

2023 Bristol Bay Sockeye Salmon Forecast

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The 2023 Bristol Bay sockeye salmon forecast is 49.98 million. This forecast is 13% lower than the recent 10-year average (57 million) and 4% higher than the recent 20-year average (48 million) of observed sockeye runs to Bristol Bay. This estimate is the sum of individual predictions for each of the predominant 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 34.95 million sockeye with an estimated weight of 195.1 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 50%, and 2) an estimate of the 2023 South Peninsula harvest (1.5 million) from the predicted total run. We estimate the South Peninsula catch for the coming season by averaging the sockeye harvest from South Unimak and Shumagin Islands for the prior 10 years.

Harvest predictions for 2023 are provided in tables 1 and 2 (below). This harvest estimate depends on realized escapement in 2023 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 average weight of 2 or 3 ocean fish for Bristol Bay sockeye runs for the most recent 20 year averages (4.6 lbs and 6.2 lbs, respectively). For the 2023 forecast of 49.98 million, we expect 39% 2-ocean sockeye and 61% 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 5.5-7.5 lbs for 3-ocean sockeye, with average weight-at-age showing a negative relationship with total Bristol Bay run size among years.

Methods

The 2023 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 2022 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 2023 Nushagak River 1.3s based on the 2022 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 should 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 nine instances (Kvichak 2.2 & 2.3; Naknek 1.3 & 2.2; Egegik 1.2 & 2.3; Ugashik 1.3, Wood 1.3; Togiak 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 twenty instances (Kvichak 1.2, 1.3; Alagnak 1.2; Naknek 1.2; Egegik 1.3 & 2.2; Ugashik 1.2, 2.2 & 2.3; Wood 1.2, 2.2, & 2.3; Nushagak 1.2 & 2.3; Igushik 1.2, 1.3, 2.2, & 2.3; 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 2023 forecast.

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. 2023 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 | | | | |
| Naknek\Kvichak | | 6.12 | 9.33 | 1.25 | 1.13 | 17.83 | 7.30 | 0.53 | 9.98 |
| | Kvichak | 1.90 | 5.50 | 0.57 | 0.50 | 8.47 | 3.98 | 0.25 | 4.23 |
| | Naknek | 2.69 | 2.25 | 0.56 | 0.42 | 5.92 | 1.70 | 0.18 | 4.04 |
| | Alagnak ^a | 1.53 | 1.58 | 0.12 | 0.21 | 3.44 | 1.62 | 0.10 | 1.71 |
| Egegik | | 2.00 | 6.20 | 1.53 | 1.83 | 11.56 | 1.50 | 0.35 | 9.71 |
| Ugashik | | 1.18 | 1.30 | 0.40 | 0.28 | 3.16 | 0.95 | 0.10 | 2.11 |
| Nushagak | | 6.65 | 9.36 | 0.16 | 0.45 | 16.83 | 3.58 | 0.50 | 12.77 |
| | Wood | 5.24 | 2.70 | 0.08 | 0.28 | 8.30 | 1.80 | 0.25 | 6.26 |
| | Nushagak ^b | 0.80 | 5.40 | 0.07 | 0.16 | 6.64 | 1.50 | 0.20 | 4.95 |
| | Igushik | 0.61 | 1.26 | 0.01 | 0.01 | 1.89 | 0.28 | 0.05 | 1.56 |
| Togiak | | 0.11 | 0.47 | 0.01 | 0.01 | 0.60 | 0.20 | 0.02 | 0.38 |
| Totals^c | | 16.06 | 26.66 | 3.35 | 3.70 | 49.98 | 13.53 | 1.50 | 34.95 |

millions of fish

^aThe 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

^bThe Nushagak River total forecast includes 214,128 age 0.3 and age 1.4 sockeye

^cThe '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. 2023 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) |
| Naknek\Kvichak | 16.31 | 31.44 | 3.33 | 4.00 | 55.08 | 9.98 |
| Egegik | 7.74 | 32.29 | 5.91 | 9.53 | 55.47 | 9.71 |
| Ugashik | 3.64 | 5.41 | 1.24 | 1.17 | 11.46 | 2.11 |
| Nushagak^a | 23.20 | 43.68 | 0.56 | 2.06 | 70.78 | 12.77 |
| Togiak | 0.34 | 1.87 | 0.04 | 0.01 | 2.26 | 0.38 |
| Totals^b | 51.23 | 114.69 | 11.08 | 16.77 | 195.05 | 34.95 |

^aThe Nushagak District harvest totals cannot be summed horizontally because of the inclusion of age 0.3 and age 1.4 sockeye

^bThe Harvest totals cannot be summed horizontally because of the inclusion of Nushagak river age 0.3 and age 1.4 sockeye

Table 3. 2023 and 2022 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 2012-2022.

| RIVER | 2023 Forecast | 2022 Forecast (last year's) | ACTUAL RETURNS | | | | | | | | | | |
|---------------|------------------|-----------------------------------|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | | | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 |
| Kvichak | 8.47 | 11.50 | 13.69 | 8.89 | 9.87 | 7.94 | 7.47 | 7.25 | 14.20 | 23.10 | 17.6 | 6.32 | 12.26 |
| Naknek | 5.92 | 8.46 | 6.48 | 7.10 | 10.10 | 8.82 | 6.93 | 5.98 | 5.04 | 6.09 | 5.32 | 3.07 | 3.32 |
| Alagnak | 3.44 | 4.38 | 4.66 | 6.07 | 4.56 | 1.86 | 2.87 | 4.43 | 4.94 | 8.24 | 1.62 | 1.93 | 2.23 |
| Egegik | 11.56 | 13.51 | 18.22 | 7.73 | 15.60 | 15.43 | 6.10 | 12.44 | 9.89 | 8.51 | 5.08 | 5.12 | 5.92 |
| Ugashik | 3.16 | 4.09 | 7.56 | 10.66 | 5.08 | 3.6 | 4.77 | 6.67 | 7.19 | 4.25 | 1.15 | 2.63 | 2.92 |
| Wood | 8.30 | 11.54 | 12.45 | 12.67 | 8.00 | 12.34 | 22.68 | 11.29 | 6.38 | 5.02 | 7.17 | 3.29 | 2.70 |
| Nushagak | 6.64 | 15.20 | 16.39 | 15.07 | 3.63 | 4.31 | 9.60 | 8.20 | 2.58 | 2.48 | 1.51 | 2.01 | 1.04 |
| Igushik | 1.89 | 2.06 | 3.00 | 2.02 | 1.21 | 1.36 | 1.92 | 1.23 | 1.85 | 1.64 | 1.44 | 0.69 | 0.51 |
| Togiak | 0.60 | 1.17 | 0.83 | 0.96 | 0.62 | 1.29 | 1.36 | 0.67 | 0.74 | 0.53 | 0.53 | 0.59 | 0.83 |
| TOTALS | 49.98 | 71.91 | 83.28 | 71.17 | 58.67 | 56.95 | 63.70 | 58.16 | 52.81 | 59.86 | 41.42 | 25.65 | 31.73 |

Figure 1. Stock-specific comparison of the 2023 preseason forecast by age class (right panel) with observed run size by age class 1970 - 2022 (left panel).





