

Causes and Effects of Bias in Anticipated Mark Rates in Mark-Selective Fisheries for Coho Salmon.

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One issue that has been raised regarding mark-selective fisheries is that observed mark rates for coho have consistently been lower than predicted mark rates. As a result of this, more unmarked fish are encountered per marked fish landed in mark-selective fisheries than is expected pre-season. One possible consequence of unexpectedly high encounter rates is that more unmarked fish may be killed as a result of incidental mortality in mark-selective fisheries than is being projected pre-season. To evaluate this potential problem, we examine the magnitude of the bias in pre-season mark-rate projections, look for possible explanations of the bias, and evaluate the post-season impacts of mark-selective fisheries on unmarked coho.

Each year the STT reports anticipated and observed mark rates for coho as well as quotas or catch expectations, expected incidental mortality, observed catches and estimates of unmarked coho released and incidental mortality in mark-selective fisheries. These values are reported in Table I-9 of the 2010 Review of Ocean Salmon Fisheries (STT 2011a) and in table I-8 in the same document for prior years back to 2000. In most years, post-season estimates of mark rates in commercial mark-selective fisheries are not available, so we focus here primarily on recreational fisheries.

Magnitude of the bias in projected mark rates

Comparison of pre-season anticipated mark rates with observed rates does reveal evidence of bias (Table 1). This bias appears to vary by year and by area, ranging from a 6% relative error in 2006 to 51% relative error in 2003, and from 7% in the buoy 10 fishery to 58% in the recreational fishery in LaPush. The average bias across all years and catch areas amounts to 24% of the post-season observed mark rates. However, this simple average rate is not very meaningful. The LaPush area, with the highest relative error, typically has the smallest recreational fishery of all the catch areas.

Likely Explanations

The expected mark rates in coho fisheries are calculated using the coho Fishery Regulation Assessment Model (FRAM). Each coho stock is divided into marked and unmarked components. Forecast abundance of natural stocks is all unmarked and the marked component is

zero. For hatchery stocks, the forecast is divided into marked and unmarked components using the proportion of hatchery releases that were marked. The base period contribution rates of individual stocks are multiplied by the ratio of forecast abundance to base period abundance, and these are summed over marked and unmarked components.

Observed mark rates are either based on at-sea observers who ride along on commercial passenger fishing vessels (CPFVs), or they are based on dockside sampling by port samplers who interview recreational anglers from both CPFVs and private boats.

Observed mark rates would be less than expected mark rates if: 1) the abundance of hatchery fish is less than forecast, 2) the abundance of unmarked fish is greater than forecast, or 3) the survival of marked fish is less than that of unmarked fish.

Hatchery Forecasts

Hatchery forecasts in the time period when we have had fairly extensive mark-selective recreational fisheries have tended to underestimate hatchery abundance (Table 2). Overall, in the years from 2000 to 2010, forecasts have underpredicted the post-season abundance estimate for aggregate hatchery abundance in the Oregon Production Index (OPI) area by 7%. However, the bias this prediction error would cause in mark rates is in the wrong direction; it would tend to produce observed mark rates higher than expected rather than lower. So this can be ruled out as a source of bias.

Differential Survival

There is relatively little information available to evaluate this potential source of bias. The Pacific Salmon Commission's Selective Fishery Evaluation Committee reviewed available studies and concluded that the difference in survival between unmarked fish and fish marked with an adipose fin clip and coded-wire tag was negligible (SFEC 2006). If there is a difference in survival, it is unlikely that it would be sufficient to compensate for the apparent bias in forecasting hatchery abundance, much less be responsible for the apparent bias in anticipated mark rates.

Natural Abundance Forecasts

If forecasts of natural coho abundance tend to underestimate natural coho abundance, then expected mark rates would be higher than observed mark rates. Preseason Report I (STT 2011b) presents forecasts and post-season reconstructions of abundance for OPI, Washington Coast, and Puget Sound stocks. Average aggregate abundance of all three of these stock groups has been underestimated during the 2000-2010 time period (Table 3). The apparent bias ranges from 9% for the Washington coastal coho stocks, to 37% for Puget Sound coho stocks. For all hatchery stocks combined, the abundance has been underpredicted by an average of 29%. This bias is of the comparable magnitude to the bias in forecasting mark rate, and is in the direction that would

produce the observed bias. Thus it seems that underpredicting the abundance of natural coho is likely responsible for most of the observed bias in predicting mark rates for coho.

This explanation is supported by the patterns of correlations between errors in forecasting mark rates and errors in forecasting abundance components (Table 4). The patterns of correlations in forecasting error is generally what is expected: correlations are predominantly negative between mark rate and natural stock abundance, and positive between mark rate and OPI hatchery stock abundance. While these patterns are simply a reflection of the structural relationship between mark rate and the abundance of hatchery and natural stock components, it is somewhat reassuring that both forecasts have sufficient precision that observed correlations bear this out. Because these correlations are for year-to-year variability, they do not directly bear on the question of the source of bias. However, the strongest correlations are between mark rate errors and natural stock forecasting errors.

The anomalies to the expected patterns are somewhat surprising. Errors in forecasting OCN coho do not appear to be correlated with errors in forecasting mark rates, and the errors in forecasting OPI hatchery coho (which are primarily from the Columbia River) do not appear to be well correlated with mark rates in the Columbia River catch area. Possible explanations for these anomalies are that OCN coho do not contribute much to fisheries north of the Columbia River, and that in the Columbia Catch area, the majority of fish encountered in the fishery are of hatchery origin, so errors in predicting natural and hatchery components are less important than forecasting the mark rate of the hatchery component.

Consequences of Biased Mark Rates

The major concern about bias resulting in observed mark rates being less than anticipated on average is that more unmarked fish are encountered than anticipated, and consequently more fish may die from incidental mortality in mark-selective fisheries than anticipated during the preseason planning process. While this is a valid concern, the record does not suggest that this has been a problem in mark-selective coho fisheries.

Encounter rates of unmarked to marked fish in mark-selective coho fisheries have, on average, been higher than anticipated (Table 5). In some cases, this bias has been substantial. For example, in the LaPush recreational fishery, averaged over all years, more than one additional unmarked fish has been encountered for every marked fish than was anticipated. However, most of these unmarked fish survive, and as pointed out earlier, this fishery has the smallest landings of any of the coastal fishing areas.

In addition, in most years mark-selective fisheries do not land their preseason expected catch or quota. Comparison of preseason expected catches and incidental mortalities in mark-selective coho fisheries with post-season observations reveals that both catches and incidental mortalities have been less than expected on average (Table 6). The difference between expected catches and observed catches has been sufficiently large that, despite higher than anticipated encounter rates

of unmarked coho, post-season estimates of incidental mortalities have been less on average than anticipated. The lower mortalities of unmarked fish, coupled with higher than predicted abundance means that incidental mortality rates have been lower still.

Table 1. Expected and observed mark rates in mark-selective recreational coho fisheries reported in Table I-8 from Review of Ocean Salmon Fisheries reports from 2000 through 2009, and Table I-9 in Review of 2010 Ocean Salmon Fisheries (STT 2011a). Expected values are based on forecasts of hatchery and natural production, and hatchery mark rates. Observed values are based on at-sea observations where available and on shore-based catch sampling where at-sea observations are unavailable.

Area	Year											Average
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Expected Mark Rates												
Neah Bay	0.48	0.58	0.49	0.51	0.39	0.38	0.45	0.53	0.48	0.57	0.51	0.49
La Push	0.75	0.73	0.48	0.59	0.45	0.40	0.49	0.59	0.53	0.60	0.54	0.56
Westport	0.77	0.80	0.61	0.74	0.57	0.52	0.57	0.65	0.56	0.67	0.59	0.64
Columbia River	0.87	0.86	0.76	0.85	0.68	0.66	0.69	0.72	0.64	0.72	0.67	0.74
Falcon to Humbug	0.81	0.82	0.68	0.72	0.58	0.50	0.58	0.51	0.50	0.56	0.46	0.61
Strait of Juan de Fuca	0.38	0.54	0.49	0.40	0.40	0.33	0.38	0.48	0.48	0.51	0.47	0.44
Buoy 10	0.87	0.83	0.70	0.81	0.58	0.67	0.69	0.74	0.68	0.72	0.66	0.72
Observed Mark Rates												
Neah Bay	0.34	0.39	0.39	0.39	0.36	0.30	0.40	0.36	0.41	0.39	0.36	0.37
La Push	0.51	0.32	0.28	0.31	0.28	0.31	0.43	0.30	0.35	0.48	0.42	0.36
Westport	0.70	0.57	0.56	0.53	0.46	0.46	0.55	0.51	0.58	0.54	0.51	0.54
Columbia River	0.86	0.78	0.58	0.57	0.58	0.62	0.65	0.61	0.60	0.61	0.50	0.63
Falcon to Humbug	0.74	0.68	0.56	0.44	0.48	0.50	0.52	0.52	0.53	0.41	0.46	0.53
Strait of Juan de Fuca	0.43	0.36	0.36	0.27	0.42	0.45	0.39	0.38	0.43	0.32	0.39	0.38
Buoy 10	0.83	0.79	0.74	0.61	0.66	0.68	0.70	0.60	0.64	0.57	0.69	0.68
Relative Error (expected - observed)/observed												
Neah Bay	0.41	0.49	0.26	0.31	0.08	0.27	0.13	0.47	0.17	0.46	0.42	0.31
La Push	0.47	1.28	0.71	0.90	0.61	0.29	0.14	0.97	0.51	0.25	0.29	0.58
Westport	0.10	0.40	0.09	0.40	0.24	0.13	0.04	0.27	-0.03	0.24	0.16	0.18
Columbia River	0.01	0.10	0.31	0.49	0.17	0.06	0.06	0.18	0.07	0.18	0.34	0.18
Falcon to Humbug	0.09	0.21	0.21	0.64	0.21	0.00	0.12	-0.02	-0.06	0.37	0.00	0.16
Strait of Juan de Fuca	-0.12	0.50	0.36	0.48	-0.05	-0.27	-0.03	0.26	0.12	0.59	0.21	0.19
Buoy 10	0.05	0.05	-0.05	0.33	-0.12	-0.01	-0.01	0.23	0.06	0.26	-0.04	0.07
Average Error	0.15	0.43	0.27	0.51	0.16	0.07	0.06	0.34	0.12	0.34	0.19	0.24

Table 2. Forecasting error for Oregon Production Index hatchery abundance. Data from Preseason Report I, Table III-1 (STT 2011b). Errors are expressed as relative error (forecast - observed)/observed.

Year	Forecast	Observed	Error
2000	671.4	677.1	-0.01
2001	1,707.6	1,395.5	0.22
2002	361.7	660.1	-0.45
2003	863.1	952.5	-0.09
2004	623.9	634.6	-0.02
2005	389.9	443.1	-0.12
2006	398.8	440.6	-0.09
2007	593.6	476.5	0.25
2008	216.1	565.4	-0.62
2009	1,073.1	1,066.2	0.01
2010	408.0	551.3	-0.26
Total	7,307.2	7,862.9	-0.07

Table 3. Forecasting errors for natural coho stocks. Data from Tables III-1, III-3, and III-4 in Preseason Report I (STT 2011b). Totals for Washington coast and Puget Sound are calculated for 2000-2009 only. Errors are expressed as relative error.

Year	Oregon Coast			Washington Coast			Puget Sound			Combined		
	Forecast	Observed	Error	Forecast	Observed	Error	Forecast	Observed	Error	Forecast	Observed	Error
2000	55.9	69.0	-0.19	58.2	78.6	-0.26	90.1	146.0	-0.38	204.2	293.6	-0.30
2001	50.1	163.2	-0.69	85.4	156.3	-0.45	105.5	307.4	-0.66	241.0	626.9	-0.62
2002	71.8	304.5	-0.76	85.9	173.0	-0.50	120.0	182.2	-0.34	277.7	659.7	-0.58
2003	117.9	278.8	-0.58	103.5	141.3	-0.27	150.8	364.1	-0.59	372.2	784.2	-0.53
2004	150.9	197.0	-0.23	140.1	105.8	0.32	235.8	444.6	-0.47	526.8	747.4	-0.30
2005	152.0	150.1	0.01	115.1	83.7	0.38	170.3	150.5	0.13	437.4	384.3	0.14
2006	60.8	116.4	-0.48	86.0	41.3	1.08	166.9	74.3	1.25	313.7	232.0	0.35
2007	255.4	60.0	3.26	89.2	54.6	0.63	104.6	195.0	-0.46	449.2	309.6	0.45
2008	60.0	170.9	-0.65	67.7	70.5	-0.04	98.3	73.2	0.34	226.0	314.6	-0.28
2009	211.6	257.0	-0.18	119.4	141.0	-0.15	73.5	145.7	-0.50	404.5	543.7	-0.26
2010	148.0	266.8	-0.45	132.0	-	-	95.6	-	-	375.6	-	-
Total	1,334.4	2,033.7	-0.34	950.5	1,046.1	-0.09	1,315.8	2,083.1	-0.37	3,452.7	4,896.1	-0.29

Table 4. Correlations between errors in expected mark rates in Mark-selective coho fisheries and errors in forecasting stock abundance. Reported values are simple correlation coefficients between relative error in forecasting mark rate and error in forecasting stock abundance over 2000-2010 for OCN and OPI hatchery stocks, and over 2000-2009 for the other series.

Catch Area	Forecast Error				
	Natural				Hatchery
	OCN	WACO	PS	Combined	OPI
Neah Bay	0.36	-0.40	-0.60	-0.10	0.52
La Push	0.23	-0.45	-0.65	-0.41	0.39
Westport	0.19	-0.28	-0.72	-0.29	0.71
Columbia River	-0.08	-0.34	-0.44	-0.40	-0.13
Falcon to Humbug	-0.32	-0.42	-0.43	-0.54	0.19
Strait of Juan de Fuca	-0.03	-0.52	-0.51	-0.47	0.15
Buoy 10	0.36	-0.16	-0.35	0.02	0.32
All Areas	0.12	-0.53	-0.72	-0.47	0.40

Table 5. Errors in expected encounter rates. Reported values are the difference between the expected and observed ratio of unmarked to marked fish based on the mark rates reported in Table 1.

Area	Year											Average
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Neah Bay	0.86	0.84	0.52	0.60	0.21	0.70	0.28	0.89	0.36	0.81	0.82	0.63
La Push	0.63	1.76	1.49	1.53	1.35	0.73	0.28	1.64	0.97	0.42	0.53	1.03
Westport	0.13	0.50	0.15	0.54	0.42	0.25	0.06	0.42	-0.06	0.36	0.27	0.28
Columbia River	0.01	0.12	0.41	0.58	0.25	0.10	0.09	0.25	0.10	0.25	0.51	0.24
Falcon to Humbug	0.12	0.25	0.32	0.88	0.36	0.00	0.20	-0.04	-0.11	0.65	0.00	0.24
Strait of Juan de Fuca	-0.31	0.93	0.74	1.20	-0.12	-0.81	-0.07	0.55	0.24	1.16	0.44	0.36
Buoy 10	0.06	0.06	-0.08	0.40	-0.21	-0.02	-0.02	0.32	0.09	0.37	-0.07	0.08
Average	0.21	0.64	0.51	0.82	0.32	0.14	0.12	0.58	0.23	0.57	0.36	0.41

Table 6. Landings and incidental mortality in mark-selective fisheries. Reported values are tabulated from Table I-8 in Review of Ocean Salmon Fisheries reports from 2000 through 2009, and Table I-9 in Review of 2010 Ocean Salmon Fisheries (STT 2011a).

Year	Landings		Incidental Mortality		Difference
	Expected	Observed	Expected	Observed	
Recreational					
2000	193,969	152,610	18,916	17,719	-1,197
2001	420,072	416,590	22,378	42,189	19,811
2002	200,533	148,838	48,558	29,218	-19,340
2003	384,693	345,651	34,144	84,748	50,604
2004	327,931	231,455	37,080	61,967	24,887
2005	207,515	98,476	61,746	24,264	-37,482
2006	134,692	64,779	24,721	14,073	-10,648
2007	189,325	167,716	40,026	38,089	-1,937
2008	49,588	45,809	13,570	9,688	-3,882
2009	425,751	295,417	81,944	72,551	-9,393
2010	123,902	65,069	40,316	15,647	-24,669
Commercial					
2000	21,000	17,294	1,943	2,368	425
2001	75,000	17,445	2,363	4,286	1,923
2002	5,000	1,695	21,200	20,600	-600
2003	75,000	15,668	19,552	6,045	-13,507
2004	67,500	9,805	28,800	6,711	-22,089
2005	23,200	4,064	14,232	3,615	-10,617
2006	6,800	2,679	6,208	1,183	-5,025
2007	22,400	17,441	8,462	3,976	-4,486
2008	22,400	2,084	3,256	632	-2,624
2009	33,600	32,743	10,521	7,263	-3,258
2010	11,800	3,142	11,044	856	-10,188
Totals					
Recreational	2,657,971	2,032,410	423,399	410,153	-13,246
Commercial	363,700	124,060	127,581	57,535	-70,046
Combined	3,021,671	2,156,470	550,980	467,688	-83,292

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