Agenda Item D.2.a
Supplemental STT Report 3
November 2022

SALMON TECHNICAL TEAM REPORT
INVESTIGATON OF EFFORT FORECASTS PRODUCED FOR AREAS SOUTH OF CAPE FALCON USING THE KLAMATH OCEAN HARVEST MODEL

Introduction

As part of the annual stock assessment and fishery planning process, the Salmon Technical Team (STT) produces effort forecasts for planned fisheries in management areas south of Cape Falcon, Oregon (Table 1). Effort forecasts are produced by a sub-model of the Klamath Ocean Harvest Model (KOHM). These forecasts are then used as inputs to other models, such as the Chinook and coho Fishery Regulation Assessment Model (FRAM) and the Sacramento Harvest Model (SHM).

Recent evidence of over-forecasting fishing effort has been noted in some months, management areas, and fisheries, which led the Pacific Fishery Management Council (PFMC) to request that the STT conduct an evaluation of forecast accuracy and potential modifications that could lead to improved effort forecast performance. The STT provided reports to the Council on this topic in April 2022 (Agenda Item D.3.a), June 2022 (Agenda Item C.8.a), and September 2022 (Agenda Item D.1.a).

In this report, we first examine effort forecast performance at the month/area/fishery level of stratification. We then examine whether effort forecast performance could be improved using more contemporary data. Currently, effort forecasts are made using data from 1998 through the most recent year with postseason effort data (generally, management year – 1). Detailed descriptions of methods used to forecast effort are described in Mohr (2006) and Mohr and O'Farrell (2014).

The focus of this evaluation is effort forecasts in fisheries that are not generally managed through quotas. Commercial fisheries in the Oregon Klamath Management Zone (KO) and the California Klamath Management Zone (KC), are predominantly quota-based, and effort projections have little effect on the projections on fishery harvest and impacts. As such, the focus of this report will be on effort projections outside of Klamath Management Zone commercial fisheries.

Table 1. Definition of management areas south of Cape Falcon, Oregon.

Management Area	Location
NO	Northern Oregon
CO	Central Oregon
KO	Oregon Klamath Management Zone
KC	California Klamath Management Zone
FB	Fort Bragg
SF	San Francisco
MO	Monterey

Methods and Results

Commercial fishery participation

To evaluate potential causes for effort forecasting errors, we began with an examination of changes in commercial salmon fleet participation in Oregon and California. Figures 1 and 2 display changes in fishery participation for Oregon and California, respectively. The number of vessels making salmon landings peaked around 1980 in both states, then declined through the mid-1990's. Subsequently, there has been a general reduction in fishery participation. Recent years (2015-2021) have the lowest levels of commercial fishery participation over the available time series. This is likely due to a consistent decrease in the number of permitted vessels and prohibition of new vessel permits in both California and Oregon. In California, the limited-entry salmon vessel permit system was implemented in 1983. Since that time no new permits have been issued, and any permit that is not renewed by the annual deadline becomes void, thereby slowly reducing fleet size over time. A similar process occurs for Oregon, with a limited entry permit system that began in 1980.

Figure 3 provides a closer look at the number of commercial vessels making salmon landings in California and Oregon since 2011. We note that commercial fisheries were closed or highly constrained south of Cape Falcon, Oregon, from 2008-2010 due to the collapse of the Sacramento River fall Chinook salmon (SRFC) stock. Following that closure, there was a period of generally good abundance of key salmon stocks and an increase in fishery participation in both states. Salmon abundances subsequently began to decline, leading to overfished designations for SRFC and Klamath River fall Chinook salmon (KRFC) in 2018, based on the geometric mean of escapement in years 2015-2017. During this time, commercial fishery participation declined in both states, but has subsequently rebounded to some degree in California. A similar rebound in fishery participation has not been realized in Oregon.

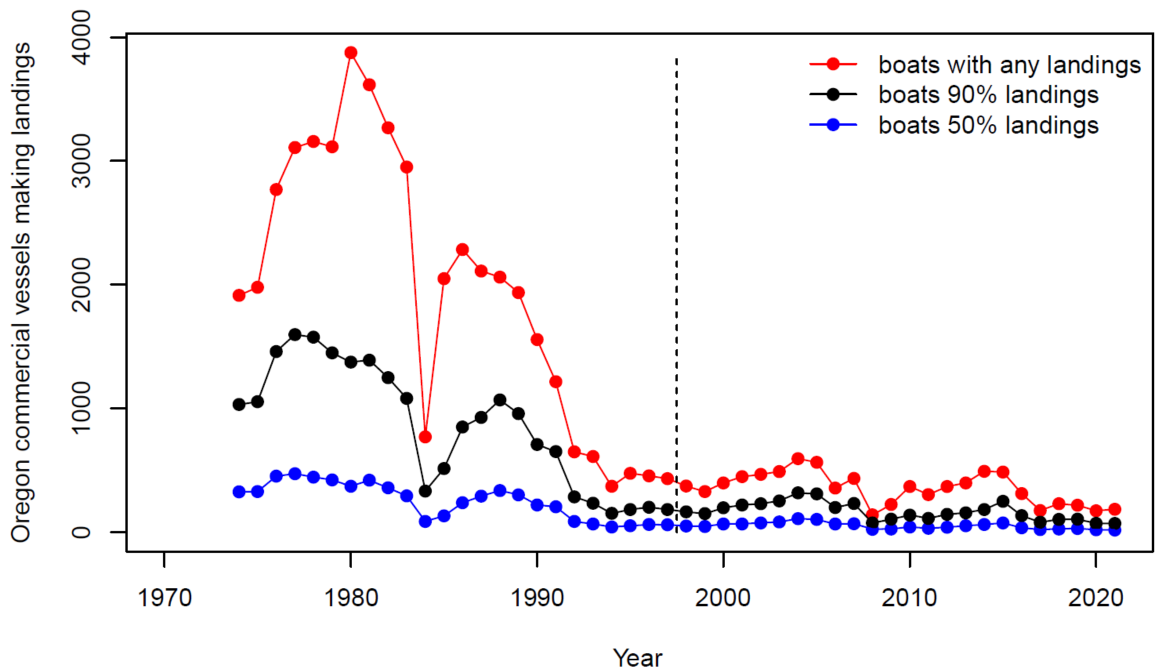

Figure 1. The number of Oregon commercial vessels making salmon landings, contributing 90 percent of landings, and contributing 50 percent of landings. The dashed line indicates year 1998, which is the first year of the data range currently used to forecast fishing effort.

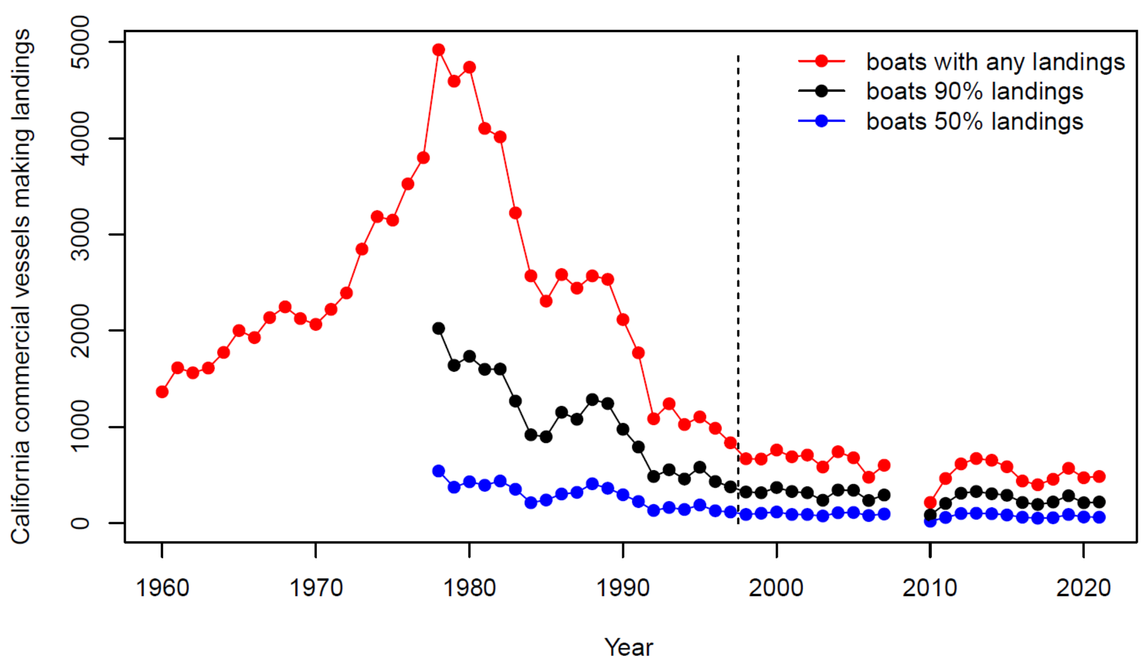

Figure 2. The number of California commercial vessels making salmon landings, contributing 90 percent of landings, and contributing 50 percent of landings. The dashed line indicates year 1998, which is the first year of the data range currently used to forecast fishing effort.

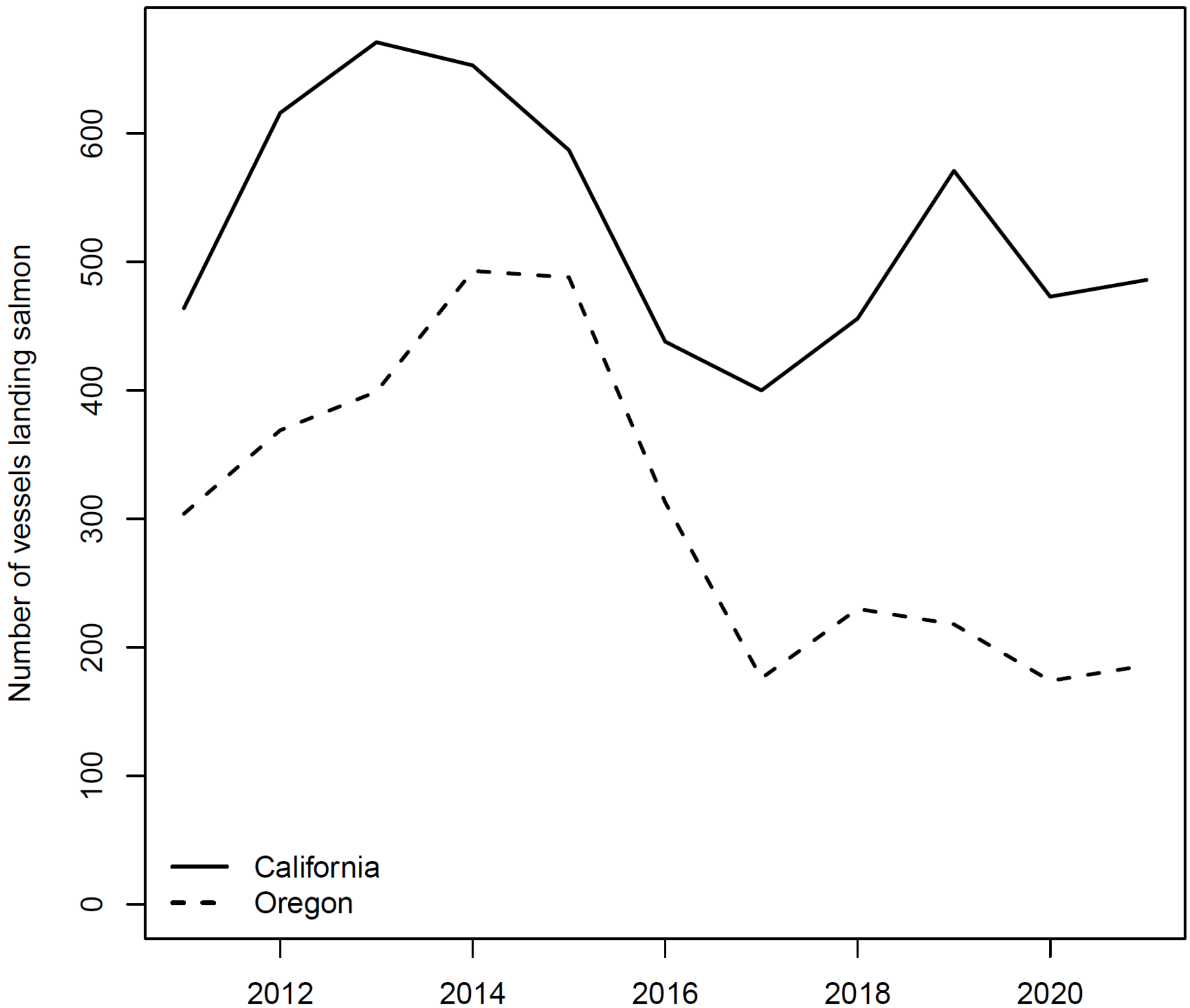

Figure 3. The number of vessels making salmon landings in California and Oregon, 2011–2021.

Patterns in effort forecast errors

Effort in the commercial fishery are quantified by boat days. Plots of effort residuals (forecast – observed) in the commercial fishery (Figure 4) indicate a propensity to over-forecast effort in some month/area/fishery strata. Recent over-forecasting of effort is most notable for CO and FB. There has been some under-forecasting of effort recently in SF.

Effort in the recreational fishery are quantified by angler days. Plots of effort residuals (forecast – observed) in the recreational fishery (Figure 5) indicate a propensity to over-forecast effort, but the effect is not consistent across all times and areas. Recent over-forecasting of effort is most notable for CO and FB.

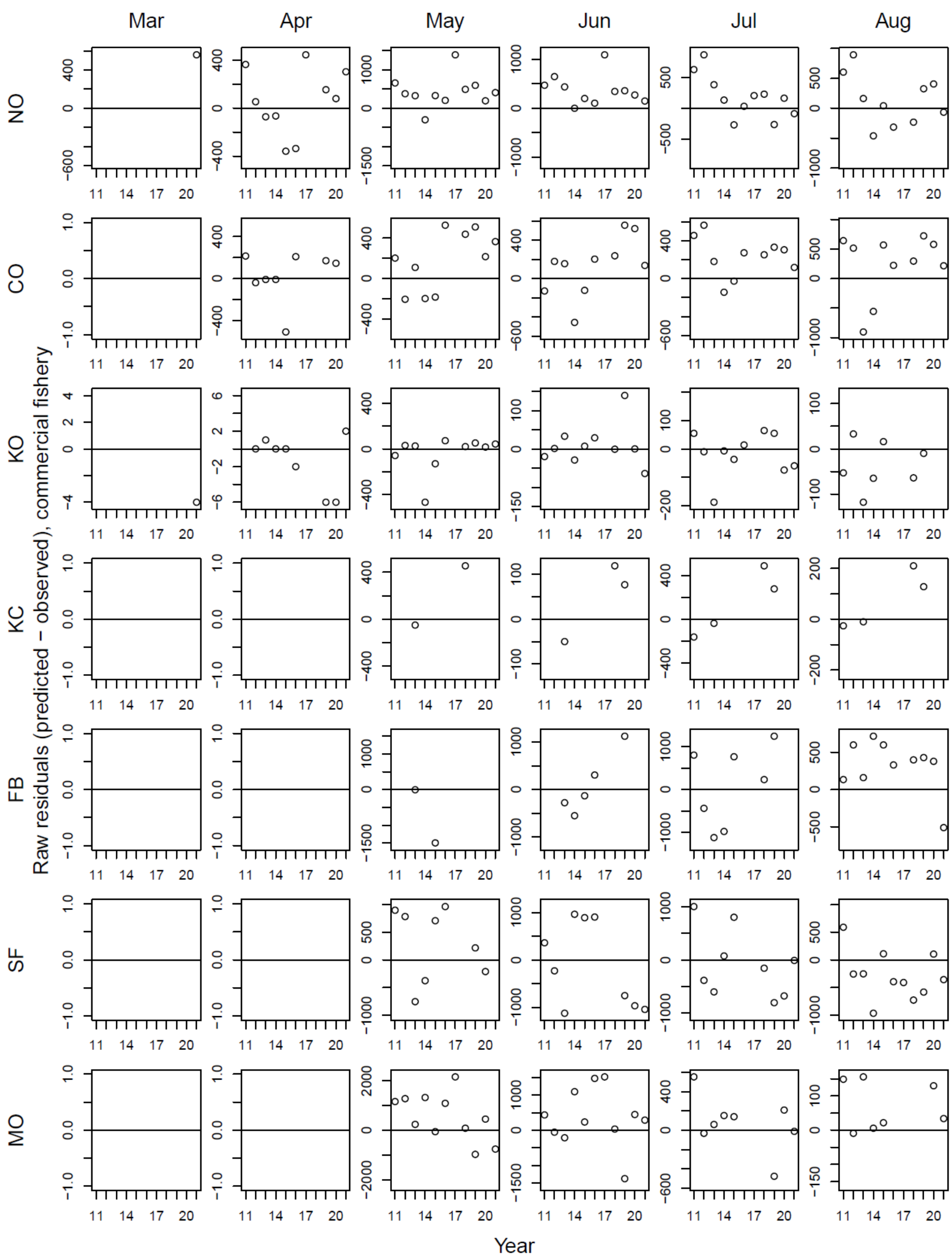

Figure 4. Raw effort residuals (forecasted effort - observed effort) for the commercial fishery, 2011-2021. Effort units are boat days. Points above the horizontal zero line represent over-forecasted effort.

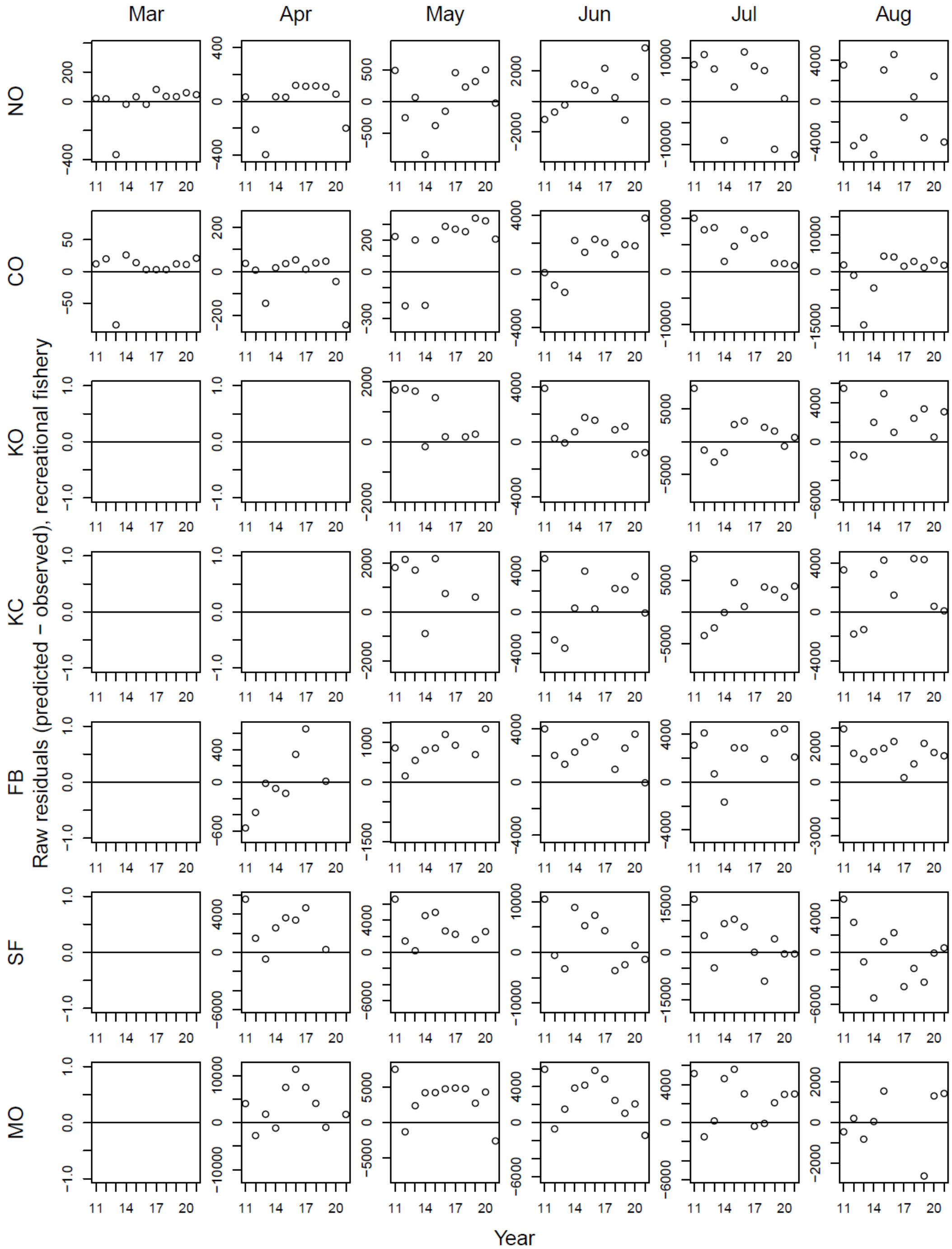

Figure 5. Raw effort residuals (forecasted effort - observed effort) for the recreational fishery, 2011-2021. Effort units are angler days. Points above the horizontal zero line represent over-forecasted effort.

The effect of stock abundances on observed effort per day open

Sacramento River fall Chinook often make up a large fraction of the salmon catch in California and Oregon fisheries (O'Farrell et al. 2013, Bellinger et al. 2015, Satterthwaite et al. 2015), and thus abundance forecasts for this stock could help improve effort forecast performance. The STT has made some preliminary investigations into the potential for the Sacramento Index forecast to improve effort forecasts. These initial investigations indicated that effort per day open was higher when SI forecasts were higher in some strata but the pattern was not consistent across management areas or months. More work would be needed to evaluate the potential to improve effort forecasts using key stock abundances and to develop methods to incorporate that information into the KOHM effort submodel.

Evaluation of effort forecast performance using more contemporary data

Effort forecast performance was assessed using a one-year-ahead cross-validation approach. In short, effort was projected at the scale of month/area/fishery in a management year given the data available at the time (as is done in practice). These forecasts were then compared to postseason estimates of effort. We examined three data range scenarios:

1. Status quo, consisting of data from years 1998 through management year – 1

2. 2011 through management year – 1

3. 2015 through management year – 1.

Scenario 2 (2011-forward) represents a range of management years following the extensive closures experienced in 2008-2010. This range of years includes a period of relatively high abundance for key salmon stocks important to South of Falcon fisheries (2012-2014) as well as a period of low abundance (2015-2017) that resulted in overfished status for SRFC and KRFC.

Scenario 3 (2015-forward) is the shortest data range practically feasible. Given that fisheries are not open in all month/area/fishery strata in each year, shorter data ranges would result in some strata having very few or no data available for effort forecasting. Even with a 2015-forward data range, some month/area/fishery strata will have few (or potentially zero) effort estimates available to inform forecasts because of fishery closures during this period.

Effort forecast performance was evaluated for the three data range scenarios using Mean Percent Error (MPE) and Mean Raw Error (MRE).

Mean Percent error is defined as

$$\text{MPE} = \frac{1}{n}\sum_{y=1}^{n}\frac{f_{pre.y} - f_{post,y}}{f_{post,y}}$$

where $f_{pre,y}$ is preseason-projected effort in year y, $f_{post,y}$ is postseason-estimated effort in year *y,* and *n* is the total number of pre/post comparisons. MPE is useful for assessing whether forecasts are biased, on average. Positive values of MPE indicate mean over-forecasting, while negative values of MPE indicate mean under-forecasting. For brevity, we omit multiplying the right hand side of the MPE expression by 100, which would express MPE as a percent.

Figure 6 displays MPE results by month/area/fishery for the commercial fishery and Figure 7 displays these results for the recreational fishery. The figure headers indicate the data range scenarios used to make effort projections. MPE values were calculated using predicted and observed effort over the 2019-2021 management year range. Evaluation was limited to management years 2019-2021 because this was the only year range for which the three data range scenarios could be simultaneously evaluated. There is a need for some years of "base period" effort data to make effort projections for the most contemporary 2015-forward data range scenario. For this evaluation, effort forecasts for the 2019 management year would be informed by effort per day open data from 2015-2018 under for the 2015-forward data range scenario. In some months and areas where fisheries were closed for parts of management years 2015-2018, there would be fewer than four data points used to base effort projections for management year 2019.

For the commercial fisheries in NO, CO, and FB, effort forecasts made with more contemporary data ranges generally performed better (were less biased) than the status quo data range. However, there was still a propensity for over-forecasting effort in these areas. In contrast, for the SF and MO management areas, the status quo data range (1998-forward) resulted in better effort forecast performance relative to more contemporary data ranges. In these areas, there was a propensity for under-forecasting, particularly in the SF management area.

Data range: 1998-forward

	Apr	May	Jun	Jul	Aug
NO	2.23	3.31	1.19	-0.07	0.87
CO	6.06	14.12	6.66	3.42	28.92
KO	-0.33	3.67	2.10	-0.27	-0.10
KC	NA	NA	0.77	2.77	1.28
FB	NA	NA	3.74	4.16	1.49
SF	NA	0.08	-0.42	-0.25	-0.18
MO	NA	-0.09	0.16	-0.01	0.82

Data range: 2011-forward

	Apr	May	Jun	Jul	Aug
NO	2.34	2.10	0.42	-0.32	0.62
CO	6.13	11.85	6.28	1.85	22.62
KO	-0.40	6.70	2.09	-0.27	-0.11
KC	NA	NA	0.76	2.75	1.26
FB	NA	NA	3.54	3.97	1.04
SF	NA	-0.06	-0.45	-0.34	-0.47
MO	NA	-0.29	-0.08	-0.07	-0.14

Data range: 2015-forward

	Apr	May	Jun	Jul	Aug
NO	4.02	1.52	0.39	0.01	1.16
CO	7.85	7.72	4.49	1.52	6.07
KO	-0.17	4.00	2.09	-0.28	-0.13
KC	NA	NA	0.76	2.70	1.19
FB	NA	NA	2.67	1.76	0.18
SF	NA	-0.50	-0.49	-0.34	-0.55
MO	NA	-0.34	-0.17	-0.08	-0.09

MPE
28.92
0.00
-0.55

Figure 6. Mean Percent Error (MPE) computed from forecasted and observed commercial fishery effort under three data ranges: 1998-forward (left), 2011-forward (middle), and 2015-forward (right) for management years 2019 – 2021. Blue shading indicates under-forecasting of effort while red shading indicates over-forecasting of effort over the management year range.

For the recreational fishery (Figure 7), more contemporary data ranges resulting in less mean over-forecasting of effort. In particular, effort forecasts were generally improved for the 2015-forward data range relative to the other two scenarios. However, for the SF and MO areas, the 2015-forward data range resulted in mean under-forecasting in several months. Under-forecasting of effort in NO, CO, and KO is also apparent in July for the 2015-forward data range. This is likely due to a strong effort response to high coho abundance, which was not well represented in the range of years used to make effort projections.

Data range: 1998-forward

	Apr	May	Jun	Jul	Aug
NO	0.20	1.07	1.33	-0.29	-0.03
CO	1.14	2.55	4.51	0.19	0.41
KO	NA	2.52	0.14	0.33	1.82
KC	NA	1.53	2.47	1.37	1.25
FB	0.02	2.85	3.50	1.15	0.91
SF	0.10	0.80	-0.17	0.08	-0.06
MO	0.03	0.83	0.21	0.76	1.71

Data range: 2011-forward

	Apr	May	Jun	Jul	Aug
NO	0.38	1.12	0.97	-0.45	-0.06
CO	1.02	1.74	2.33	-0.40	0.30
KO	NA	0.61	-0.30	0.15	1.02
KC	NA	0.95	2.19	1.21	0.77
FB	0.07	1.75	1.47	0.73	0.27
SF	-0.33	0.13	-0.39	-0.10	-0.06
MO	-0.17	0.09	-0.28	0.32	2.18

Data range: 2015-forward

	Apr	May	Jun	Jul	Aug
NO	-0.72	0.92	0.66	-0.49	-0.12
CO	0.05	0.72	0.86	-0.44	-0.04
KO	NA	0.22	-0.56	-0.43	-0.18
KC	NA	0.57	0.84	0.23	-0.08
FB	-0.23	1.09	0.65	0.42	0.21
SF	-0.56	-0.09	-0.39	-0.06	-0.01
MO	-0.41	-0.23	-0.51	-0.12	1.80

MPE
4.51
0.00
-0.72

Figure 7. Mean Percent Error (MPE) computed from forecasted and observed recreational fishery effort under three data ranges: 1998-forward (left), 2011-forward (middle), and 2015-forward (right) for management years 2019 – 2021. Blue shading indicates under-forecasting of effort while red shading indicates over-forecasting of effort over the management year range.

Mean Raw Error is defined as

$$\text{MRE} = \frac{1}{n}\sum_{y=1}^{n} f_{pre,y} - f_{post,y}.$$

MRE has some use for assessing bias in forecasts but can also provide some context to the magnitude of forecast errors. Figure 8 displays MRE results by month/area/fishery for the commercial fishery and Figure 9 displays these results for the recreational fishery. Positive values of MRE indicate mean over-forecasting, while negative values of MPE indicate mean under-forecasting. However, positive and negative errors can balance each other, resulting in a MRE value of near zero. Such a scenario would correctly indicate that the forecasts are unbiased, on average, but does not indicate that forecasts are accurate from year to year, or that the overall magnitude of effort is small.

The MRE results for commercial fisheries were generally (but not perfectly) consistent with the results described for the MPE performance measure (Figure 8). Effort forecasts had lower MRE under the 2015-forward data range for CO and FB relative to the other data range scenarios (as indicated by the area-specific row sums). The lowest summed MRE for NO occurred for the 2011-forward data range scenario. For SF and MO, use of the status quo data range (1998-forward) resulted in the lowest summed MRE values. For all three scenarios, summed MRE for the SF and MO management areas was negative (indicating mean under-forecasting), while for more northerly areas the summed MRE was positive (indicating mean over-forecasting).

The magnitude of the mean raw errors in the FB, SF, and MO management areas was much higher, in general, relative to NO and CO when evaluated over management years 2019-2021. This result is indicative of the higher levels of overall effort in those California management areas relative to the Oregon management areas over the set of years evaluated. This pattern was less apparent for the 1998-forward data range.

Data range: 1998-forward

	Apr	May	Jun	Jul	Aug	SUM
NO	179	399	259	-64	221	995
CO	158	364	405	251	506	1684
KO	-3	37	25	-27	-10	22
KC	NA	NA	77	277	128	482
FB	NA	NA	1121	1249	99	2469
SF	NA	4	-922	-499	-279	-1697
MO	NA	-430	-215	-93	82	-656

Data range: 2011-forward

	Apr	May	Jun	Jul	Aug	SUM
NO	180	246	87	-186	154	481
CO	158	301	385	136	401	1380
KO	-4	67	25	-27	-11	50
KC	NA	NA	76	275	126	477
FB	NA	NA	1062	1192	-23	2231
SF	NA	-133	-1003	-694	-709	-2540
MO	NA	-859	-379	-123	-14	-1374

Data range: 2015-forward

	Apr	May	Jun	Jul	Aug	SUM
NO	289	172	81	-27	317	832
CO	200	188	278	116	111	893
KO	-2	40	25	-28	-13	22
KC	NA	NA	76	270	119	465
FB	NA	NA	800	527	-207	1120
SF	NA	-541	-1065	-814	-842	-3262
MO	NA	-1003	-459	-127	-9	-1598

MRE
1249
0
-1065

Figure 8. Mean Raw Error (MRE) computed from forecasted and observed commercial fishery effort under three data ranges: 1998-forward (left), 2011-forward (middle), and 2015-forward (right) for management years 2019 – 2021. Blue shading indicates mean under-forecasting of effort while red shading indicates mean over-forecasting of effort over the management year range. The SUM column reports summed MRE over months April through August for each management area and data range scenario.

For the recreational fishery (Figure 9), MRE values indicated that more contemporary data ranges resulted in lower levels of over-forecasting than the status quo data range, which is generally consistent with the MPE results. However, there are some instances where the MPE and MRE results diverge. The summed MRE results for NO, CO, and KO indicate the lowest level of bias occurs for the 1998-foreward scenario for NO and the 2011-forward scenario for CO and KO. This is likely due to a strong effort response to high coho abundance in recent years, which was not well represented in the short range of years used to make effort projections for the 2015-forward data range scenario. Mean under-forecasting of effort was notable in the SF and MO management areas under the more contemporary data range scenarios. The magnitude of mean forecast errors was highest in July and August in NO and CO, while for California, the magnitude of mean forecast errors was highest in SF and MO prior to August.

Data range: 1998-forward

	Apr	May	Jun	Jul	Aug	SUM
NO	-13	260	1289	-7602	-1706	-7772
CO	-81	289	2509	1402	1984	6103
KO	NA	252	-197	532	2311	2898
KC	NA	611	1823	3283	1614	7331
FB	12	1017	2043	3558	1760	8389
SF	307	2098	-816	1112	-999	1702
MO	361	1490	568	2684	41	5144

Data range: 2011-forward

	Apr	May	Jun	Jul	Aug	SUM
NO	5	274	311	-10867	-2270	-12547
CO	-84	191	902	-2976	1286	-681
KO	NA	61	-680	88	1338	806
KC	NA	380	1620	2890	1080	5970
FB	44	607	782	2166	501	4100
SF	-1059	218	-2773	-2125	-1052	-6792
MO	-2212	-1089	-1639	1106	319	-3515

Data range: 2015-forward

	Apr	May	Jun	Jul	Aug	SUM
NO	-90	202	-145	-11748	-3052	-14832
CO	-107	69	241	-3248	-417	-3461
KO	NA	22	-946	-1350	-143	-2417
KC	NA	226	381	327	64	999
FB	-140	356	248	1148	376	1987
SF	-1798	-410	-2850	-1276	-366	-6700
MO	-5306	-2222	-2681	-541	-269	-11020

MRE
3558
0
-11748

Figure 9. Mean Raw Error (MRE) computed from forecasted and observed recreational fishery effort under three data ranges: 1998-forward (left), 2011-forward (middle), and 2015-forward (right) for management years 2019 – 2021. Blue shading indicates mean under-forecasting of effort while red shading indicates mean over-forecasting of effort over the management year range. The SUM column reports summed MRE over months April through August for each management area and data range scenario.

Summary

One-year-ahead cross-validation of effort forecasts compared to postseason estimates under three data range scenarios suggested that the use of more contemporary data ranges improved forecast performance in some area/month strata. We base our assessment of forecast performance by examination of the MPE and MRE results, with the performance of the three effort data range scenarios being primarily evaluated using MPE. Patterns of MPE and MRE were roughly consistent with each other, though there were some differences in particular month/area/fishery strata. There were month/area/fishery strata with very high MPE values, but relatively low MRE values (e.g., some months for the CO commercial fishery). This can occur when the overall level of effort in that stratum is low, but effort forecasts are much higher than the postseason estimates. In such cases, the MPE results may indicate alarmingly poor forecast performance. However, the effects of these errors on salmon stocks are likely to be relatively low because of the overall magnitude of the fisheries in that stratum was relatively small.

For commercial fisheries in NO, CO, and FB, effort forecasts made with more contemporary data ranges performed better (were less biased, on average) than the status quo data range. However, there was still a propensity for over-forecasting in these areas. In contrast, for the SF and MO management areas, the status quo data range resulted in better effort forecast performance relative to more contemporary data ranges. In these areas, there was a propensity for under-forecasting.

For the recreational fishery, more contemporary data ranges performed generally better in all areas except SF and MO. Effort forecasts were most improved under the 2015-forward data range for areas north of SF. For the SF and MO areas, the status quo data scenario resulted in a mixture of under- and over-forecasting of effort, while the 2015-forward data range predominately resulted in under-forecasting.

There are several limitations to this analysis. In particular, because a sufficient "base period" of effort data is needed to make effort projections, we are only able to evaluate effort forecast performance for all three scenarios over a common set of three management years: 2019-2021. There is some concern that an evaluation over such a limited range of years may not be representative of future forecast performance. Management years 2019-2021 generally featured constrained fisheries and low abundance levels for key stocks, and thus might not be representative of years with more fishing opportunity and higher catch rates. On the other hand, it is likely most representative of the recent past. The 2011-2021 management year range is representative of post-closure years (following 2008-2010) which feature a larger range of abundance relative to 2019-2021. However, commercial fishery participation has decreased, particularly in Oregon, since approximately 2015 (Figure 3).

Our analysis has been limited to modifications of data ranges only, with no change to the general effort forecasting methods. There may be some utility to investigating alternative methods, but such an investigation would require more time to identify and/or develop those methods and would likely be a candidate for a future methodology review.

STT recommendation

The STT provides the following recommendation for changes to the data ranges used to forecast effort in commercial and recreational salmon fisheries south of Cape Falcon, OR:

For effort forecasting in commercial and recreational fisheries, employ a 2015-forward data range for all management areas, except SF and MO, for which the data range would remain the status quo of 1998-forward.

For the commercial fishery, if the STT-recommended data ranges were in place for the planning of 2022 fisheries, effort projections would be lower for nearly all months in the NO, CO, and FB management areas. The effort projections for the SF and MO management areas would be equivalent (Table 2).

Table 2. Projected effort in the commercial fishery for the status quo data range (left), the STT-recommended data ranges (middle), and the difference in effort between the recommended and status quo data ranges (right).

	Data range: status quo					Data range: STT Recommendation					Recommendation - status quo				
	Apr	May	Jun	Jul	Aug	Apr	May	Jun	Jul	Aug	Apr	May	Jun	Jul	Aug
NO	584	666	1377	564	188	628	341	1253	525	183	44	-325	-124	-39	-5
CO	0	510	0	0	177	0	240	0	0	31	0	-270	0	0	-146
KO	12	0	69	45	8	14	0	69	45	8	2	0	0	0	0
KC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FB	0	0	0	673	482	0	0	0	549	510	0	0	0	-124	28
SF	0	0	0	515	390	0	0	0	515	390	0	0	0	0	0
MO	0	1457	850	274	78	0	1457	850	274	78	0	0	0	0	0

For the recreational fishery, if the STT-recommended data ranges were in place for the planning of 2022 fisheries, effort projections would be substantially lower for nearly all months in the NO, CO, KO, KC, and FB management areas. The effort projections for the SF and MO management areas would be equivalent (Table 3).

Table 3. Projected effort in the recreational fishery for the status quo data range (left), the STT recommended data ranges (middle), and the difference in effort between the recommended and status quo data ranges (right).

	Data range: status quo					Data range: STT Recommendation					Recommendation - status quo				
	Apr	May	Jun	Jul	Aug	Apr	May	Jun	Jul	Aug	Apr	May	Jun	Jul	Aug
NO	110	673	4780	14898	13019	67	586	3506	13293	12888	-43	-87	-1274	-1605	-131
CO	69	396	3556	8573	7292	74	186	1307	4937	5424	5	-210	-2249	-3636	-1868
KO	0	0	657	3313	3168	0	0	427	2017	1095	0	0	-230	-1296	-2073
KC	0	4414	0	0	5706	0	2641	0	0	2397	0	-1773	0	0	-3309
FB	0	1871	3830	3017	3601	0	921	1301	1942	2275	0	-950	-2529	-1075	-1326
SF	5631	6856	2608	19477	14008	5631	6856	2608	19477	14008	0	0	0	0	0
MO	14451	6324	5449	6052	1757	14451	6324	5449	6052	1757	0	0	0	0	0

If the STT-recommended effort forecast data ranges were in place for the planning of 2022 fisheries, projected ocean harvest rates for KRFC and SRFC would have been lower than harvest rates projected under the status quo data range (Table 4). The projected Sacramento River winter Chinook (SRWC) age-3 impact rate would be unchanged as the harvest model for this stock only accounts for fishery impacts south of Point Arena, CA (where the data ranges are identical to the status quo and STT recommendation). The Lower Columbia River Natural Tule fall Chinook (LRC Tule) exploitation rate would have been reduced by a small amount if the STT-recommended effort data range were in place in 2022 (Table 4).

Table 4. Projected harvest and exploitation rates under the status quo and STT-recommended effort forecasting data range scenarios, given 2022 fishery structures.

	Effort Forecasting Scenario	
Metric	Status quo	STT recommendation
KRFC age-4 ocean harvest rate	0.100	0.092
SRFC ocean harvest rate	0.417	0.384
SRWC age-3 impact rate	0.152	0.152
LCR Tule exploitation rate	0.380	0.375

PFMC
11/02/22

References

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