2021 Bristol Bay Sockeye Salmon Forecast

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The 2021 Bristol Bay sockeye salmon forecast is 50.9 million. This forecast is within 5.6% (above) of the recent 10-year average (48.2 million) and 19.8% higher than the recent 20-year average (42.5 million). 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 36.2 million sockeye with an estimated weight of 179.2 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 2021 South Peninsula harvest from the predicted total run (1.35 million salmon). South Peninsula catch for 2021 is estimated as the average of the catch (South Unimak and Shumagin Islands) from 1990 to 2020. Harvest predictions for 2021 given in Tables 1 and 2 are "forecasted" inshore harvest, differing from what we have referred to as "potential" harvest in prior preseason forecasts only by the removal of the estimated 2021 South Peninsula catch. This harvest estimate depends on observed escapement in 2021 equaling the assumed values in Table 1, and industry's ability 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 5 years (4.2 lbs and 5.7 lbs, respectively). For the 2021 forecast of 50.9 million we expect 55% 2-ocean sockeye and 45% 3-ocean sockeye. Over the recent 20 year period the average range for weight of 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 2021 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 2021 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 2021 Wood River 1.3s based on the 2020 abundance of 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, age-group, and Bay-wide level. In eight instances (Naknek 1.2; Egegik 2.3; Igushik 1.2; Wood 1.2; Nushagak 2.2 & 2.3; Togiak 2.2 & 2.3) forecasts were produced using machine-learning methods. In addition to machine-learning models, in recent years we have increasingly used Dynamic Linear Models (DLM). DLMs are sibling models where both the intercept (average production of the forecasted stock-age group) and coefficients describing the effect of younger sibling age classes, are allowed to change or 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. DLMs were used in fifteen instances (Kvichak 1.3 & 2.3; Alagnak 1.2; Naknek 2.3; Egegik 2.2; Ugashik 1.2, 2.2 & 2.3; Igushik 1.3, 2.2, & 2.3; Nushagak 1.3; Wood 1.3, 2.2, & 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 2021 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. 2021 pre-season forecast of the number of sockeye salmon in millions returning to Bristol Bay, Alaska by river system and age class.

		AGES						Estimated	Inshore	
DISTRICT	RIVER	**1.2**	**1.3**	**2.2**	**2.3**	TOTAL	ESCAPEMENT	S. PEN CATCH	HARVEST	
Naknek\Kvichak		**7.10**	**8.14**	**0.76**	**0.33**	**16.33**	**6.46**	**0.43**	**9.45**	
	Kvichak	2.77	2.22	0.31	0.06	5.36	2.68	0.14	2.54	
	Naknek	2.86	3.92	0.43	0.21	7.42	2.00	0.20	5.23	
	Alagnak[a]	1.47	2.00	0.02	0.06	3.55	1.78	0.09	1.68	
Egegik		**6.22**	**2.32**	**1.99**	**1.10**	**11.63**	**1.50**	**0.31**	**9.83**	**millions of fish**
Ugashik		**4.12**	**1.70**	**0.29**	**0.09**	**6.20**	**1.40**	**0.16**	**4.64**	
Nushagak		**6.78**	**8.67**	**0.09**	**0.03**	**15.66**	**3.04**	**0.42**	**12.20**	
	Wood	5.12	2.59	0.07	0.00	7.79	1.80	0.21	5.78	
	Nushagak[b]	1.14	5.05	0.01	0.02	6.30	0.90	0.17	5.24	
	Igushik	0.52	1.03	0.01	0.01	1.57	0.34	0.04	1.18	
Togiak		**0.50**	**0.55**	**0.02**	**0.01**	**1.08**	**0.27**	**0.03**	**0.78**	
Totals[c]		**24.72**	**21.38**	**3.15**	**1.56**	**50.90**	**12.67**	**1.35**	**36.90**	

[a]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

[b]The Nushagak River total forecast includes 76,304 age 0.3 and age 1.4 sockeye

[c]The 'Totals' catergory 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. 2021 pre-season Bristol Bay sockeye forecast in millions of pounds by fishing district and age class.

					Inshore Harvest	
DISTRICT	1.2	1.3	2.2	2.3	lbs (millions)	no. of fish (millions)
Naknek\Kvichak	16.90	27.13	1.91	1.19	**47.13**	9.45
Egegik	22.08	11.16	7.08	5.29	**45.61**	9.83
Ugashik	12.93	7.26	0.92	0.38	**21.49**	4.64
Nushagak[a]	21.61	39.27	0.29	0.17	**61.71**	12.20
Togiak	1.53	2.26	0.06	0.03	**3.88**	0.78
Totals[b]	**75.05**	**87.08**	**10.26**	**7.06**	**179.82**	**36.90**

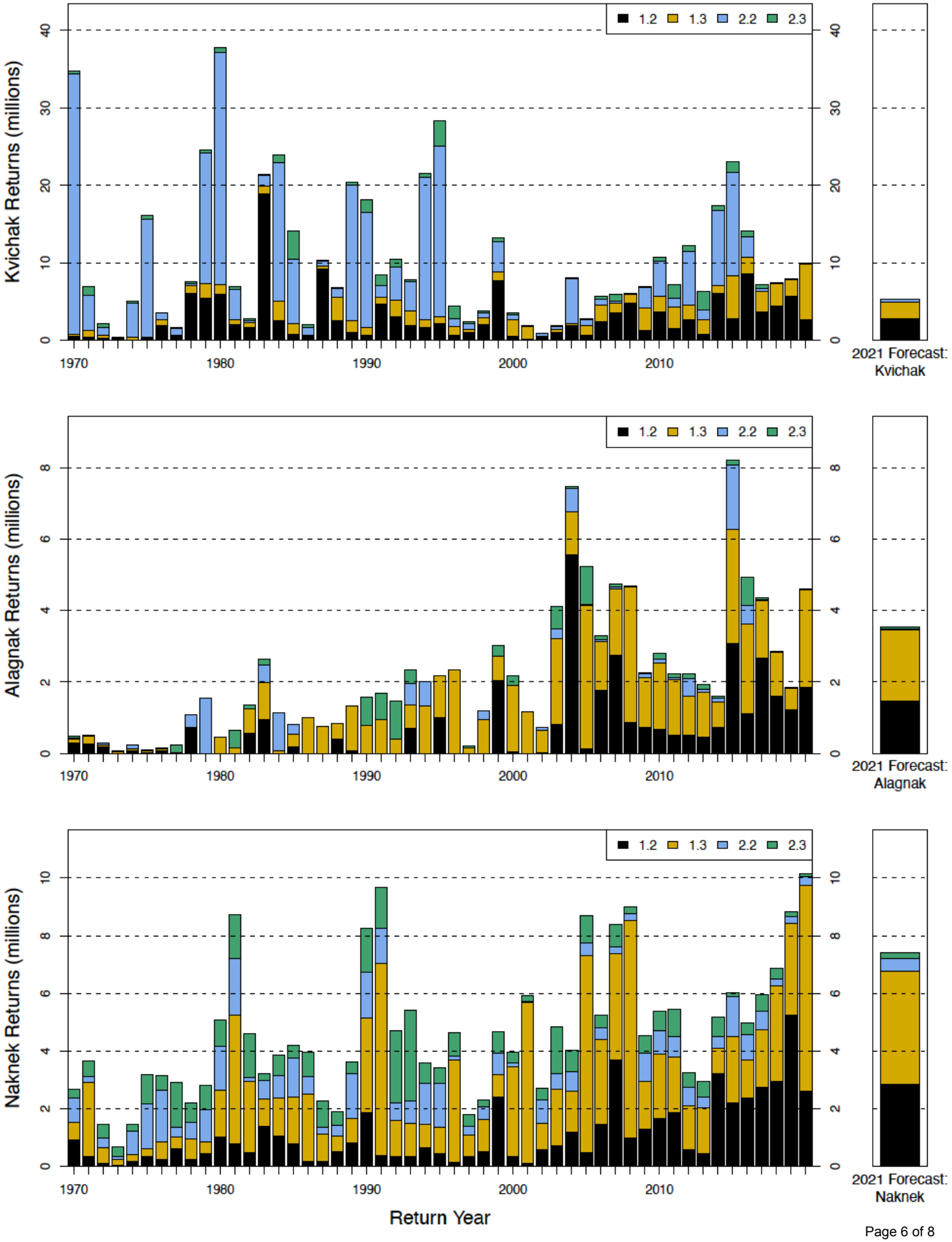
[a]The Nushagak District harvest totals cannot be summed horizontally because of the inclusion of age 0.3 and age 1.4 sockeye

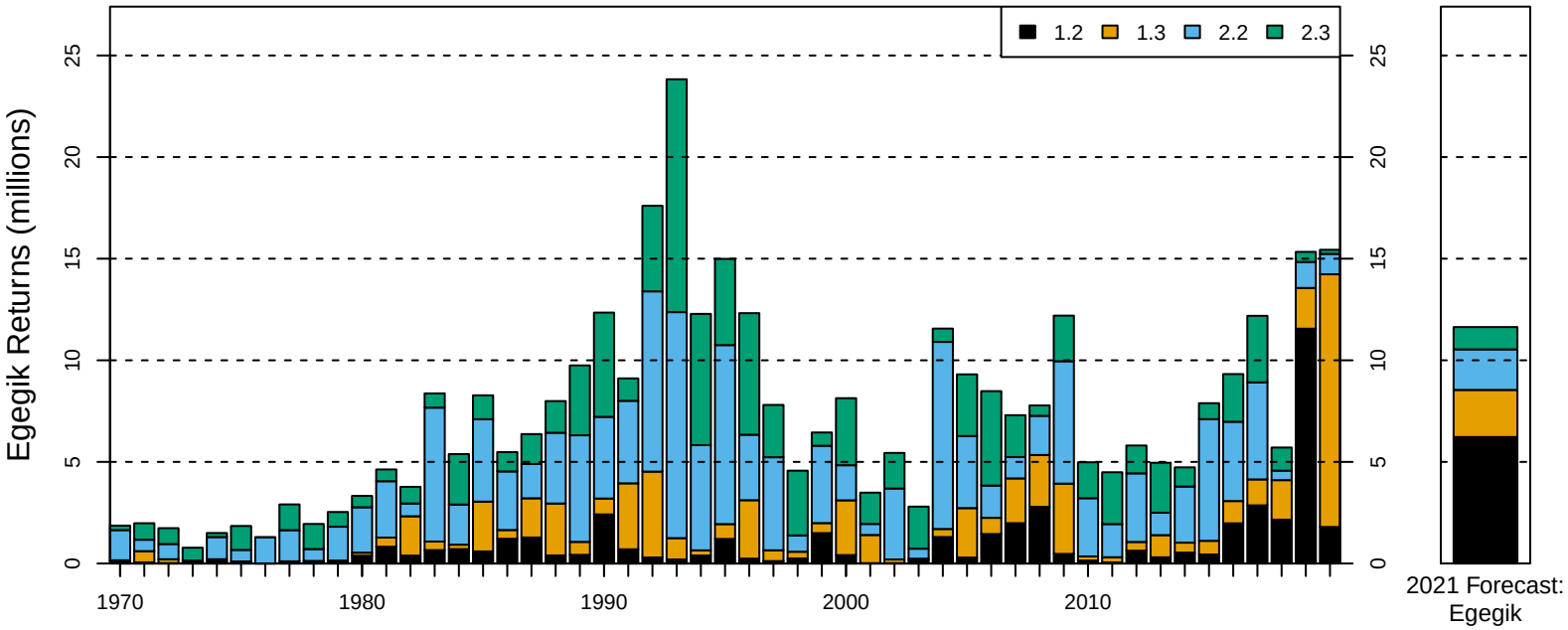
[b]The Harvest totals cannot be summed horizontally because of the inclusion of Nushgak river age 0.3 and age 1.4 sockeye

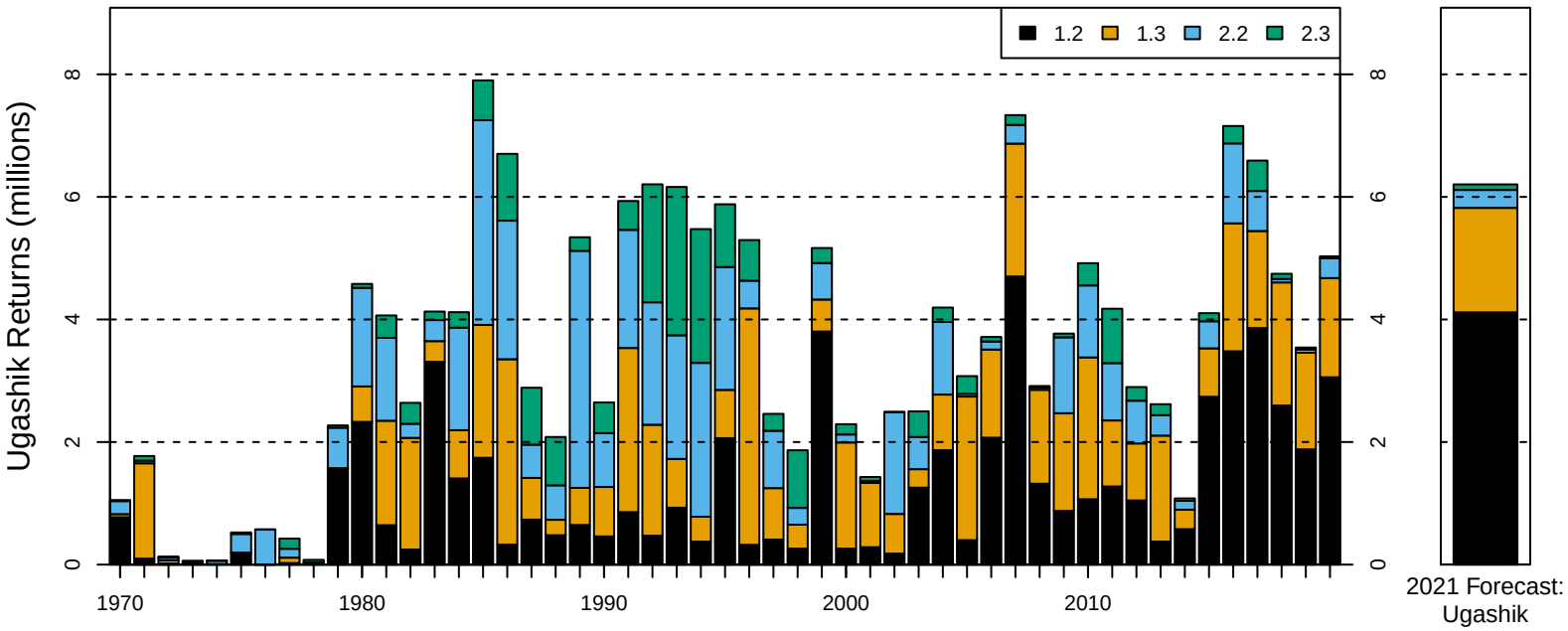
Table 3. 2021 and 2020 preseason forecast of the number of sockeye salmon in millions returning to Bristol Bay, Alaska by river system, and actual returns of sockeye salmon in millions by river system 2010-2020.

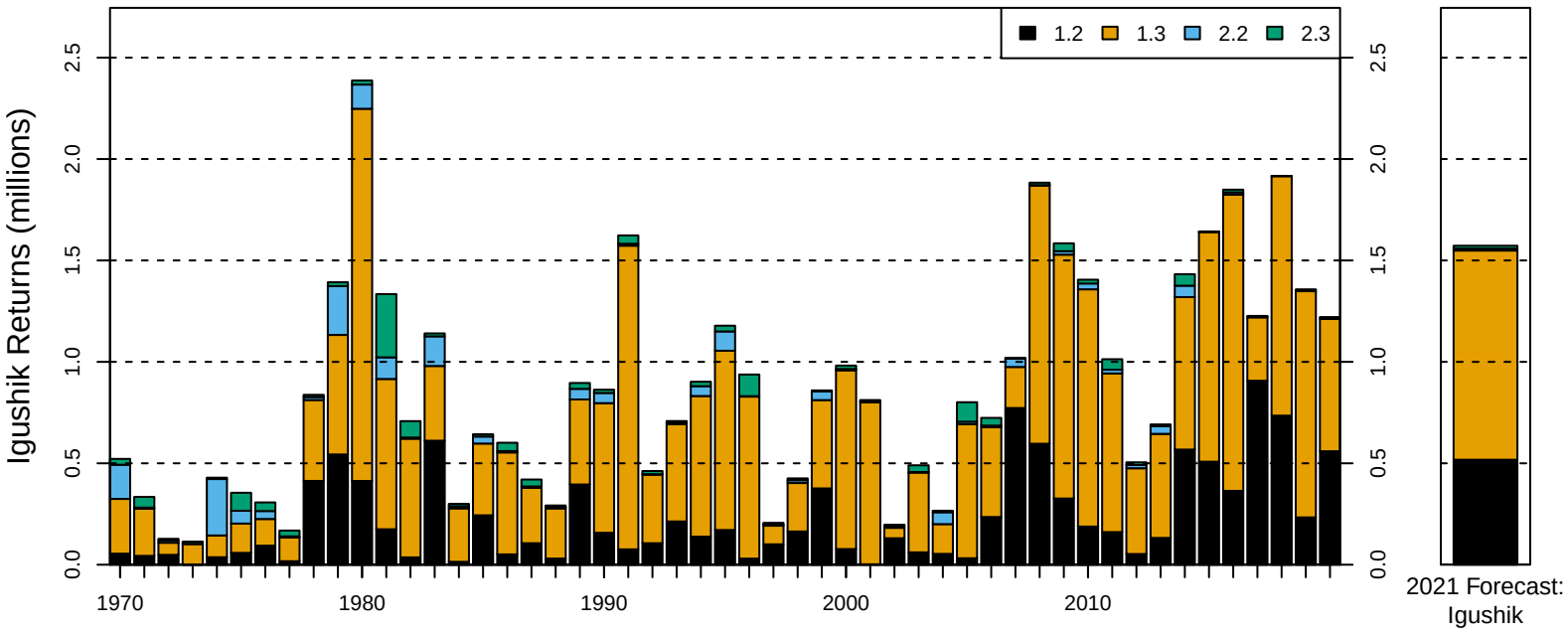
			ACTUAL RETURNS										
RIVER	2021 Forecast	2020 Forecast (last year's)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
Kvichak	5.36	5.97	9.98	7.90	7.47	7.78	12.03	16.60	14.23	4.79	11.15	6.18	9.41
Naknek	7.42	6.00	10.21	8.80	6.92	6.51	5.44	4.82	5.91	2.35	3.38	5.11	5.82
Alagnak	3.55	2.54	4.61	1.85	2.88	4.80	5.16	12.45	0.89	2.49	2.60	2.52	2.64
Egegik	11.63	10.18	15.79	15.53	6.12	12.38	9.40	8.80	7.80	5.96	6.01	5.89	6.01
Ugashik	6.20	4.22	5.14	3.54	4.77	6.63	8.80	6.95	1.94	3.46	3.24	3.79	4.92
Wood	7.79	14.10	8.10	12.25	22.68	11.32	5.49	5.07	7.47	3.17	2.64	4.58	7.77
Nushagak	6.30	4.04	3.67	4.31	9.6	8.16	3.20	2.25	1.66	2.09	1.14	1.58	2.17
Igushik	1.57	0.98	1.22	1.35	1.92	1.23	1.95	1.65	0.98	0.74	0.50	1.20	1.38
Togiak	1.08	0.88	0.72	1.28	1.38	0.73	0.94	0.57	0.58	0.66	0.86	0.98	0.85
TOTALS	50.90	48.92	59.44	56.81	63.74	59.54	52.40	59.16	41.46	25.71	31.52	31.83	40.98

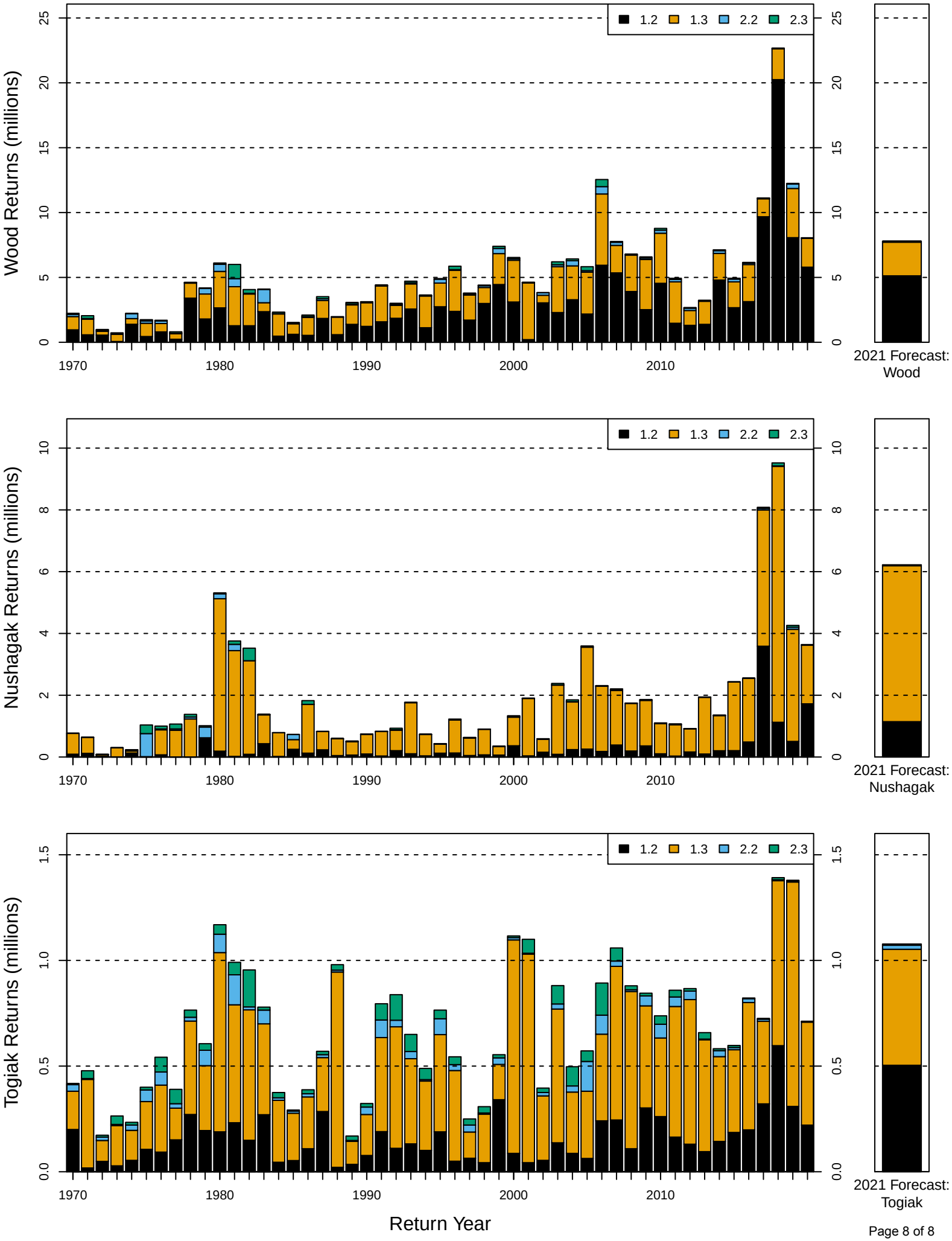
Figure 1. Stock-specific comparison of the 2021 preseason forecast by age class (right panel) with observed run size by age class 1970-2020 (left panel).




1.2
1.3
2.2
2.3
Egegik Returns (millions)
0
5
10
15
20
25
1970
1980
1990
2000
2010
2021 Forecast:
Egegik


1.2
1.3
2.2
2.3
Ugashik Returns (millions)
0
2
4
6
8
1970
1980
1990
2000
2010
2021 Forecast:
Ugashik


1.2
1.3
2.2
2.3
Igushik Returns (millions)
0.0
0.5
1.0
1.5
2.0
2.5
1970
1980
1990
2000
2010
2021 Forecast:
Igushik
Return Year


Wood Returns (millions)
1.2
1.3
2.2
2.3
0
5
10
15
20
25
1970
1980
1990
2000
2010
2021 Forecast:
Wood
Nushagak Returns (millions)
0
2
4
6
8
10
2021 Forecast:
Nushagak
Togiak Returns (millions)
0.0
0.5
1.0
1.5
2021 Forecast:
Togiak
Return Year