

# 2024 Bristol Bay Sockeye Salmon Forecast

University of Washington

Alaska Salmon Program

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**The 2024 Bristol Bay sockeye salmon forecast is 44.85 million.** This forecast is 25% lower than the recent 10-year average (60.2 million) and 10% lower than the recent 20-year average (49.6 million) of observed sockeye runs to Bristol Bay. This estimate is the sum of individual predictions for each of the dominant age classes (1.2, 1.3, 2.2, 2.3) for all nine major river systems – Kvichak, Egegik, Ugashik, Naknek, Alagnak, Wood, Nushagak-Mulchatna, Igushik, and Togiak, and the contribution of the Nushagak 0.3 and 1.4 age classes (Table 1, Figure 1). The predicted inshore harvest based on this forecast is 30.95 million sockeye salmon with an estimated weight of 166.52 million pounds (Table 2).

To generate the forecast for inshore harvest we subtract: 1) estimated escapement to each river; in most cases derived from the relationship between realized escapement and run size in prior years, except for the Kvichak and Alagnak rivers where we assume a harvest rate of approximately 50%, and 2) an estimate of the 2024 South Peninsula harvest (1 million) from the predicted total run. We estimate the South Peninsula catch for the coming season by averaging sockeye harvest from South Unimak and Shumagin Islands for the most recent 10 years, excluding 2021 and 2022 which both had Bristol Bay returns exceeding 70 million sockeye.

Harvest predictions for 2024 are provided in tables 1 and 2 (below). This harvest estimate depends on realized escapement in 2024 equaling the assumed values in Table 1, and industry's ability and opportunity to harvest all surplus fish. To determine the harvest in pounds for each age group we multiplied the forecasted catch by the 10-year average weight of 2 or 3 ocean fish taken from Bristol Bay sockeye runs with the closest total return sums (1980-2023) to our 2024 forecast. The average weights used for the 2024 preseason forecast were 4.8 lbs and 6.6 lbs for 2-ocean and 3-ocean sockeye, respectively. For the 2024 forecast of 44.85 million, we expect 68% 2-ocean sockeye and 32% 3-ocean sockeye. Over the recent 20-year period the average range of weights for 2-ocean sockeye is 4.0-5.1 lbs and 5.5-7.1 lbs for 3-ocean sockeye, with average weight-at-age showing a negative relationship with total Bristol Bay run size among years.

## Methods

The 2024 preseason forecast is based on historical catch and escapement data collected by the Alaska Department of Fish and Game, and annual stock and age specific run sizes reconstructed (1963-present) using methods described in Cunningham et al. (2018). The overall UW-ASP Bristol

Bay forecast is comprised of 38 individual stock by age class forecasts. The majority of these 2024 stock-age forecasts were generated from models based on prior returns of “siblings” or younger ocean age-classes from the same stock and brood year, but returning in previous years (e.g. predicting 2024 Nushagak River 1.3s based on the 2023 abundance of Nushagak River 1.2s). The prior return abundance of younger age classes is informative because they experienced the same environmental conditions as juveniles in freshwater and at ocean entry as the age class being forecasted, and likely exhibit similar patterns in survival.

Rather than simply choosing the best sibling relationship for each age and river, for all forecasts based on sibling abundance data, we use a technique that weights the forecasts from models with different combinations of predictor sibling age classes according to how well each has performed in the past. While the best sibling relationship carries the most weight in our forecasts for each stock-age group, retrospective analysis indicates that there is useful information conveyed by other models (i.e. sibling models that include alternative age classes and different combinations thereof), and that this information increases forecast accuracy.

In addition to sibling or cohort regression models based on prior returns within a single river system, other forecast model types were used based on their performance over the last 20 years. Other statistical (i.e. predictive) models utilized included several machine learning methods from the field of artificial intelligence. Retrospective analysis indicates machine learning methods based on Bristol Bay sockeye return numbers across many different age classes and river systems at once, together with data on environmental factors such as sea-surface temperature and abundance of other salmon species during a cohort’s ocean phase, can improve preseason forecast accuracy at the river system and age-group levels. In six instances (Kvichak 2.2 & 2.3; Naknek 1.3 & 2.2; Wood 1.3; Nushagak 1.2) forecasts were produced using machine learning methods.

In recent years we have increasingly relied on Dynamic Linear Models (DLM) to generate forecasts based on their performance. DLMs are sibling models where both the intercept (average production of the forecasted stock-age group) and coefficients describing the relationship between younger and older sibling age classes, are allowed to evolve over time. As such, DLMs are more robust to environmentally-driven variation in average survival and changes in the likelihood that a salmon returns after 1, 2, or 3 years at sea (i.e. the maturation schedule). DLMs were used in fourteen instances (Alagnak 1.3; Naknek 1.2 & 2.3; Egegik 1.2 & 2.2; Ugashik 1.3 & 2.2; Wood 2.3; Nushagak 1.3 & 2.3; Igushik 1.3 & 2.2; Togiak 1.3 & 2.3). Finally, ensemble models that average the range of forecasts generated by all model types under the assumption that multiple models provide predictive information were explored for each stock-age combination in the 2024 forecast.

## Preseason vs Preliminary Forecast

In August of 2023 UW-ASP began the release of a Bristol Bay sockeye forecast, referred to as the 2024 “Preliminary Forecast”. The preliminary forecast uses the last ADF&G Bristol Bay ‘Daily’ release and the last ADF&G inseason age composition report to generate an aggregate forecast for Bristol Bay sockeye. Use of these two reports allow for a forecast that can be made available a full two months prior to the annual preseason forecast (described here) that is typically released each year in the first or second week of November. A nineteen-year retrospective analysis of the total run forecasts generated from these two methods show a mean absolute percent error of 15.5% for preseason forecasts and 18.2% for preliminary forecasts. Though the difference in percent error between forecasts methods is reasonably small, the preliminary methodology only allows for an aggregate (i.e. total run) forecast for Bristol Bay as a whole to be generated.

For 2024, our preliminary (August) forecast came in at 38.9 million sockeye, while our formal preseason forecast sums to 44.9 million sockeye. Most of the 14% difference between these two forecasts is in the 1.2 age class of sockeye, and is almost entirely attributable to the 2024 1.2 estimate for Ugashik. A record number of 1.1 jacks (primary age class used to forecast 1.2 sockeye) was observed for the Ugashik river system in 2023. Ugashik is one of the latest returning stocks (only Togiak is later) to Bristol Bay, as such the 1.1 component of the return (largely recorded from escapement numbers) for Ugashik was not yet fully observed at the time of the last inseason age composition report.

## References

Cunningham, C. J., T. A. Branch, T. H. Dann, M. Smith, J. E. Seeb, L. W. Seeb, and R. Hilborn. 2018. A general model for salmon run reconstruction that accounts for interception and differences in availability to harvest. *Canadian Journal of Fisheries and Aquatic Sciences* **75**:439-451.

**Table 1.** 2024 pre-season forecast of the number of sockeye salmon in millions returning to Bristol Bay, Alaska by river system and age class.

DISTRICT	RIVER	AGES				TOTAL	ESCAPEMENT	Estimated S. PEN CATCH	Inshore HARVEST
		1.2	1.3	2.2	2.3				
<b>Naknek\Kvichak</b>		<b>8.95</b>	<b>5.36</b>	<b>1.52</b>	<b>0.89</b>	<b>16.72</b>	<b>6.83</b>	<b>0.37</b>	<b>9.52</b>
	Kvichak	5.65	1.06	0.99	0.49	8.19	4.00	0.18	4.01
	Naknek	2.41	3.06	0.48	0.27	6.22	1.70	0.14	4.39
	Alagnak <sup>a</sup>	0.89	1.24	0.05	0.13	2.31	1.13	0.05	1.12
<b>Egegik</b>		<b>2.24</b>	<b>0.49</b>	<b>2.08</b>	<b>0.71</b>	<b>5.52</b>	<b>1.16</b>	<b>0.12</b>	<b>4.24</b>
<b>Ugashik</b>		<b>6.83</b>	<b>0.73</b>	<b>0.49</b>	<b>0.18</b>	<b>8.23</b>	<b>1.40</b>	<b>0.18</b>	<b>6.65</b>
<b>Nushagak</b>		<b>7.40</b>	<b>5.44</b>	<b>0.23</b>	<b>0.17</b>	<b>13.34</b>	<b>3.30</b>	<b>0.31</b>	<b>9.75</b>
	Wood	6.19	2.60	0.21	0.11	9.11	2.00	0.20	6.91
	Nushagak <sup>b</sup>	0.78	2.09	0.01	0.05	3.03	0.90	0.08	2.06
	Igushik	0.43	0.75	0.01	0.01	1.20	0.40	0.03	0.78
<b>Togiak</b>		<b>0.52</b>	<b>0.50</b>	<b>0.01</b>	<b>0.01</b>	<b>1.04</b>	<b>0.22</b>	<b>0.02</b>	<b>0.79</b>
<b>Totals<sup>c</sup></b>		<b>25.94</b>	<b>12.52</b>	<b>4.33</b>	<b>1.96</b>	<b>44.85</b>	<b>12.91</b>	<b>1.00</b>	<b>30.95</b>

millions of fish

<sup>a</sup>The spawning goal for the Alagnak River was set by ADFG as the estimated escapement based on exploiting the return of sockeye to the Alagnak at the same rate as the return to the Kvichak

<sup>b</sup>The Nushagak River total forecast includes 94,097 age 0.3 and age 1.4 sockeye

<sup>c</sup>The 'Totals' category cannot be summed horizontally because the Nushagak 1.4's and 0.3's are not included in the 'Ages' part of the table.

**Table 2.** 2024 pre-season Bristol Bay sockeye forecast in millions of pounds by fishing district and age class.

DISTRICT	1.2	1.3	2.2	2.3	Inshore Harvest	
					lbs (millions)	no. of fish (millions)
<b>Naknek\Kvichak</b>	23.49	21.64	4.07	3.28	<b>52.48</b>	9.52
<b>Egegik</b>	8.25	2.50	7.67	3.59	<b>22.01</b>	4.24
<b>Ugashik</b>	26.48	3.89	1.92	0.97	<b>33.26</b>	6.65
<b>Nushagak<sup>a</sup></b>	26.42	25.61	0.84	0.79	<b>54.28</b>	9.75
<b>Togiak</b>	1.92	2.51	0.02	0.04	<b>4.49</b>	0.79
<b>Totals<sup>b</sup></b>	<b>86.56</b>	<b>56.15</b>	<b>14.52</b>	<b>8.67</b>	<b>166.52</b>	<b>30.95</b>

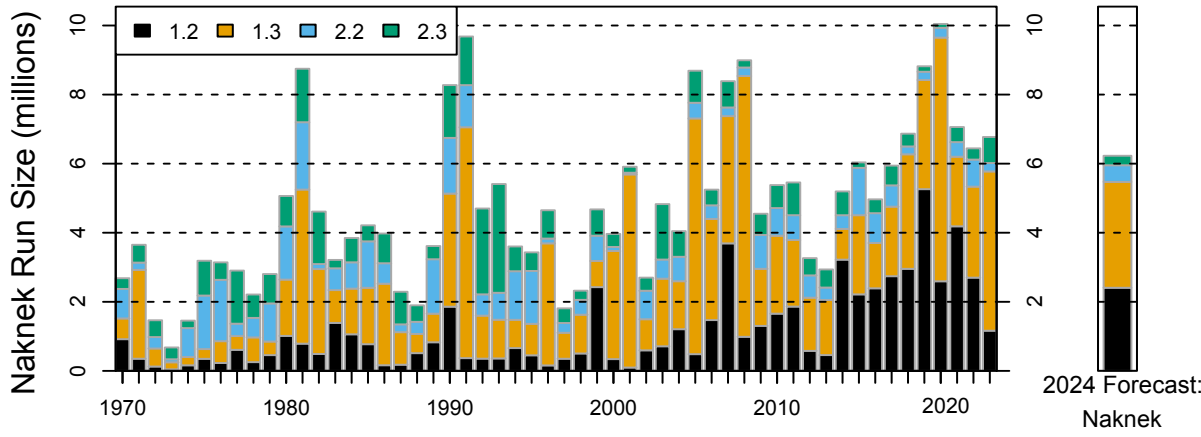
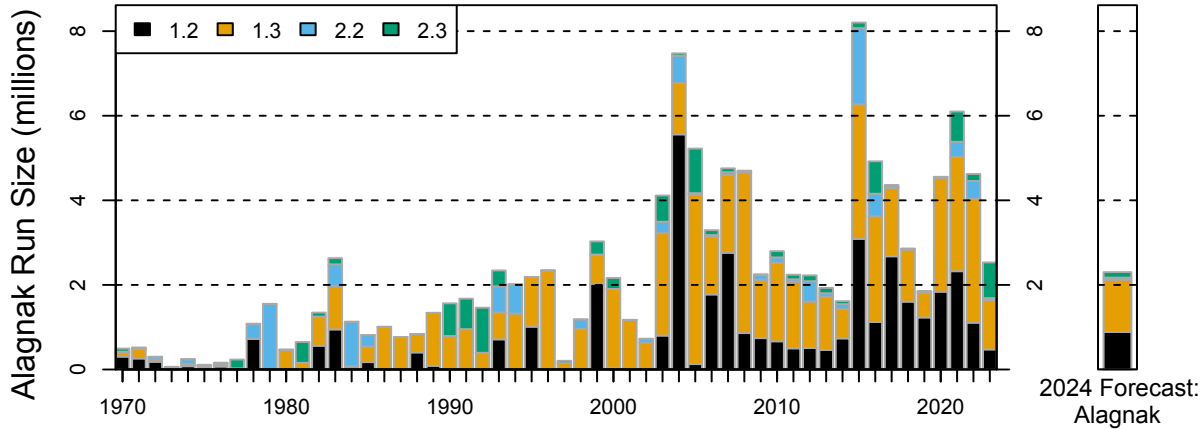
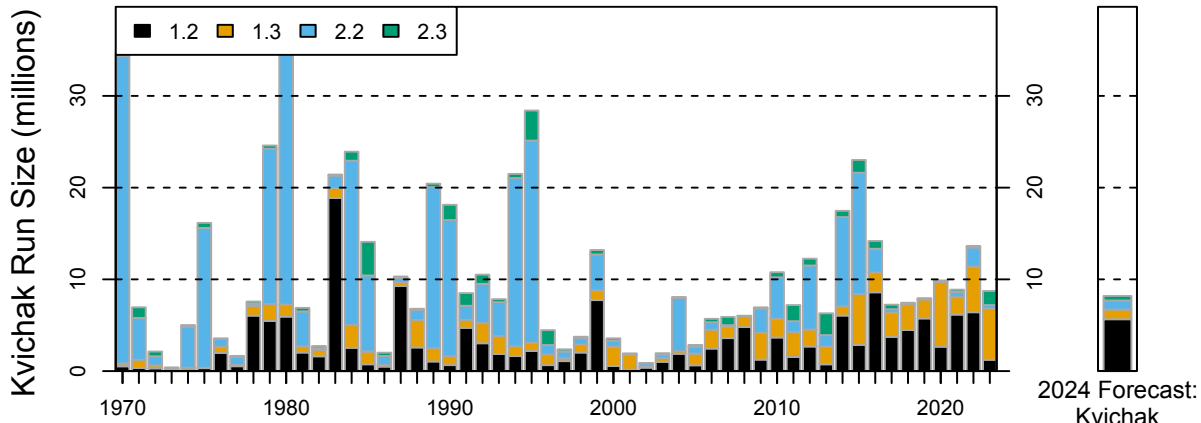
<sup>a</sup>The Nushagak District harvest totals cannot be summed horizontally because of the inclusion of age 0.3 and age 1.4 sockeye

<sup>b</sup>The Harvest totals cannot be summed horizontally because of the inclusion of Nushgak river age 0.3 and age 1.4 sockeye

**Table 3.** 2024 and 2023 preseason forecast of the number of sockeye salmon in millions returning to Bristol Bay, Alaska by river system, and actual returns of sockeye salmon in millions by river system 2013-2023.

RIVER	2024 Forecast	2023 Forecast (last year's)	ACTUAL RETURNS										
			2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013
Kvichak	8.19	8.47	8.76	13.69	8.89	9.87	7.94	7.47	7.25	14.20	23.10	17.6	6.32
Naknek	6.23	5.92	6.90	6.48	7.10	10.10	8.82	6.93	5.98	5.04	6.09	5.32	3.07
Alagnak	2.30	3.44	2.54	4.66	6.07	4.56	1.86	2.87	4.43	4.94	8.24	1.62	1.93
Egegik	5.52	11.56	14.81	18.22	7.73	15.60	15.43	6.10	12.44	9.89	8.51	5.08	5.12
Ugashik	8.24	3.16	4.38	7.56	10.66	5.08	3.6	4.77	6.67	7.19	4.25	1.15	2.63
Wood	9.11	8.30	10.42	12.45	12.67	8.00	12.34	22.68	11.29	6.38	5.02	7.17	3.29
Nushagak	3.03	6.64	5.45	16.39	15.07	3.63	4.31	9.60	8.20	2.58	2.48	1.51	2.01
Igushik	1.20	1.89	1.38	3.00	2.02	1.21	1.36	1.92	1.23	1.85	1.64	1.44	0.69
Togiak	1.03	0.60	0.72	0.83	0.96	0.62	1.29	1.36	0.67	0.74	0.53	0.53	0.59
<b>TOTALS</b>	<b>44.85</b>	<b>49.98</b>	<b>55.36</b>	<b>83.28</b>	<b>71.17</b>	<b>58.67</b>	<b>56.95</b>	<b>63.70</b>	<b>58.16</b>	<b>52.81</b>	<b>59.86</b>	<b>41.42</b>	<b>25.65</b>

**Figure 1.** Stock-specific comparison of the 2024 preseason forecast by age class (right panel) with observed run size by age class 1970 - 2023 (left panel).



Return Year

