APPENDIX MS2013-02. MITIGATION FOR POTENTIAL DECLINES IN SNAKE RIVER SPRING/SUMMER CHINOOK SALMON DUE TO FRESHWATER AND MARINE CLIMATE CHANGES

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SUMMARY

We employed an established life cycle model to evaluate the impact of climate change on three populations of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), listed as threatened under the Endangered Species Act. We used downscaled temperature and stream flow projections for the 2040s from 10 global circulation models (GCMs) and 2 emissions scenarios to characterize freshwater climate changes. We conducted a sensitivity analysis of ocean conditions by systematically varying periods of relatively favorable and unfavorable climate regimes from the historical record. We found that populations differed in their sensitivity to freshwater changes from neutral to negative responses. In all populations, spawner abundance declined in an approximately linear manner as the percentage of unfavorable ocean regimes increased. However, there was a dramatic increase in extinction risk if ocean regimes shifted from 60% to 80% unfavorable. Because the 60% scenario produced very similar levels of risk and abundance as our historical scenario, these populations might already be near a tipping point. Any decline in ocean conditions thus poses a very serious risk. However, the management scenario we considered (based on recent improved survival of juveniles through the Columbia and Snake River hydrosystem), increased median population abundance 1.6-2.2 times across all climate scenarios and all populations. The maximum extinction risk, assuming increased juvenile survival, dropped from 62% to 19%. Most importantly, higher survival through the hydrosystem successfully mitigated for the increased extinction risk due to climate warming in all three populations. Abundance still declined from baseline under the worst ocean scenarios in two populations. Whether this recent high survival can be sustained is not clear, but these results suggest a significant opportunity for recovery in these threatened populations.

INTRODUCTION

For anadromous salmon and trout, limiting environmental factors vary as fish move through different habitats over their life cycle (Crozier et al. 2008a, McDaniels et al. 2010). In freshwater, stream temperature and flow govern many aspects of juvenile growth and survival. Low temperature can limit growth, especially in high mountain streams. But high temperature can lower survival and reproductive success (McCullough 1999, Martins et al. 2012). High streamflow can benefit juvenile migrants (Williams et al. 2005) but also scour nests (Goode et al. 2013) and raise energetic costs of maintaining position or swimming

upstream during the adult migration (Rand et al. 2006). Environmental conditions also shape habitat structure and the quantity and quality of prey (Power et al. 2008), as well as pressure from competitors and predators (Wenger et al. 2011, Kuehne et al. 2012, Lawrence et al. 2012). Some of these pressures vary with fish density. For example, there might be a limited number of refugia from high temperatures or low flows, causing the environmental drivers to determine the carrying capacity of a given habitat.

In this report, we examine environmental drivers in freshwater and ocean stages independently. Regional climate drivers affect freshwater habitat productivity in population-specific ways, influencing relative population vulnerability to climate change (Crozier et al. 2008b). Previous analyses identified fall flow and summer temperature as strong correlates of juvenile survival in Snake River spring/summer Chinook salmon (Crozier and Zabel 2006, Crozier and Zabel 2013), which are listed as threatened under the Endangered Species Act. Climate regimes, defined largely by the Pacific Decadal Oscillation (PDO), shape salmon population dynamics at the decadal scale (Mantua et al. 1997). Cooler ocean conditions, associated with negative phases of the PDO, bring nutrient-rich prey and reduced predator populations, improving survival for Columbia River salmon. Warmer ocean conditions, on the other hand, such as the 1977-1997 positive phase of the PDO, result in lower salmon survival (Zabel et al. 2006). We explored the consequences of more or less frequent stretches of less-favorable climate regimes for population viability. Because we currently lack specific projections of the indices needed to model salmon survival from GCM and oceanographic models, we conducted a sensitivity analysis by increasing the frequency of poor-ocean periods from 20% to 80% of our time series. Models with appropriate resolution (Gruber 2011) are being developed, however, and will be incorporated into the next IEA report.

An increasingly pressing concern for the recovery of at-risk populations is whether mitigating for climate-related losses is possible. If climate change reduces population growth rates, what management actions could reduce this effect (Beechie et al. 2012)? The primary management lever under consideration for Columbia River salmon involves operation of the major Federal hydroelectric dams on the Columbia and Snake Rivers (NOAA Fisheries 2010). Here we consider a scenario of improved juvenile survival (Zabel et al. 2013b) based on recent observations (2005-2009 outmigration years). This is the first population viability analysis using this scenario. We present preliminary results to demonstrate the approach and propose further integration of the effects of changes in mainstem Columbia River conditions and additional scenarios of ocean conditions.

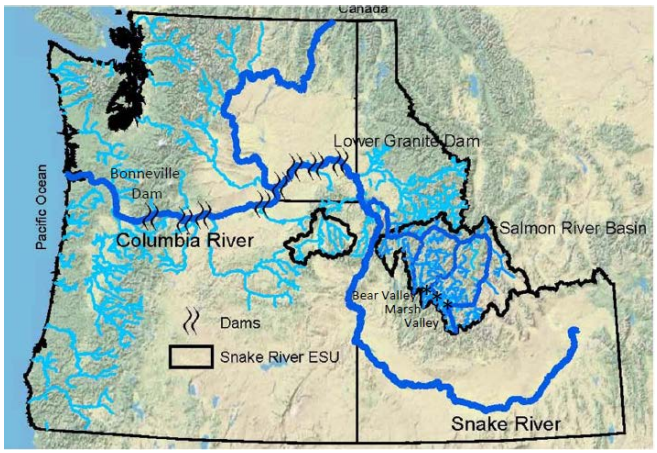

Figure 1. Map of the Columbia and Snake Rivers, with the modelled populations labelled. The eight major hydrosystem dams affecting these populations are shown.

BACKGROUND ON SNAKE RIVER SPRING/SUMMER CHINOOK SALMON

Snake River spring/summer Chinook salmon spawn and rear in tributaries of the Salmon River in central Idaho, the Grande Ronde and Imnaha rivers in northeastern Oregon, and the Tucannon River in southeast Washington (Fig. 1). In response to severe population declines throughout the second half of the 20th century, they were listed as threatened under the Endangered Species Act in 1990 (NMFS 1992). The Salmon River Basin populations considered here mostly spawn and rear at high elevation (1946-2010 meters above sea level), within legally protected wilderness areas, although agriculture and grazing affect some areas and historically mining and logging occurred in the basin. The hydrological regime is snow-dominated, with large flows in spring and low flows in late summer. Juveniles spend a full year in tributaries before migrating 1100-1500 km through the lower Snake and Columbia rivers to the Pacific Ocean. They return to natal habitats to spawn only once after 1-3 years in the ocean.

Here we focus on three populations in the Salmon River Basin with differing sensitivities to climate change, as identified by Crozier and Zabel (2013). Populations from Bear Valley and Valley creeks both have negative responses to temperature, whereas the Marsh Creek population has a neutral response (Fig. 2). Flow has a generally negative impact on the Bear Valley Creek population, but a positive impact on both Marsh and Valley Creek populations (Crozier and Zabel (2013).

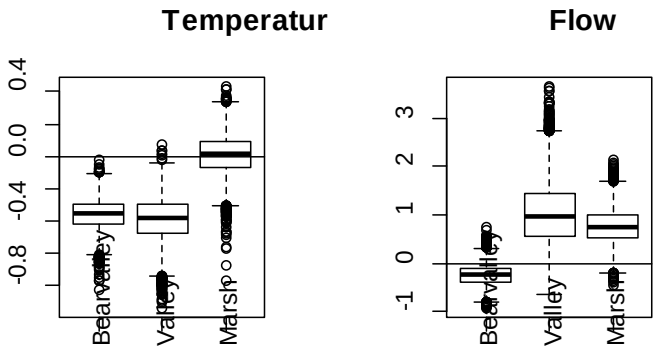

Figure 2. Box and whisker plots depicting the posterior distribution of the A. temperature and B. flow standardized regression coefficients for parr-to-smolt survival (see Crozier and Zabel 2013) based on Bayesian model analysis. The zero line is shown. Boxes show the 25th-75th quantile range; the whiskers show 1.5 times that range. The horizontal lines within each box show the median.

METHODS

We applied the life cycle modeling framework originally developed by Zabel et al (2006). The model is explained in detail elsewhere (ICTRT and Zabel 2007, Jorgensen, this report, Zabel et al. 2013a). This stochastic, age-structured matrix model includes multiple life stages in some annual steps. The spawner-to-year 1, and year 1-to-year 2 transitions are modeled as population-specific, density-dependent functions. Freshwater environmental drivers are incorporated into the asymptotic recruitment of year 1-to-year 2. Survival through the hydrosystem affects survival in year 2, and mainstem Columbia River and ocean conditions (indexed by the April upwelling and May PDO) affect survival in year 3. Fish return to spawn over years 3-5, with constant proportions in each age group.

FRESHWATER CLIMATE SCENARIOS

Freshwater climate drivers are 1) summer average air temperature across the Salmon River Basin from May through August, which largely determines growth opportunity in these mountain streams, and 2) mean flow in September and October, measured on the Salmon River at Salmon, Idaho (USGS 2005, Station ID 13302500). We established our baseline, "historical" conditions using the monthly mean temperature records from 1962 to 2005 at seven weather stations distributed around the Salmon River Basin (see Crozier et al. 2008b for station IDs and methods). The Climate Impacts Group modeled historical flows (http://www.hydro.washington.edu/2860/). We used modeled historical flows rather than observed flows for a fair comparison with future scenarios that rely on hydrological modeling. We used the climate projections for A1B and B1 emissions scenarios from 10 Global Circulation Models (GCMs) that the Climate Impacts Group downscaled using the "Hybrid Delta" method followed by the Variable Infiltration Capacity

hydrological model (Fig. 3, Hamlet et al. 2013). We added the differential in air temperature projected by each GCM for the Middle Fork Lodge near Yellow Pine (SALYP 2031) to our historical time series (the "Delta" method). We analyzed projections for the "2040s", which average over GCM output from 2029 to2059.

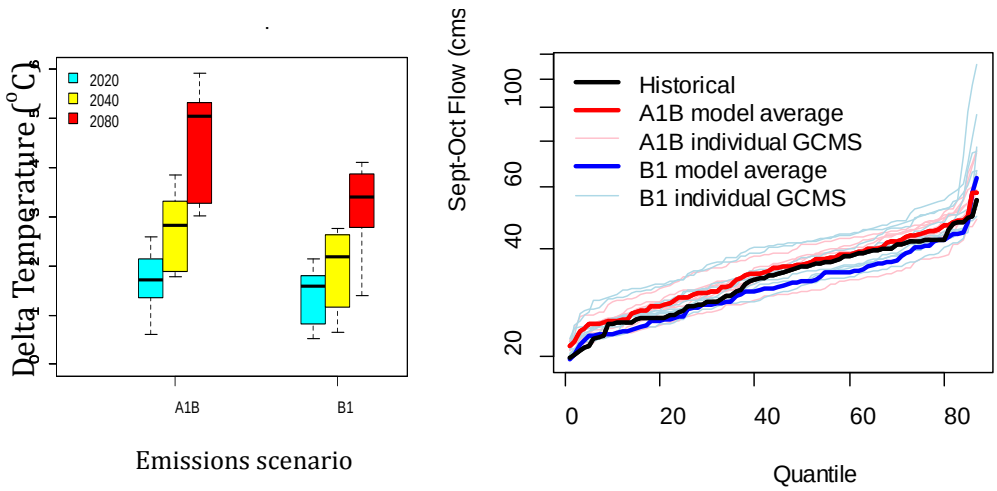

Figure 3. Freshwater climate perturbations. A. Temperature boxplots depict the offsets from all GCMs under a given emissions scenario and time frame. The median is depicted by the horizontal line, the interquartile range lies within the boxes and the whiskers show the most extreme GCMs. Only the 2040s are analyzed In this report, but we show the earlier and later periods for reference. B. A quantile plot of modeled streamflows (averaged over September and October). Note the log scale on the y axis.

"HYDRO" SCENARIOS

As juveniles migrate downstream, a variable proportion of them are transported in barges through the hydropower system and released below Bonneville Dam. Transported fish have different rates of adult return than fish that migrate in-river, based on PIT-tagged fish from 1994-2001 (Berggren et al. 2006). Within a scenario, we held the proportion transported and survival rates constant. Previous analyses have manipulated these rates under different management scenarios of the Columbia River Hydrosystem. We explored two scenarios. The first was used by ICTRT and Zabel (2007), which they called "current," and we called the "1990s" scenario. The second was derived in Zabel (2013b) based on more recent returns. We called this alternate scenario the "2000s" because it describes survival from outmigration years 2005 to 2009. This scenario involves higher in-river survival and a much lower proportion of fish transported.

OCEAN SCENARIOS

Some of the most profound impacts of environmental conditions on salmon occur during their first year in the ocean. ICTRT and Zabel (2007, pp 23-26) identified three factors for Snake River spring/summer Chinook salmon that characterize variation in this term: mainstem Columbia River water travel time (inversely related to flow), April

upwelling off the mouth of the Columbia, and the PDO index for May. Higher spring flows and high levels of spill reduce water travel time. The PDO and upwelling indices describe ocean conditions affecting juvenile salmon: cooler, high-nutrient water corresponds to a negative PDO and strong upwelling. This term varies stochastically, but we used historical conditions from 1946 to 2001 as the baseline for our simulations. Our alternate scenarios vary the proportions of favorable and unfavorable regimes within the historical record. The 1977-1997 period characterized "bad" conditions, and the 1961-1976 period characterized "good" conditions. The scenarios contained from one to four blocks of bad conditions (20%, 40%, 60% or 80%) in 20 year units (repeated as necessary) [Fig. 4]. The remainder of the 100-year time series consisted of good blocks. We alternated bad and good conditions in the intermediate scenarios, but the extremes contained one 20-year stretch of one type of conditions followed by 80 years of the other condition. We randomized the start year of the environmental time series to avoid trends due to the ordering of good and bad regimes.

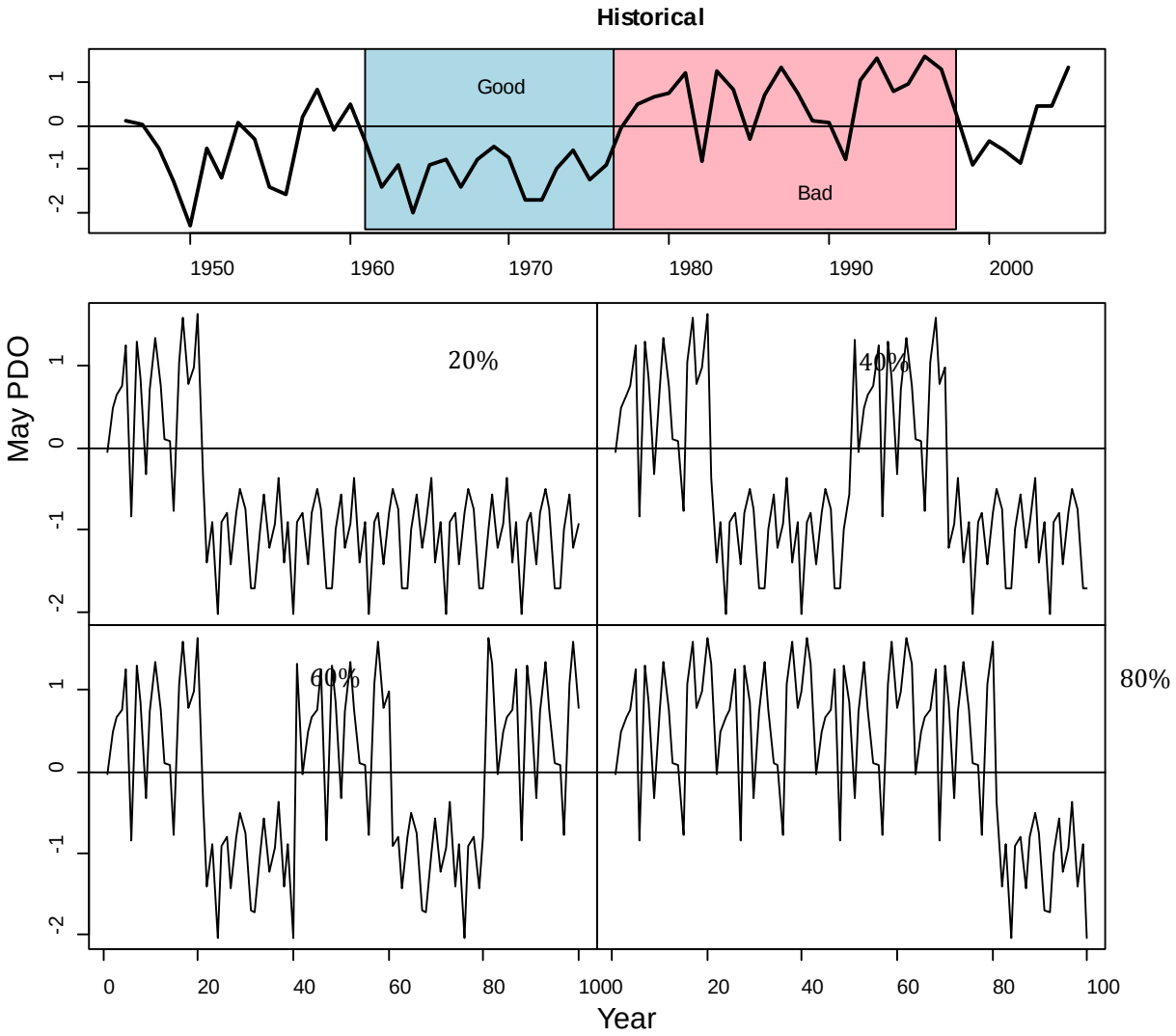

Figure 4. Ocean scenarios. Historical time-series of May PDO, with shaded boxed indicating the "Good" and "Bad" periods used in the scenarios, followed by 20%-80% "bad" regimes.

SIMULATIONS AND RESPONSE METRICS

We initiated our simulations with the mean spawner abundance observed over the last five years for each population ("N_o" in Appendix A). We ran the model for 100 years for each iteration, and ran 1000 iterations for each scenario. Our response metrics captured the core viability criteria of extinction risk and population abundance. We characterized extinction risk as the frequency across iterations within a scenario of population projections falling below a quasi-extinction threshold of 50 spawners in a 4-year running-mean. Our primary measure of abundance is the mean across iterations of the median spawner abundance within each iteration. Additional metrics are reported in Appendix A (for a full explanation of metrics, see Zabel et al. 2013a).

RESULTS AND CONCLUSION

The risk of extinction in our scenarios depended mostly on ocean conditions, but the 2000s hydrosystem management scenario had a very large mitigating effect. Our "baseline" conditions entail the historical freshwater and ocean conditions and the 1990s hydrosystem management scenario (horizontal lines in Fig. 5). Maintaining that hydrosystem management scenario, all populations showed dramatic increases in extinction risk when 80% of the years exhibited positive PDO conditions (red and pink boxes, Fig. 5A). Under the new management scenario, however, extinction risks dropped back to or below baseline conditions for all three populations, in even the worst ocean conditions (blue boxes). If ocean conditions were similar to the historical or improved (≤60% bad), the new management scenario reduced extinction risks to negligible levels. Under historical ocean conditions, one population reduced extinction risk even under the 1990s hydrosystem management scenario. Marsh Creek suffered no ill effects from rising temperature, and benefitted from the higher precipitation/high flow scenarios. Rising temperature lowered juvenile survival in the other two populations, and only excellent ocean conditions compensated for declines in freshwater. The two emissions scenarios showed very similar patterns (red vs. pink, and light vs. dark blue) because this time frame (the 2040s) precedes significant divergence in greenhouse gas concentrations.

Trends in population abundance ultimately drove changes in extinction risk, but displayed more subtle responses to the scenarios (Fig. 5B). Relative to the historical baseline, Bear Valley declined in almost all of the scenarios. The only exception was superb ocean conditions combined with high mainstem survival. The strong response to freshwater climate scenarios reflected the negative effect of rising temperature without ameliorating benefits from the high precipitation / high flow scenarios (Fig. 2). Valley Creek and Marsh Creek benefitted more from higher flows. In combination with high mainstem survival, these two populations grew as long as ocean conditions stayed at the historical quality or improved. Under the worst ocean conditions, abundance of all populations declined severely.

The three Snake River salmon populations modeled here showed high sensitivity to climate-driven changes in freshwater and ocean conditions, which could be largely mitigated by maintaining mainstem survival at recent levels. Across the wide range of ocean conditions we explored, population mean abundance declined in a relatively linear manner as ocean conditions deteriorated. However, extinction risk increased dramatically in all populations when unfavorable ocean conditions increased from 60% and 80%. We suspect that these populations might already be near this tipping point because the 60% scenario produced similar levels of risk and abundance as our historical scenario. Although changes in upwelling and the PDO are currently not well modeled by GCMs, rising sea surface temperature is very certain and a recent analysis (Burke et al. 2013) found that sea surface temperature has an even stronger effect on ocean survival than the PDO or upwelling. Our analysis indicated that any decline in ocean conditions poses a very serious risk.

Recent increases in survival through the Snake and Columbia rivers prevented climate-driven increases in extinction risk, and buffered against some declines in spawner abundance. This scenario successfully mitigated for the increased extinction risk due to climate conditions in all three populations. Abundance still declined under the worst climate scenarios in Valley Creek, and under 4 of the 6 ocean scenarios in Bear Valley Creek. Nonetheless, across all climate scenarios and all populations, median population abundance was 1.6-2.2 times higher under the new hydrosystem survival rates compared with the 1990s paradigm. The maximum extinction risk dropped from 62% to 19%. The extent to which this survival rate depends on climate conditions, however, is not entirely clear. Over the past 5 years, far fewer fish were transported and spill was high. However, in-river survival depends on fish travel time, which in turn depends on meteorological conditions (especially snowpack and spring melting) in addition to spill, so it is not entirely under the control of dam operators.

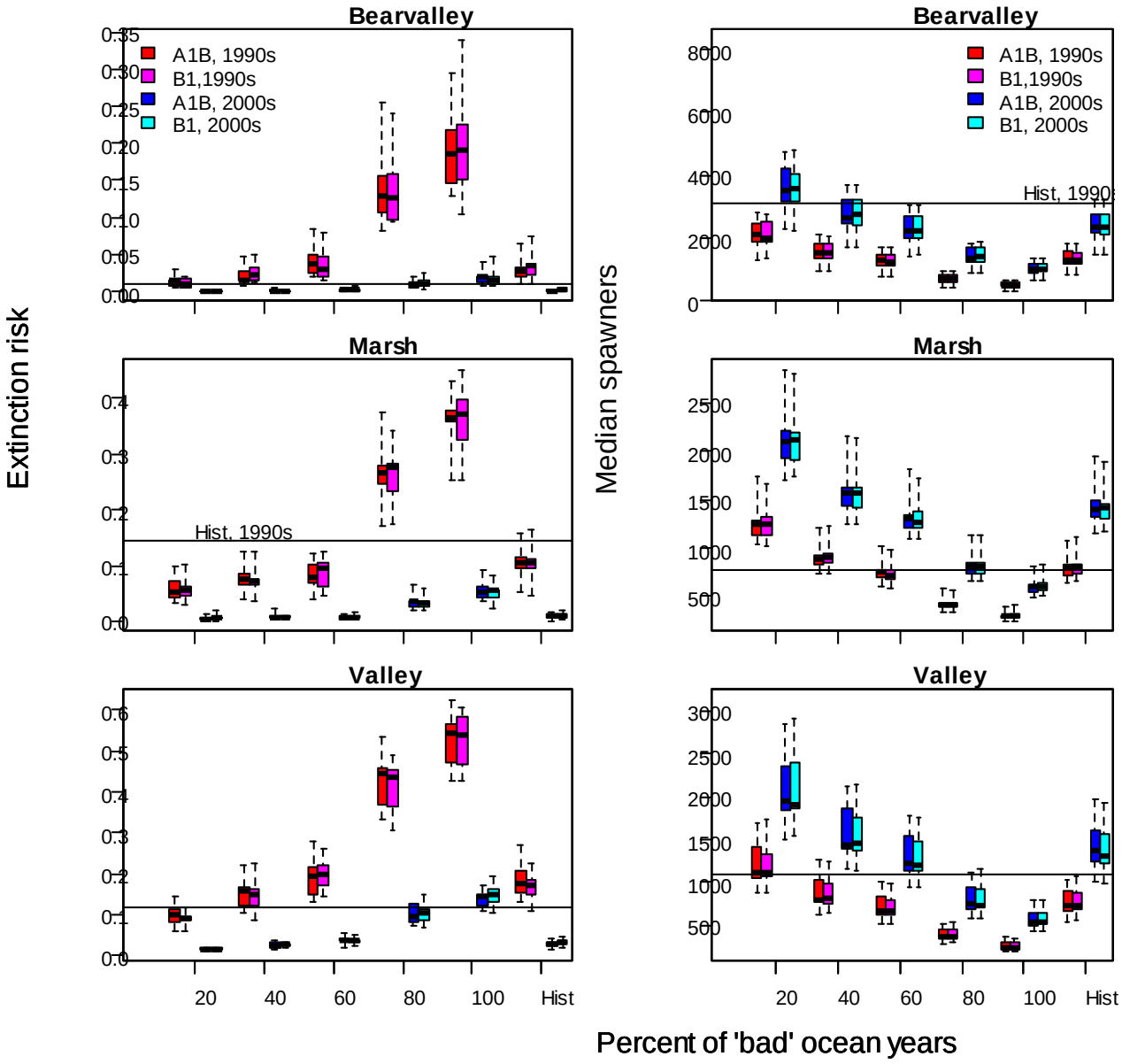

Figure 5. Probability of quasi-extinction (left) and median spawner abundance (right) for three populations as a function of freshwater climate scenarios (A1B or B1), hydrosystem survival ("Current" or "recent"), and ocean conditions. Ocean conditions are characterized in terms of the percent of years with consistently positive PDO, and are compared with the actual historical time series ("Historic"). The baseline scenario used the historical freshwater and ocean conditions and the "current" hydrosystem management, and is shown by the horizontal line. The boxes show the range across all GCMS for a given scenario (line shows the median GCM, the boxes show the interquartile range, and the whiskers show the full range of all GCMs).

Changes in freshwater conditions will likely lower population abundance and raise extinction risks for the most temperature-sensitive populations. However, because most of the habitat within the Salmon River Basin is over 1900-m elevation, populations in the coldest streams will likely benefit from warming, at least temporarily (Crozier and Zabel 2013), and stream temperatures are unlikely to exceed lethal limits in the foreseeable future. Rather, low flows pose an alternative limiting factor for many populations, so declining precipitation could hinder recovery of all of these populations (Crozier et al. 2008b). Because the climate scenarios considered here ranged from only moderate decreases to substantial increases in flow, freshwater conditions for some populations improved under the climate scenarios. Uncertainty stemming from the emissions scenario (A1B vs B1) was negligible because atmospheric CO_2 levels do not diverge between scenarios much by the 2040s. Uncertainty stemming from different GCMs generally did not affect the direction of population response, but only its magnitude.

Our conclusions include some very important caveats. First, we do not fully understand the impacts of temperature and flow from a mechanistic perspective, so our analysis is based on observed statistical relationships; these correlations might change in future decades. Second, climate change might impact other life stages, such as juvenile and adult migrants, and change population viability rates substantially. Finally, important competitors or predators in these streams are already responding to changing conditions, as will prey resources. Invading smallmouth bass and other exotic species already occupy many streams in the Columbia River Basin (Rahel and Olden 2008, Sanderson et al. 2009, Lawrence et al. 2012), with negative effects on native prey (Hughes and Herlihy 2012). Additional management "levers" to control invasive species might well be necessary. Thus our results should not be used as predictions for final decision making. Nonetheless, they do capture a mosaic of responses and point to some potential benefits of possible increases in fall precipitation, risks from warming in this region, and implications of shifting ocean conditions.

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Appendix 1. Bear Valley Creek response metrics[1]

FWclimate	CO2	Ocean	Hydro	GCM	N0	P5.25	P50.25	P95.25	P5.100	P50.100	P95.100	NL	NM	NH	PrQET25	PrQET100	PrQETNmin	MeanSurv	MeanSp
hist	hist	bad.20	current	hist	560	557.9	4599.4	22340	490.9	4484.9	22074.1	790	4848	19853	0.001	0.002	0.01	0.109	4379.9
2040	A1B	bad.20	current	modavg	560	241.8	2038.4	9220	250	2050.9	8768.4	398	2191	8133	0.005	0.012	0.053	0.0974	1997.9
2040	B1	bad.20	current	modavg	560	217.5	2083.4	8922.2	281	2009.4	9115.1	405	2200	8205	0.003	0.006	0.04	0.0971	2021
hist	hist	bad.20	20052009	hist	560	1166.5	7606.1	35357.5	1281.6	7664.9	40529.2	1597	8530	32289	0	0	0	0.0957	7866.5
2040	A1B	bad.20	20052009	modavg	560	502.9	3432.5	13138.3	627.2	3582.8	13511.8	788	3719	12881	0	0	0.007	0.0823	3458.7
2040	B1	bad.20	20052009	modavg	560	601.6	3627	15146	688.6	3570.2	14235.3	776	3732	13072	0	0	0.002	0.0826	3471.3
hist	hist	bad.40	current	hist	560	346.9	3000.6	18916.8	341	3298.2	22559	517	3495	17206	0.004	0.009	0.022	0.1186	3216.7
2040	A1B	bad.40	current	modavg	560	193.9	1539.2	7604.6	198.1	1508.2	7388.9	269	1637	6614	0.003	0.016	0.073	0.107	1486.5
2040	B1	bad.40	current	modavg	560	182	1475.1	6780.4	210.4	1452.9	7220.3	265	1592	6442	0.009	0.016	0.063	0.1066	1450.2
hist	hist	bad.40	20052009	hist	560	715	5417.8	29494.4	887.1	5714	29932.8	1035	6209	26313	0	0	0.001	0.1035	5679.9
2040	A1B	bad.40	20052009	modavg	560	356.8	2653.6	12214.3	419.5	2596.1	11486.3	527	2838	10552	0	0.001	0.004	0.0901	2604.3
2040	B1	bad.40	20052009	modavg	560	377	2556.9	11046.2	433.7	2506.7	12370.7	524	2732	10087	0	0	0.002	0.0899	2522
hist	hist	bad.60	current	hist	560	267.6	2905.6	18585.5	368.7	2965.5	18502.9	437	3007	15102	0.004	0.007	0.037	0.1224	2774.2
2040	A1B	bad.60	current	modavg	560	149.9	1406.4	6705.6	155.7	1291.1	8006.9	196	1332	6532	0.01	0.032	0.123	0.1123	1228.3
2040	B1	bad.60	current	modavg	560	146.7	1238.4	7523.6	162.2	1362	8017.2	195	1298	6460	0.017	0.029	0.095	0.1127	1206.5
hist	hist	bad.60	20052009	hist	560	627.5	5679.5	32814.1	705.6	5519.6	26887.1	906	5467	24323	0	0	0.002	0.1059	5089.3
2040	A1B	bad.60	20052009	modavg	560	319.3	2368.8	12164.3	351	2443	12404.5	390	2330	10355	0	0.001	0.01	0.0955	2177.8
2040	B1	bad.60	20052009	modavg	560	320.2	2398.2	11917.8	318.3	2426.1	11840.2	398	2374	10838	0.001	0.003	0.011	0.0952	2226.6
hist	hist	bad.80	current	hist	560	92.8	1326.3	12350.8	137.6	1636.8	12377	244	1718	10784	0.023	0.048	0.114	0.1375	1623.7
2040	A1B	bad.80	current	modavg	560	57.9	709.7	4083.1	55.9	686.4	4812	108	739	4162	0.029	0.139	0.32	0.1281	694.8
2040	B1	bad.80	current	modavg	560	63.6	683.2	4404.2	64.7	712	5282.5	112	736	4187	0.026	0.116	0.289	0.1276	702.2
hist	hist	bad.80	20052009	hist	560	364.5	2857.2	18502.6	388.6	3016.4	19882.8	543	3221	17205	0	0.001	0.009	0.1205	3099.9
2040	A1B	bad.80	20052009	modavg	560	204	1405.4	7334.4	191.8	1260.9	7452.8	265	1469	7027	0.004	0.012	0.062	0.108	1409.1
2040	B1	bad.80	20052009	modavg	560	184.9	1323.3	7512.1	182.8	1303.5	7729.1	273	1467	6996	0	0.003	0.037	0.1076	1414.8
hist	hist	BAD.iea	current	hist	560	68.9	954.5	6360.1	102.8	938.6	6425.7	165	1117	5371	0.018	0.066	0.168	0.1471	1020.5
2040	A1B	BAD.iea	current	modavg	560	41.7	434.5	2421	40.7	451	2266.2	85	514	2254	0.052	0.173	0.391	0.1399	473
2040	B1	BAD.iea	current	modavg	560	37.4	496.8	2550.9	35.4	415	2468.9	83	520	2286	0.044	0.188	0.396	0.1398	476.5
hist	hist	BAD.iea	20052009	hist	560	281.6	1987.9	9312	274.5	2155.4	11043.4	442	2388	10083	0.003	0.004	0.021	0.1277	2233.2
2040	A1B	BAD.iea	20052009	modavg	560	127.1	1006.5	4776.8	157.9	931.4	4489.6	209	1081	4056	0.004	0.016	0.071	0.1187	1002.1
2040	B1	BAD.iea	20052009	modavg	560	153.3	979.7	4294.5	132.2	1041.2	4620.1	212	1078	4000	0.005	0.015	0.053	0.1175	1001.8
hist	hist	historic.iea	current	hist	560	214	2397.2	17292.1	307.7	2579.9	16635.5	463	3139	15904	0.005	0.01	0.041	0.1208	2905.4
2040	A1B	historic.iea	current	modavg	560	129.9	1185.1	6511.1	147.6	1142	5839	228	1403	6416	0.007	0.025	0.091	0.1105	1301.8
2040	B1	historic.iea	current	modavg	560	117.2	1247	6220.1	132.8	1176.4	6284.4	234	1403	6390	0.009	0.023	0.085	0.1097	1305.6
hist	hist	historic.iea	20052009	hist	560	519	4460.7	24732.4	657.3	4999.9	26318.5	937	5475	25717	0	0.001	0.002	0.1056	5165
2040	A1B	historic.iea	20052009	modavg	560	300.6	1976.1	10883.7	307	2259.7	10481.5	468	2436	10074	0	0	0.008	0.0937	2304.7
2040	B1	historic.iea	20052009	modavg	560	299.3	1992.5	9652.4	287.8	2002	10926.1	470	2450	10199	0.002	0.002	0.011	0.0932	2312.7

The "Fwclimate" column indicates the historic freshwater conditions ("hist"), or conditions characteristic of the 2040s. "CO2" column indicates historic atmospheric conditions or the A1B or B1 emissions scenario. "Ocean" indicates the ocean scenario (see text). "Hydro" is the mainstem survival management lever. N0 is the initial number of spawners at the beginning of each simulation. The next six columns show the 5th, 50th, and 95th quantile spawner abundance across simulations at a given time point, either in simulation year 25 or year 100. NL, NM and NH are the geometric means across simulations of the 5th, 50th, and 95th quantile spawner abundance, respectively, within each simulation across the full 100 years. PrQET indicates the probability of passing the quasi-extinction threshold of 50 spawners within the first 25 years (PrQET25) or at any time within the full 100 years of simulation (PrQET100), or of passing a population-specific threshold (historical minimum) in 100 years (PrQETNmin). MeanSurv shows the average parr-to-smolt survival rate for each scenario. See Zabel et al (2013) for more explanation of these metrics.