012
2008	2010	849,305	2011	2012	2013
2009	2011	832,941	2012	2013	2014
2010	2012	794,781	2013	2014	2015
2011	2013	769,182	2014	2015	2016
2012	2014	802,716	2015	2016	2017
2013	2015	646,755	2016	2017	2018
2014	2016	685,230	2017	2018	2019
2015	2017	654,947	2018	2019	2020
2016	2018	669,208	2019	2020	2021
2017	2019	710,669	2020	2021	2022
2018	2020	642,420	2021	2022	2023
2019	2021	550,398	2022	2023	2024
2020	2022	761,188	2023	2024	2025
2021	2023	809,010	2024	2025	2026

1. Release target is 720,000 to 810,000 smolts, but was intentionally reduced in start-up years of 1997 and 1998.
2. Approximately ½ of production destroyed due to high presence of agents causing Bacterial Kidney Disease (BKD).

Appendix A

Time series forecasting can be a challenging problem especially with limited historical data. In the realm of time series forecasting, a spectrum of techniques is available, ranging from advanced Neural Network based models to classical statistical methods like ARIMA (AutoRegressive Integrated Moving Average). These methods vary in complexity and applicability. While advanced machine learning models possess the ability to capture intricate patterns in time series data, they typically demand a substantial volume of data for effective training. In situations where data is scarce, as in our case, these sophisticated models become susceptible to overfitting. Overfitting can lead to predictions that are overly influenced by noise in the data, resulting in inaccurate forecasts.

Conversely, a simpler model like Linear Regression does not demand an extensive dataset to produce a meaningful insight. Nevertheless, it assumes a linear relationship potentially resulting in underfitting and inability to account for temporal dependencies and non-linear trends in time series data. Linear regression is also sensitive to outliers and may not perform well in the presence of noise and irregular fluctuations.

Furthermore, while the inclusion of additional predictor variables can enhance the complexity of time series forecasting models and potentially improve accuracy, our specific scenario, characterized by a paucity of data, did not yield significant benefits from this approach. In fact, the incorporation of additional predictors led to less accurate predictions, including instances of predicting negative values. This underscores the challenges of multivariate time series forecasting in data-scarce situations.

Given the limitation of the aforementioned modeling approaches in the context of small datasets, it is prudent to explore other simpler forecasting techniques. Classical univariate statistical methods like ARIMA, Exponential Smoothing, and Prophet exhibit proficiency in capturing temporal dependencies and trends, rendering them suitable choices for forecasting in scenarios with limited historical data availability. Additionally, it is worth considering the inclusion of the simple univariate linear regression approach, as it has demonstrated reliability, yielding three and two accurate predictions for NOR and HOR returns, respectively, over the last five years. These four methods predicted a 2024 Yakima River return ranging from 1,800 to 3,450 adult spring Chinook (Table 1).

Table 1. Time-series based forecasts for Natural-origin (NOR), hatchery-origin (HOR), and combined (aggregate) adult spring Chinook returns to the Yakima River mouth in 2024.

	2024 forecast
NOR	
Univariate ARIMA(2,1,0)	1,409
Univariate Prophet	834
Univariate (SimExpSm)	1,561
Univariate Lin. Reg	1,000
Mean	1,201
Median	1,205
HOR	
Univariate ARIMA(2,2,0)	1,606
Univariate Prophet	912
Univariate Holt's (DoubleExpSm)	1,360
Univariate Lin. Reg	1,163
Mean	1,260
Median	1,262
Aggregate	
Univariate ARIMA(1,1,0)	3,449
Univariate Prophet	1,792
Univariate Holt's (DoubleExpSm)	3,029
Univariate Lin. Reg	2,163
Mean	2,608
Median	2,596