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MEMORANDUM

TO: Rich Carmichael, ODFW

Michele DeHart

FROM: Michele DeHart,
Comparative Survival Study Oversight Committee

DATE: October 3, 2012

RE: AMIP model inputs

In response to your request, the Comparative Survival Study (CSS) Oversight Committee (Committee) has summarized the functional relationships developed based on Comparative Survival Study data and analyses and retrospective data analyses. The Committee members also reviewed the Adaptive Management Implementation Plan (AMIP) work plan in order to understand the context in which the CSS relationships would be applied. As we understand the work plan, the objective of this effort is fundamentally to update the COMPASS model and the Technical Recovery Team matrix model, as well as developing model relationships for additional species such as fall Chinook. The Committee views this effort as a unique opportunity to improve both modeling efforts. The following discussion identifies areas that should be addressed and improved in both modeling efforts.

The Committee is concerned that both the TRT Matrix model and the COMPASS model structures are not amenable to incorporation of CSS based functional relationships without significant modifications, in particular the incorporation of delayed mortality effects on subsequent life cycle stage survival. COMPASS is a highly parameterized model with multiple short reaches, separate and independent relationships for reservoir versus concrete survival, and assumed values for route-specific survival at each project. COMPASS does not include clear connections between hydro system mortality and delayed mortality. The CSS functional relationship the Committee is providing incorporates delayed mortality and ocean effects. The Committee is concerned that the basic structure of COMPASS does not accommodate the functional relationships we have developed in CSS. The general structure of the models developed in CSS differs from COMPASS in that, the CSS, models are based upon long reach survivals and smolt passage experience during outmigration. Unlike COMPASS, survival rates are not broken into short reaches, and reservoir survival is not separated from “at” concrete survivals. Because of these basic differences, the Committee is concerned that the CSS functional relationships do not lend themselves to incorporation or translation to the COMPASS model structure.

The Committee has several comments and recommendations regarding the life cycle modeling exercise as described in the AMIP work plan. The overarching concern relates to the initial, retrospective allocation of mortality, which in turn, feeds into the prospective model runs for alternative management actions (STUFA 2000; Wilson 2003). In general, any life cycle model framework where mortality is misallocated will produce erroneous results when run prospectively. Both STUFA (2000) and Wilson (2003) demonstrated that a matrix model framework could approximate the results from more complex model frameworks, such as used in PATH (Deriso et al. 2001), when life cycle mortality was allocated similarly. Specifically, evidence related to the magnitude and causes of delayed (or latent) hydrosystem mortality (Budy et al. 2002) need to be accounted for in the passage sub-model(s) used to evaluate management actions. Our primary concern is that, to date, approaches used in the matrix model and COMPASS have not adequately accounted for this delayed hydrosystem mortality. By not adequately accounting for this delayed mortality retrospectively, prospective model results may lead to unsubstantiated conclusions (from the empirical information) on the efficacy of future management actions.

The CSS convened a workshop in 2011 (Marmorek et al. 2011) examining weight of evidence related to delayed hydrosystem mortality, that included inferences from spatial/temporal contrasts of spawner/recruit and SAR data (Schaller and Petrosky 2007); evaluation of effects of FCRPS and marine conditions on SARs and marine survival rates (Petrosky and Schaller 2010; Haeseker et al. 2012); evaluation of multiple bypass effects (Tuomikoski et al. 2010); and other relevant studies. One key finding from the 2011 CSS workshop was that “[t]he evidence presented for the impacts of the hydrosystem on survival and for delayed mortality arising from earlier experience in the hydrosystem is strong and convincing”. Workshop participants also considered how retrospective findings might be used in management experiments to improve in-river and life-cycle survival rates, an ongoing focus of the CSS. The following recommendations for the AMIP modeling exercise are based in CSS retrospective information and the design of potential FCRPS management experiments.

Functional Relationships

First year ocean survival The CSS-OC would recommend, as one option, using the multiple regression results from Petrosky and Schaller (2010; Tables 2 and 3) for the purpose of evaluating a Snake River dam removal scenario as described in the AMIP work plan. Petrosky and Schaller (2010) constructed multiple regression models that explained the survival rate patterns using environmental indices for ocean conditions and in-river conditions experienced during seaward migration. The time series of (negative log-transformed) first-year ocean survival rates for the period 1964-2006 for Snake River wild spring/summer Chinook and 1964-2005 for Snake River wild steelhead has considerable contrast in ocean and river conditions, spanning a major period of FCRPS dam construction. There were four FCRPS dams in place at the start of the time series 1964-1967 (BON, TDA, MCN, IHR); by 1975, all eight FCRPS projects were in place.

For Snake River spring/summer Chinook, the best-fit, simplest model (AIC and BIC) included two ocean condition variables (May PDO and April Upwelling at 45N) and one FCRPS migration variable (water travel time, WTT). For Snake River steelhead, the best-fit, simplest model (AIC and BIC) included one ocean variable (May PDO) and one FCRPS variable (WTT). The water travel time variable in these regression models for early ocean survival represents the delayed (latent) mortality due to hydrosystem conditions. Model coefficients are shown in Table 1.

Table 1. Best-fit, simplest models (AIC and BIC) describing variation in first-year ocean mortality rates, -ln(S.o1), for Snake River wild spring/summer Chinook and steelhead, 1964-2006 smolt migration years (Petrosky and Schaller 2010).

Species	Variable	Estimate	SE	p
Chinook	Intercept	1.8600	0.2789	<0.0001
	May PDO	0.3035	0.1247	0.0209
	Apr Upwelling	-0.0113	0.0058	0.0615
	WTT	0.0747	0.0162	<0.0001
Steelhead	Intercept	1.8773	0.3093	<0.0001
	May PDO	0.5337	0.1056	<0.0001
	WTT	0.0486	0.0176	0.0094

Survival rate scalars can be calculated for WTT changes under different management scenarios using the coefficients in Table 1. For example, the estimated effect on instantaneous mortality in the first year ocean life stage for a Chinook cohort experiencing WTT of 20 days or 10 days would be 1.50 or 0.75, respectively. In other words, changing WTT from 20 to 10 days would reduce instantaneous mortality by 0.75 (1.50-0.75), or improve survival in this life stage by 2.1 fold ($1/e^{-0.75}$), assuming fixed ocean conditions. Model results suggest that for an 8.7 day reduction in water travel time (the average change from observed to a breach scenario from the 1980-2008 period; Table 2), first-year ocean survival would increase by an average 1.9 fold for Chinook and 1.5 fold for steelhead. Annual survival scalars for 1964-2008 migration years for a breach scenario are shown in Figure 1. These modeled increases would be in addition to changes in the direct survival effect for in-river fish and the differential delayed mortality effect for transported fish (D).

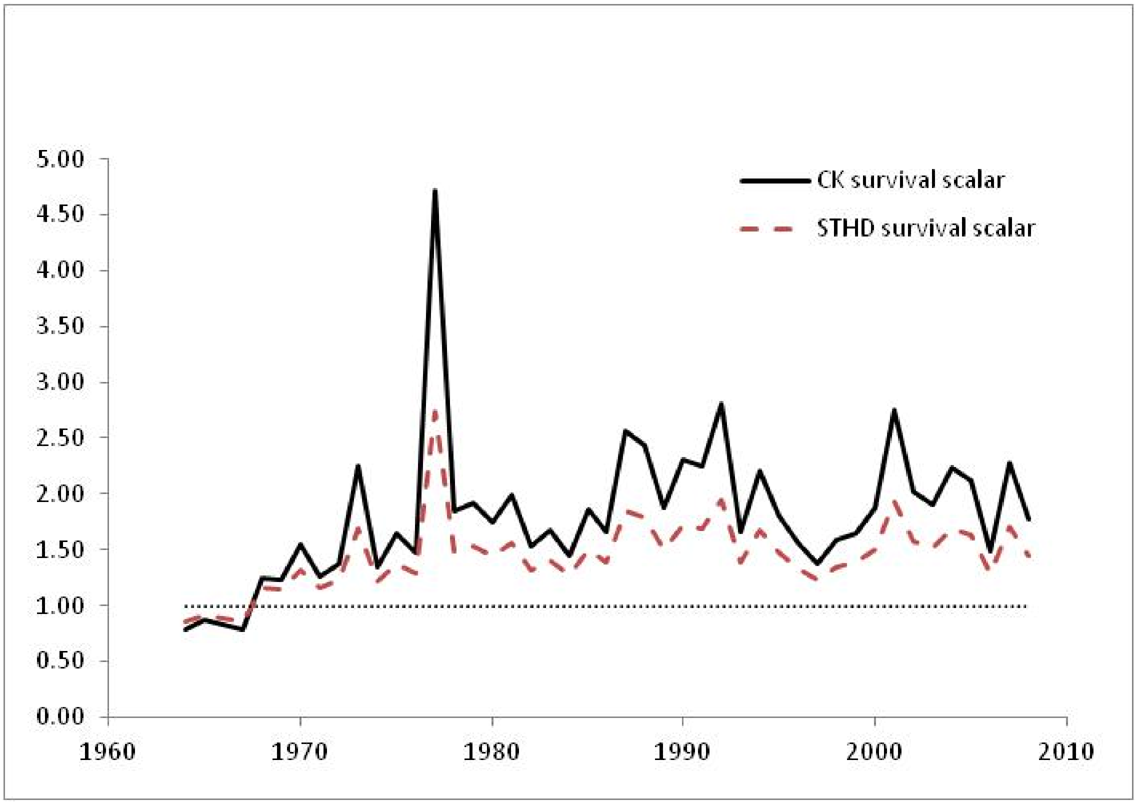

Figure 1. Annual first-year ocean survival rate scalars for Snake River spring/summer Chinook and steelhead between observed water travel times and those projected under a Snake River dam-breach scenario.

Implementation of the model results into the matrix model will require two major steps. First, these model coefficients and updated estimates of in-river survival, proportion transported and D need to be incorporated into the matrix model calibration. In the prospective phase of the matrix model, survival changes from the base period can be accomplished by incorporating the appropriate survival rate scalars for each prospective scenario (as described above and illustrated in Figure 1). In addition, near-shore and broad-scale ocean variables would need to be specified in the prospective model scenarios.

Table 2. Annual water travel times (in days) during the spring migration period (April 16-May 31) for observed conditions and projected under a Snake River dam-breach prospective scenario, migration years 1964-2008.

Migr. year	Observed	Prospective
1964	7.2	10.3
1965	4.8	6.8
1966	8.6	11.2
1967	8.1	11.4
1968	17.5	14.5
1969	9.8	7.0
1970	16.7	11.0
1971	9.5	6.3
1972	11.7	7.4
1973	27.7	16.9
1974	11.4	7.4
1975	15.7	9.0
1976	12.9	7.7
1977	39.8	19.1
1978	18.2	10.0
1979	20.0	11.3
1980	18.2	10.7
1981	20.8	11.6
1982	13.5	7.7
1983	15.3	8.4
1984	12.8	7.9
1985	18.8	10.4
1986	16.2	9.3
1987	24.5	11.9
1988	25.6	13.7
1989	18.3	9.9
1990	22.1	11.0
1991	20.2	9.4
1992	26.0	12.2
1993	16.8	10.0
1994	23.1	12.6
1995	18.2	10.3
1996	13.1	7.1
1997	10.2	5.9
1998	14.9	8.7
1999	15.3	8.6
2000	17.4	9.0
2001	32.1	18.6
2002	19.3	9.9
2003	19.2	10.5
2004	22.7	12.0
2005	22.1	12.0
2006	12.8	7.5
2007	20.9	9.9
2008	17.0	9.4

<u>Correlation between freshwater and ocean-adult survival rates</u>- The AMIP statement of work states an interest in updating previous models that examined how “changes in life-stage specific survival affect long term viability metrics” as well as updating “the TRT stochastic life-cycle models to incorporate most recent population data.” To properly conduct these analyses using the most recent population data on life-stage specific survival rates, the models must include the recent identification of positive correlation between freshwater and ocean-adult survival rates for both Snake River spring/summer Chinook salmon and steelhead (Haeseker et al. 2012). In that publication, the authors calculated estimates of in-river survival (S_H) from Lower Granite Dam to Bonneville Dam as well as estimates of ocean-adult survival, defined as survival from smolts at Bonneville Dam until return as adults at Lower Granite Dam (S_{OA}). The authors found significant, positive correlation between estimates of in-river and ocean-adult survival rates, which provides an additional line of evidence on the influence of hydrosystem mortality factors on subsequent (delayed) mortality rates. Previous analyses have failed to consider the influence of hydrosystem survival on subsequent survival rates (Kareiva et al. 2000, McClure et al. 2003), resulting in erroneous and misleading conclusions on the efficacy of improvements to hydrosystem survival rates and the corresponding effects on long term viability metrics. The correlation between logit-transformed estimates of S_H and S_{OA} was 0.49 for spring/summer Chinook salmon and 0.55 for steelhead (Haeseker et al. 2012).

<u>Relationship between bypass events and ocean survival rates</u>- Another line of evidence documenting the influences of hydrosystem passage experience on subsequent (delayed) mortality is the relationship between the number of bypass events and ocean survival rates (Tuomikoski et al. 2010). In this analysis, the authors estimated the ocean survival rates for smolts that were detected alive at Bonneville Dam and examined how the number of previous bypass events influenced survival back to Bonneville Dam as adults. The lowest AIC models indicated that yearling Chinook salmon ocean survival rates were reduced by 10% per bypass experience at any dam and that steelhead ocean survival rates were reduced by 6% per bypass experience at Lower Granite Dam, Little Goose Dam, or Lower Monumental Dam, and they were reduced by 22% per bypass experience at McNary Dam or John Day Dam. Subsequent analyses that incorporated arrival timing found similar reductions in survival per bypass experience, indicating that reductions in survival were not simply due to changes in arrival timing but rather delayed effects of hydrosystem passage experience. To incorporate these recent results on life-stage specific survival rates and the influence of previous hydrosystem experience, models must incorporate the influence of hydrosystem operations on site-specific bypass probability. However, these results are likely biased low due to indications that turbine passage (which represents a component of the smolts that are not detected at each dam) also reduces post-Bonneville survival (McMichael et al. 2010). Previous results from COMPASS have shown that the model performs poorly in terms of estimating bypass and powerhouse passage probabilities, which raises concerns about the ability of the COMPASS model to incorporate these recent results on life-stage specific survival and the influence of previous passage experiences.

Relationships between hydrosystem operations and in-river survival- Haeseker et al. (2012) constructed models that evaluated the influence of hydrosystem operations, seasonality, and origin (i.e., hatchery or wild) on in-river survival (S_H) from Lower Granite Dam to Bonneville Dam for Snake River steelhead and spring/summer Chinook salmon. The covariates examined included water transit time, average percent spill, Julian day of release at Lower Granite Dam, and percent hatchery composition. Using multi-model inference techniques, the models were capable of accounting for 81% and 53% of the variability in steelhead and Chinook salmon survival rates, respectively. The amount of variability explained by these parsimonious models (each only requiring five estimated parameters) is much higher than the amount of variability explained by the over parameterized COMPASS model, which contains several dozen assumed or estimated parameters. In addition, the COMPASS model has performed poorly when predicting survival rates under low spill conditions, while the models presented in Haeseker et al. (2012) accurately predicted survival under low spill conditions.

The models constructed in Haeseker et al. (2012) predicted the logit-transformed survival rate from Lower Granite Dam to Bonneville Dam using input variables that were standardized to have a mean of zero and standard deviation of one. To standardize the input variable series, the mean of the series was subtracted and the result was divided by the standard deviation of the series. The tables below present the estimated model-averaged coefficients and their unconditional standard errors along with the mean, standard deviation, and range for the input variables.

Table 3. Spring/summer Chinook salmon parameter estimates and input variable summaries.

	Estimate	SE	Mean	Std. Dev.	Range
Intercept	0.1590	0.0746	NA	NA	NA
% Hatchery	0.0013	0.0105	69.7	18.2	(28.9 - 95.2)
Julian day	-0.0107	0.0260	123.1	15.2	(104 - 106)
% Spill	0.2370	0.1220	34.1	8.6	(8.6 - 42.7)
WTT	-0.2010	0.1360	17.2	5.1	(10.6 - 31.2)

Table 4. Steelhead parameter estimates and input variable summaries.

	Estimate	SE	Mean	Std. Dev.	Range
Intercept	-0.6470	0.0914	NA	NA	NA
% Hatchery	-0.0323	0.0536	68.4	18.8	(19.7 - 91.8)
Julian day	-0.3620	0.0964	124.4	13.5	(104 -146)
% Spill	0.5250	0.1430	34.7	8.6	(9.7 - 42.7)
WTT	-0.4640	0.1330	16.6	4.3	(10.7 - 27.8)

Model parameters indicated that in-river survival rates increased with increases in average percent spill and with decreases in water transit time for both species. For steelhead, there was a significant decline in survival with Julian day of release at Lower Granite Dam, while there was little effect of this variable on spring/summer Chinook salmon. The percent hatchery composition had little effect on in-river survival rates for both species, indicating that there were little to no differences in survival between hatchery and wild fish. Given the high accuracy and parsimony of the Haeseker et al. (2012) models for predicting in-river survival rates, we strongly recommend their usage in evaluating the effects of alternative hydropower operations on in-river survival rates. However, these models would not be appropriate for examining dam breaching scenarios because of the difficulty expressing the highly influential percent spill variable under a breach condition.

Relationships between hydrosystem operations, ocean conditions, and ocean survival- Haeseker et al. (2012) constructed models that evaluated the influence of hydrosystem operations, seasonality, origin (i.e., hatchery or wild), and ocean conditions on ocean survival (S_{OA}) from Bonneville Dam as smolts back to Lower Granite Dam as adults for Snake River steelhead and spring/summer Chinook salmon. Because the analysis was interested in examining the influence of freshwater migration conditions on ocean survival rates, the data consisted of smolts that migrated in-river and were not transported. The covariates examined included water transit time, average percent spill, Julian day of release at Lower Granite Dam, percent hatchery composition, April – June upwelling, May – July sea surface temperature, and the Pacific Decadal Oscillation index during June – August. Using multi-model inference techniques, the models were capable of accounting for 66% and 87% of the variability in steelhead and Chinook salmon ocean survival rates, respectively.

The models constructed in Haeseker et al. (2012) predicted the logit-transformed S_{OA} from Bonneville Dam as smolts back to Lower Granite Dam as adults using input variables that were standardized to have a mean of zero and standard deviation of one. To standardize the input variable series, the mean of the series was subtracted and the result was divided by the standard deviation of the series. The tables below present the estimated model-averaged coefficients and their unconditional standard errors along with the mean, standard deviation, and range for the input variables.

Table 5. Spring/summer Chinook salmon parameter estimates and input variable summaries.

	Estimate	SE	Mean	Std. Dev.	Range
Intercept	-5.0800	0.0902	NA	NA	NA
% Hatchery	0.0048	0.0165	69.7	18.2	(28.9 - 95.2)
Julian day	-0.0085	0.0230	123.1	15.2	(104 - 146)
% Spill	0.8080	0.1010	34.1	8.6	(8.6 - 42.7)
WTT	-0.0063	0.0222	17.2	5.1	(10.6 - 31.2)
PDO	-0.7750	0.0913	0.01	0.65	(-0.97 - 0.84)
Upwelling	0.0025	0.0135	24.3	9.7	(3.7 - 39.3)
SST	0.0016	0.0132	14.4	0.9	(13.1 - 15.8)

Table 6. Steelhead parameter estimates and input variable summaries.

	Estimate	SE	Mean	Std. Dev.	Range
Intercept	-4.3100	0.1120	NA	NA	NA
% Hatchery	-0.0088	0.0201	68.4	18.8	(19.7 - 91.8)
Julian day	-0.2620	0.1030	124.4	13.5	(104 - 146)
% Spill	0.5390	0.1610	34.7	8.6	(9.7 - 42.7)
WTT	0.0053	0.0162	16.6	4.3	(10.7 - 27.8)
PDO	-0.1280	0.1310	-0.10	0.72	(-0.97 - 0.84)
Upwelling	0.0072	0.0220	24.0	8.0	(3.7 - 30.7)
SST	-0.0021	0.0155	14.0	0.8	(13.1 - 15.8)

Model parameters indicated that ocean survival rates (S_{OA}) for spring/summer Chinook salmon were most strongly influenced by average percent spill and the Pacific Decadal Oscillation (PDO), with S_{OA} increasing with increases in percent spill and decreases in PDO (i.e., cooler values for PDO). Steelhead ocean survival rates were most strongly influenced by average percent spill, PDO, and Julian day at Lower Granite Dam, with S_{OA} increasing with increases in percent spill, decreases in PDO, and with earlier timing at Lower Granite Dam. The models for both species indicate that the average percent spill experienced during freshwater outmigration through the hydropower system influenced ocean survival rates, providing additional evidence on the influence of freshwater migration experiences on delayed mortality rates. In addition to the percent spill, ocean conditions indexed by PDO were found to influence ocean survival rates for both species. Thus, it is the combination of freshwater hydrosystem factors and ocean factors that influence ocean survival rates. These models provide a quantitative tool for examining how changes in hydrosystem operations, in combination with variability in ocean conditions, are expected to influence life-stage specific survival rates. In this context, they may be appropriate for examining how changes in hydrosystem operations may affect long-term viability metrics.

As with the models for freshwater survival (S_H) discussed above, these models would not be appropriate for examining dam breaching scenarios because of the difficulty expressing the highly influential percent spill variable under a breach condition. The models of Petrosky and Schaller (2010) would be more appropriate for that purpose.

Relationships between hydrosystem operations, ocean conditions, and SARs- Haeseker et al. (2012) constructed models that evaluated the influence of hydrosystem operations, seasonality, origin (i.e., hatchery or wild), and ocean conditions on SARs from Lower Granite Dam as smolts back to Lower Granite Dam as adults for Snake River steelhead and spring/summer Chinook salmon. The analysis was interested in examining the influence of freshwater migration conditions on SARs, the data consisted of smolts that migrated in-river and were not transported. The covariates examined included water transit time, average percent spill, Julian day of release at Lower Granite Dam, percent hatchery composition, April – June upwelling, May – July sea surface temperature, and the Pacific Decadal Oscillation index during June – August. Using multi-model inference techniques, the models were capable of accounting for 67% and 78% of the variability in steelhead and Chinook salmon SARs, respectively.

The models constructed in Haeseker et al. (2012) predicted the logit-transformed SAR from Lower Granite Dam as smolts back to Lower Granite Dam as adults using input variables that were standardized to have a mean of zero and standard deviation of one. To standardize the input variable series, the mean of the series was subtracted and the result was divided by the standard deviation of the series. The tables below present the estimated model-averaged coefficients and their unconditional standard errors along with the mean, standard deviation, and range for the input variables.

Table 7. Spring/summer Chinook salmon parameter estimates and input variable summaries.

	Estimate	SE	Mean	Std. Dev.	Range
Intercept	-5.6900	0.0907	NA	NA	NA
% Hatchery	0.0035	0.0144	69.7	18.2	(28.9 - 95.2)
Julian day	-0.0437	0.0725	125.0	15.9	(104 - 146)
% Spill	1.1000	0.1520	33.8	10.1	(2.8 - 46.3)
WTT	-0.0826	0.1240	17.4	5.6	(10.0 - 31.7)
PDO	-0.7320	0.0850	-0.04	0.65	(-0.97 - 0.84)
Upwelling	-0.0045	0.0173	24.7	9.6	(3.7 - 39.3)
SST	-0.0129	0.0304	14.4	0.9	(13.1 - 15.8)

Table 8. Steelhead parameter estimates and input variable summaries.

	Estimate	SE	Mean	Std. Dev.	Range
Intercept	-5.6000	0.1580	NA	NA	NA
% Hatchery	-0.0402	0.0807	68.4	18.8	(19.7 - 91.8)
Julian day	-0.6940	0.1650	125.0	15.9	(104 - 146)
% Spill	0.9700	0.2840	33.7	10.5	(0.3 - 47.1)
WTT	-0.1760	0.2420	17.5	5.8	(9.9 - 33.3)
PDO	-0.0881	0.1360	-0.04	0.65	(-0.97 - 0.84)
Upwelling	-0.0002	0.0272	24.7	9.7	(3.7 - 39.3)
SST	-0.0760	0.1250	14.4	0.9	(13.1 - 15.8)

Model parameters indicated that SARs for spring/summer Chinook salmon were most strongly influenced by average percent spill and the Pacific Decadal Oscillation (PDO), with SARs increasing with increases in percent spill and decreases in PDO (i.e., cooler values for PDO). To a lesser extent, SARs increased with decreases in water transit time and earlier timing at Lower Granite Dam. Steelhead SARs were most strongly influenced by average percent spill and Julian day at Lower Granite Dam, with SARs increasing with increases in percent spill and with earlier timing at Lower Granite Dam. To a lesser extent, SARs increased with decreases in water transit time and decreases in PDO. The models for both species indicate that it is the combination of freshwater hydrosystem factors and ocean factors that influence SARs. These models provide a quantitative tool for examining how changes in hydrosystem operations, in combination with variability in ocean conditions, are expected to influence survival over the life cycle. In this context, they may be appropriate for examining how changes in hydrosystem operations may affect long-term viability metrics. As with the models for freshwater survival (S_H) discussed above, these models would not be appropriate for examining dam breaching scenarios because of the difficulty expressing the highly influential percent spill variable under a breach condition. The models of Petrosky and Schaller (2010) would be more appropriate for that purpose.

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