Supplementary Material—Salish Sea Salmon Qualitative Network Model

Appendix 1. Methods and Data Supporting Figure 1.

Methods

To arrive at population trends, we compiled available adult run sizes for salmon in rivers throughout the Salish Sea. Data were from Pacific Fishery Management Council Stock Assessment and Fishery Evaluation (SAFE) Documents (http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/review-of-2015-ocean-salmon-fisheries/), Pacific Salmon Commission Technical Committee Reports (http://www.psc.org/publications/technical-reports/technical-committee-reports/chinook/), Washington Department of Fish and Wildlife, Ogden et al. 2015, and Zimmerman et al. 2015 (Table A1.1). We used the longest time series available (typically from 1970s to >2010) and used the methods of Holmes (2001) to estimate a population trend and confidence interval for each run. If total run size (TRS, a total of catch and escapement or number of spawners) was not available, we used escapement/spawner (E) data.

Table A1.1 Salmon runs used in the calculation of population trends. TRS=Total Run Size, E=Escapement.

Run	Species	Data	Years	Data Source	Subbasin	Population Trend	95% Confidence Interval
Lake Washington	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Central Puget Sound	0.004	0.009
Green	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Central Puget Sound	-0.027	0.006
Snohomish	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Whidbey	-0.035	0.004
Hood Canal	Chinook	TRS	1981-2014	PFMC 2016	Hood Canal	0.035	0.010
Juan de Fuca	Chinook	TRS	1981-2014	PFMC 2016	Juan de Fuca	-0.006	0.006
South Puget Sound	Chinook	TRS	1981-2014	PFMC 2016	South Sound	0.013	0.005
Nooksack	Chinook	TRS	1981-2014	PFMC 2016	San Juan and Gulf Islands	-0.046	0.007
Skagit Spring	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Whidbey	0.014	0.006
Skagit Summer/fall	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Whidbey	-0.026	0.005
Stillaguamish	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Whidbey	-0.030	0.011
Willapa	Chinook	TRS	1976-2014	PFMC 2016	Pacific Coast	0.021	0.007
Grays Harbor Spring/Summer	Chinook	TRS	1976-2014	PFMC 2016	Pacific Coast	0.018	0.005

Grays Harbor Fall	Chinook	TRS	1975-2014	PSC Joint Tech. Comm. 2016	Pacific Coast	0.013	0.005
Queets Spr/Summer	Chinook	TRS	1976-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	-0.025	0.007
Queets fall	Chinook	TRS	1976-2014	PSC Joint Tech. Comm. 2016	Pacific Coast	0.002	0.004
Hoh Spring/Summer	Chinook	TRS	1976-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	-0.019	0.006
Hoh fall	Chinook	TRS	1976-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	-0.002	0.004
Quillayute spring/summer	Chinook	TRS	1976-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	-0.029	0.005
Quillayute fall	Chinook	TRS	1976-2015	PFMC 2016	Pacific Coast	-0.005	0.005
Hoko fall term	Chinook	TRS	1986-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.021	0.009
Fraser Spring/summer	Chinook	TRS	1975-2015	PSC Joint Tech. Comm. 2016	Central Strait of Georgia	0.017	0.002
Harrison	Chinook	TRS	1984-2015	PSC Joint Tech. Comm. 2016	Central Strait of Georgia	0.050	0.004
Lake Shuswap	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Central Strait of Georgia	0.026	0.006
Nanaimo	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	South Strait of Georgia, San Juan and Gulf Islands	-0.018	0.007
Cowichan	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	South Strait of Georgia, San Juan and Gulf Islands	-0.006	0.007
Nimpkish	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Johnstone Strait	-0.052	0.015
Klinaklini	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Johnstone Strait	0.030	0.009
Kakweiken	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Johnstone Strait	-0.043	0.011
Kingcome	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Johnstone Strait	-0.064	0.018
Wakeman	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Johnstone Strait	-0.151	0.028
Marble	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.013	0.005
Burman	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.061	0.012
Tahsis	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.024	0.014
Artlish	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.029	0.016
Kaouk	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.041	0.026
Tahsish	Chinook	E	1975-2015	PSC Joint Tech. Comm. 2016	Pacific Coast	0.004	0.011
Cedar River Winter	Steelhead	TRS	1987-2013	N. Kendall, WDFW pers. comm	Central Puget Sound	-0.220	0.023
Green River Winter	Steelhead	TRS	1978-2013	N. Kendall, WDFW pers. comm	Central Puget Sound	-0.053	0.004
Puyallup/Carbon Winter	Steelhead	TRS	1983-2013	N. Kendall, WDFW pers. comm comm	Central Puget Sound	-0.077	0.006
White River (Puyallup) Winter	Steelhead	TRS	1986-2013	N. Kendall, WDFW pers. comm	Central Puget Sound	-0.042	0.008
Englishman River winter	Steelhead	E	1982-2015	K. Pellett, pers. comm	Central Strait of Georgia	-0.063	0.011
East Hood Canal Winter	Steelhead	TRS	1989-2013	N. Kendall, WDFW pers. comm	Hood Canal	0.088	0.016

Skokomish Winter	Steelhead	TRS	1985-2006	N. Kendall, WDFW pers. comm	Hood Canal	-0.020	0.013
South Hood Canal Winter	Steelhead	TRS	1988-2013	N. Kendall, WDFW pers. comm	Hood Canal	-0.004	0.009
West Hood Canal Winter	Steelhead	TRS	2003-2013	N. Kendall, WDFW pers. comm	Hood Canal	0.015	0.021
Tsitika River summer	Steelhead	E	1976-2015	K. Pellett, pers. comm	Johnstone Strait	0.008	0.007
Salmon River winter	Steelhead	TRS	1981-2015	N. Kendall, WDFW pers. comm	Johnstone Strait	0.021	0.036
Sequim and Discovery Bays Tributaries Winter	Steelhead	TRS	1987-2013	N. Kendall, WDFW pers. comm	Juan de Fuca	-0.101	0.100
Strait of Juan de Fuca Independent Tributaries Winter	Steelhead	TRS	1991-2009	N. Kendall, WDFW pers. comm	Juan de Fuca	-0.028	0.022
Glendale winter	Steelhead	E	1992-2014	K. Pellett, pers. comm	Pacific Coast	-0.178	0.085
Ahnuhati winter	Steelhead	E	1992-2014	K. Pellett, pers. comm	Pacific Coast	-0.186	0.065
Kakweiken winter	Steelhead	E	1992-2014	K. Pellett, pers. comm	Pacific Coast	-0.206	0.063
Atwaykellesse winter	Steelhead	E	1992-2014	K. Pellett, pers. comm	Pacific Coast	-0.116	0.062
Wahpeeto winter	Steelhead	E	1992-2014	K. Pellett, pers. comm	Pacific Coast	-0.201	0.066
Heber River summer	Steelhead	E	1975-2015	K. Pellett, pers. comm	Pacific Coast	-0.012	0.004
Gordon River summer	Steelhead	E	1998-2015	K. Pellett, pers. comm	Pacific Coast	0.030	0.042
Nisqually Winter	Steelhead	TRS	1980-2013	N. Kendall, WDFW pers. comm	South Sound	-0.107	0.016
Samish Winter	Steelhead	TRS	1979-2013	N. Kendall, WDFW pers. comm	South Strait of Georgia	0.039	0.011
Pilchuck Winter	Steelhead	E	1981-2014	N. Kendall, WDFW pers. comm	Whidbey	-0.020	0.009
Skagit River Summer and Winter	Steelhead	TRS	1978-2013	N. Kendall, WDFW pers. comm	Whidbey	-0.034	0.007
Snohomish System Winter	Steelhead	TRS	1987-2013	N. Kendall, WDFW pers. comm	Whidbey	-0.048	0.012
Snohomish/Skykomish Winter	Steelhead	TRS	1987-2013	N. Kendall, WDFW pers. comm	Whidbey	-0.061	0.010
Snoqualmie Winter	Steelhead	TRS	1987-2013	N. Kendall, WDFW pers. comm	Whidbey	-0.056	0.008
Stillaguamish Winter	Steelhead	TRS	1987-2013	N. Kendall, WDFW pers. comm	Whidbey	-0.075	0.022
Green	Coho	TRS	1973-2010	Zimmerman et al. 2015	Central Puget Sound	0.039	0.014
Puyallup	Coho	TRS	1974-2010	Zimmerman et al. 2015	Central Puget Sound	-0.038	0.008
Big Qualicum	Coho	TRS	1973-2010	Zimmerman et al. 2015	Central Strait of Georgia	-0.143	0.011
Inch	Coho	TRS	1984-2010	Zimmerman et al. 2015	Central Strait of Georgia	0.103	0.023
Big Beef Creek	Coho	TRS	1977-2010	Zimmerman et al. 2015	Hood Canal	-0.025	0.009
Quilcene	Coho	TRS	1979-2010	Zimmerman et al. 2015	Hood Canal	0.039	0.014
Skokomish	Coho	TRS	1973-2010	Zimmerman et al. 2015	Hood Canal	0.013	0.008
Straits	Coho	TRS	1985-2010	Zimmerman et al. 2015	Juan de Fuca	-0.034	0.012
Black	Coho	TRS	1978-2010	Zimmerman et al. 2015	North Strait of Georgia	-0.052	0.021
Puntledge	Coho	TRS	1974-2010	Zimmerman et al. 2015	North Strait of Georgia	-0.151	0.020

Quinsam	Coho	TRS	1978-2004	Zimmerman et al. 2015	North Strait of Georgia	-0.104	0.010
Bingham Creek	Coho	TRS	1976-2010	Zimmerman et al. 2015	Pacific Coast	0.017	0.014
Cowlitz	Coho	TRS	1982-2010	Zimmerman et al. 2015	Pacific Coast	-0.126	0.030
Grays	Coho	TRS	1982-2010	Zimmerman et al. 2015	Pacific Coast	-0.036	0.009
Quinault	Coho	TRS	1977-2010	Zimmerman et al. 2015	Pacific Coast	0.079	0.015
Robertson	Coho	TRS	1975-2010	Zimmerman et al. 2015	Pacific Coast	-0.014	0.013
Satsop	Coho	TRS	1973-2010	Zimmerman et al. 2015	Pacific Coast	0.036	0.010
Washougal	Coho	TRS	1976-2010	Zimmerman et al. 2015	Pacific Coast	-0.102	0.023
Deschutes	Coho	TRS	1977-2008	Zimmerman et al. 2015	South Sound	-0.048	0.041
Chilliwack	Coho	TRS	1982-2004	Zimmerman et al. 2015	South Strait of Georgia	-0.066	0.060
Nooksack	Coho	TRS	1976-2009	Zimmerman et al. 2015	South Strait of Georgia	-0.071	0.028
Skagit	Coho	TRS	1991-2010	Zimmerman et al. 2015	Whidbey	-0.049	0.014
Stilliguamish	Coho	TRS	1981-2014	Zimmerman et al. 2015	Whidbey	-0.013	0.013
Snohomish	Coho	TRS	1981-2014	Zimmerman et al. 2015	Whidbey	-0.026	0.010
Baker	Coho	TRS	1983-2010	Zimmerman et al. 2015	Whidbey	-0.048	0.018
Skykomish	Coho	TRS	1978-2010	Zimmerman et al. 2015	Whidbey	0.012	0.010
Tulalip Bay	Coho	TRS	1974-2010	Zimmerman et al. 2015	Whidbey	0.011	0.017
Green River (Area 10A)	Pink	TRS	2001-2013	A. Dufault, WDFW, pers. comm.	Central Puget Sound	1.053	0.364
Puyallup River (Area 11A)	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Central Puget Sound	0.133	0.038
Chambers	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Central Puget Sound	0.096	0.206
Nisqually R. Drainage	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Central Puget Sound	0.167	0.088
Area 13A streams	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Central Puget Sound	-0.029	0.054
Area 13B streams	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Central Puget Sound	0.036	0.035
Port Gamble	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	0.425	0.593
Dosewallips	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	-0.095	0.028
Duckabush	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	-0.025	0.054
Hamma	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	0.091	0.052
Hoodsport Hatchery	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	0.063	0.024
Misc 12C	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	-0.002	0.041
Skokomish R. Drainage	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Hood Canal	0.093	0.055
Dungeness River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Juan de Fuca	-0.009	0.053

Elwha River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Juan de Fuca	-0.182	0.093
Nooksack River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	South Strait of Georgia	-0.012	0.035
Samish River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	South Strait of Georgia	0.221	0.068
Fraser	Pink	TRS	1959-2011	Ogden et al. 2015	South Strait of Georgia	0.070	0.030
Skagit River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Whidbey	0.004	0.030
Snohomish River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Whidbey	0.080	0.025
Stillaguamish River	Pink	TRS	1959-2013	A. Dufault, WDFW, pers. comm.	Whidbey	0.000	0.027
Lake Washington	Sockeye	E	1972-2015	A. Dufault, WDFW, pers. comm.	Central Puget Sound	-0.005	0.006
Fraser	Sockeye	TRS	1960-2012	Ogden et al. 2015	South Strait of Georgia	0.003	0.004
Baker Lake	Sockeye	E	1970-2015	A. Dufault, WDFW, pers. comm	Whidbey	0.044	0.012
Misc 10 -Seattle	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Central Puget Sound	0.084	0.009
Green-Duwamish River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Central Puget Sound	0.135	0.014
Misc 10e -Port Orchard	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Central Puget Sound	0.022	0.007
Misc 11 -Tacoma	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Central Puget Sound	0.020	0.006
Puyallup River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Central Puget Sound	0.062	0.012
Port Gamble Pens (9a)	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	-0.016	0.009
N. Hood Canal (12)	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	-0.015	0.008
Misc 12b -Hood Canal	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	0.013	0.007
Quilcene River (12a)	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	0.034	0.011
Misc 12c -Hood Canal	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	0.063	0.006
Hoodsport Hatchery	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	0.049	0.010
Skokomish River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	0.073	0.007
Misc 12d -Hood Canal	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Hood Canal	0.025	0.007
Dungeness River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Juan de Fuca	0.052	0.012
Elwha River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Juan de Fuca	-0.061	0.014
Misc Strait Streams	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Juan de Fuca	0.023	0.009
Grays Harbor Wild Runsize	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Pacific Coast	-0.006	0.006
Willapa Bay Wild And Hatchery Escapement And Total Runsize	Chum	TRS	1980-1999	A. Dufault, WDFW, pers. comm	Pacific Coast	-0.010	0.006
Inside South Coast (Non-Fraser)	Chum	TRS	1953-2012	Ogden et al. 2015	Pacific Coast	0.000	0.005
Hecate Lowlands	Chum	E	1954-2012	Ogden et al. 2015	Pacific Coast	-0.014	0.004
North Haida Gwaii	Chum	E	1954-2012	Ogden et al. 2015	Pacific Coast	-0.028	0.009

Portland Inlet	Chum	E	1954-2012	Ogden et al. 2015	Pacific Coast	-0.006	0.005
Rivers Inlet	Chum	E	1954-2012	Ogden et al. 2015	Pacific Coast	-0.009	0.014
Skidegate	Chum	E	1954-2012	Ogden et al. 2015	Pacific Coast	-0.013	0.006
Misc 13 -South Puget Sound	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Sound	-0.018	0.050
Chambers Creek	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Sound	0.004	0.032
Nisqually River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Sound	0.026	0.054
Misc 13a -Minter Creek	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Sound	0.062	0.008
Misc 13b -Olympia	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Sound	0.029	0.003
Nooksack River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Strait of Georgia	0.019	0.005
Samish River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Strait of Georgia	0.007	0.010
Misc 7b Streams	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	South Strait of Georgia	0.082	0.011
Skagit River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Whidbey	-0.026	0.006
Tulalip Tribe	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Whidbey	0.063	0.013
Snohomish River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Whidbey	-0.001	0.011
Stillaguamish River	Chum	TRS	1968-2009	A. Dufault, WDFW, pers. comm	Whidbey	-0.011	0.008

Appendix 2. Model Sensitivity Analysis

Methods

To assess the sensitivity of the model linkages in the simulations, we calculated means and standard deviations of the weights for all linkages from the pool of accepted models. Our hypothesis was that some linkages would be more influential in model stability and that those with mean weights different than the expected mean (μ=0.5, given assignments that were random (*U(0,1)*)) would provide some indication of linkage sensitivity.

Results

Our sensitivity analysis showed that most model edges (linkages between groups) were stable with regard to the weights applied in the simulation routine, with means from the pool of balanced models very close to the expected mean of 0.5 (>75% of 148 edges). However, some model linkages in the pool of accepted models had mean weights above or below the expected mean and we considered these model groups more sensitive (Fig. A2.1). Linkages among salmon traits were most sensitive, with means in the balanced models considerably higher or lower than the expected mean (e.g., Fitness to Size and Survival to Abundance, self-limiting loops on salmon traits). However, some food web components such as Ichthyoplankton and Forage Fish were also in the group of lower-than-expected model means, suggesting that certain food web pathway weights were sensitive in the model simulations. The links with bidirectional connectivity (positive feedbacks, e.g. Fitness to Size, arrows shown in royal blue in Fig. 2) tended to be the most sensitive to the weighting scheme, with lower-than-average weights resulting in balanced models. Model linkages with mean weights above the expected mean included many high trophic level linkages (e.g., Piscivorous Fish to Marine Mammals), as well as self-limiting loops (salmon traits especially), highly connected nodes (e.g. Zooplankton), and top-level predators (Marine Mammals and Piscivorous Birds). The linkages with both higher- and lower-than-expected means (that were not self-limiting loops) tended be highly connected food web components rather than anthropogenic impacts or physical drivers.

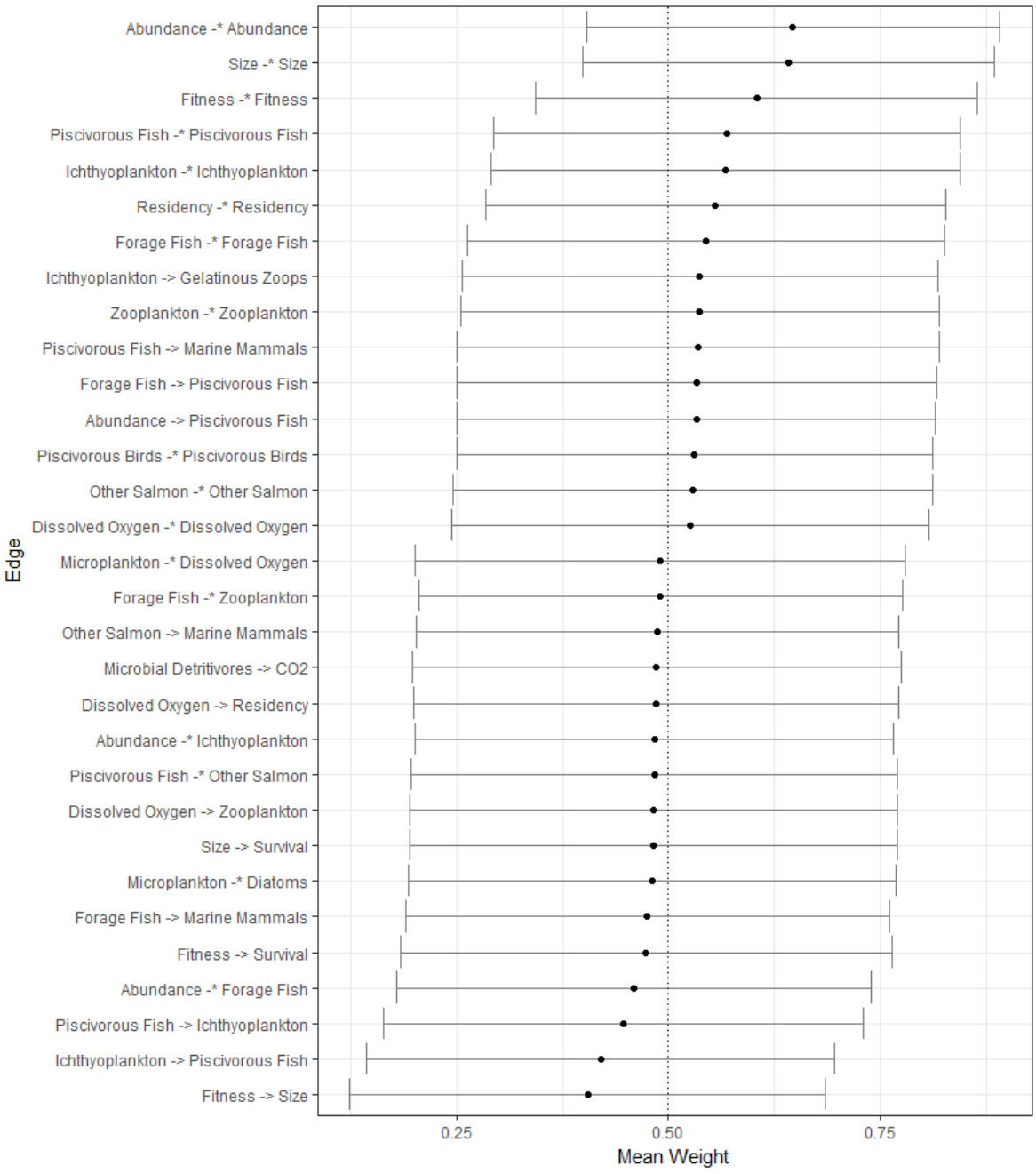

Figure A2.1. Calculated means and standard deviations from all model runs for edges (model linkages) with mean values different from the expected mean (0.5). The expected mean is denoted by the black dashed line. Positive linkages are indicated by an arrow and negative linkages are indicated by a dash and asterisk.

Drivers	Variables	Reference	Invoked Perturbation
Environmental	Sunlight	Littell et al. 2009	↑
	Winter Storms	Littell et al. 2009	↑
	Precipitation	Mauger et al. 2015, Littell et al. 2009	↑
	Upwelling[1]	Mauger et al. 2015	↓
	Stratification[2]	Mauger et al. 2015	↑
	Temperature	Littell et al. 2009, Field et al. 2006, Hollowed et al. 2001	↑
	River Flow	Littell et al. 2009[3]	↑
	Turbidity	PSEMP 2016, WADOE 2017	↓
	Dissolved Oxygen	Roberts et al. 2014	↓
Production	Nutrients	Roberts et al. 2014	↑
	Microplankton	Moore et al. 2015	↑
	Microbial Detritivores	PSEMP 2016	↑
	Diatoms	Brandenberger 2008, WADOE 2017	↓
Food web	Zooplankton[4]	Li et al. 2013	↓
	Gelatinous Zooplankton	Greene et al. 2015	↑
	Forage Fish	Greene et al. 2015	↓
	Ichthyoplankton	Palsson et al. 1998	↓
	Other Salmon	PFMC 2016, Figure 1	↑
	Piscivorous Fish	Palsson et al. 1998	↓
	Piscivorous Birds	Gaydos and Pearson 2011, Anderson et al. 2009	↓
	Marine Mammals	Chasco et al. 2017	↑
Anthropogenic	Hatcheries	Christie et al. 2012, Waples 1999	↑
	Harvest[5]		↑
	Habitat Loss	Puget Sound Water Quality Action Team 2002	↑
	CO2	Feely et al. 2010	↑
	Global Warming	IPCC 2014	↑
	Contaminants	O'Neill et al. 2009, Meador et al. 2006, Crecelius et al. 1995	↑
	Disease	Roon et al. 2015	↑

[1] While impacts to upwelling are unknown, we invoked a decrease in upwelling because it would reduce the delivery of nutrients to Puget Sound and potentially disrupt primary production.

[2] Decreased mixing as a result of changes in freshwater flow could lead to increased stratification; while the exact response is unknown (see Mauger et al. 2015), we have invoked an increase in stratification because decreased mixing would likely lead to declines in primary productivity.

[3] River flow is projected to be higher during the winter/spring period of salmon outmigration, but lower in the summers due to decreased precipitation and higher temps. during this season (Littell et al. 2009).

[4] While it is unknown if total abundance of zooplankton has decreased, there is some indication that the community has shifted. We invoked a decrease in zooplankton to reflect this shift.

[5] Harvest has decreased over the time period we used to frame this analysis; however, we were interested in the impacts of increased harvest on salmon survival so invoked an increase in harvest as the perturbation

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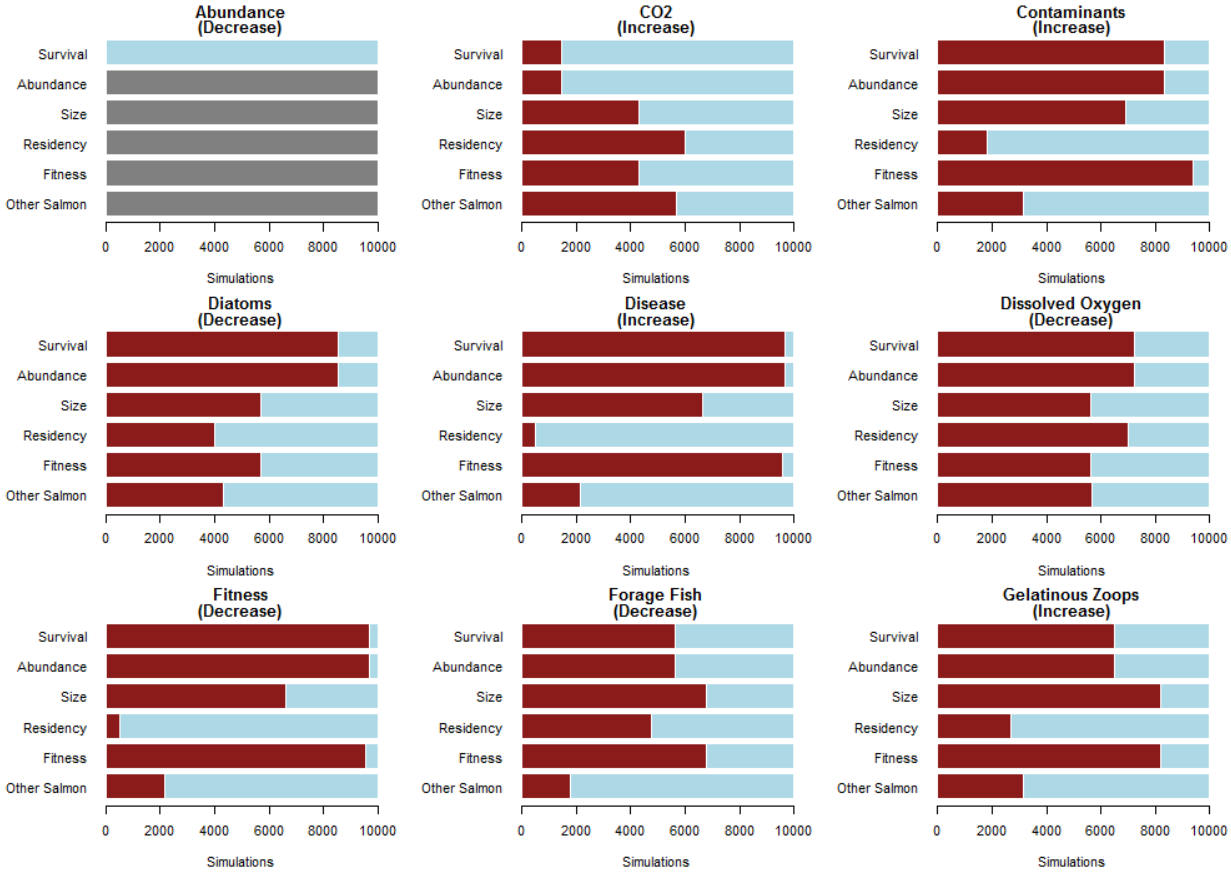
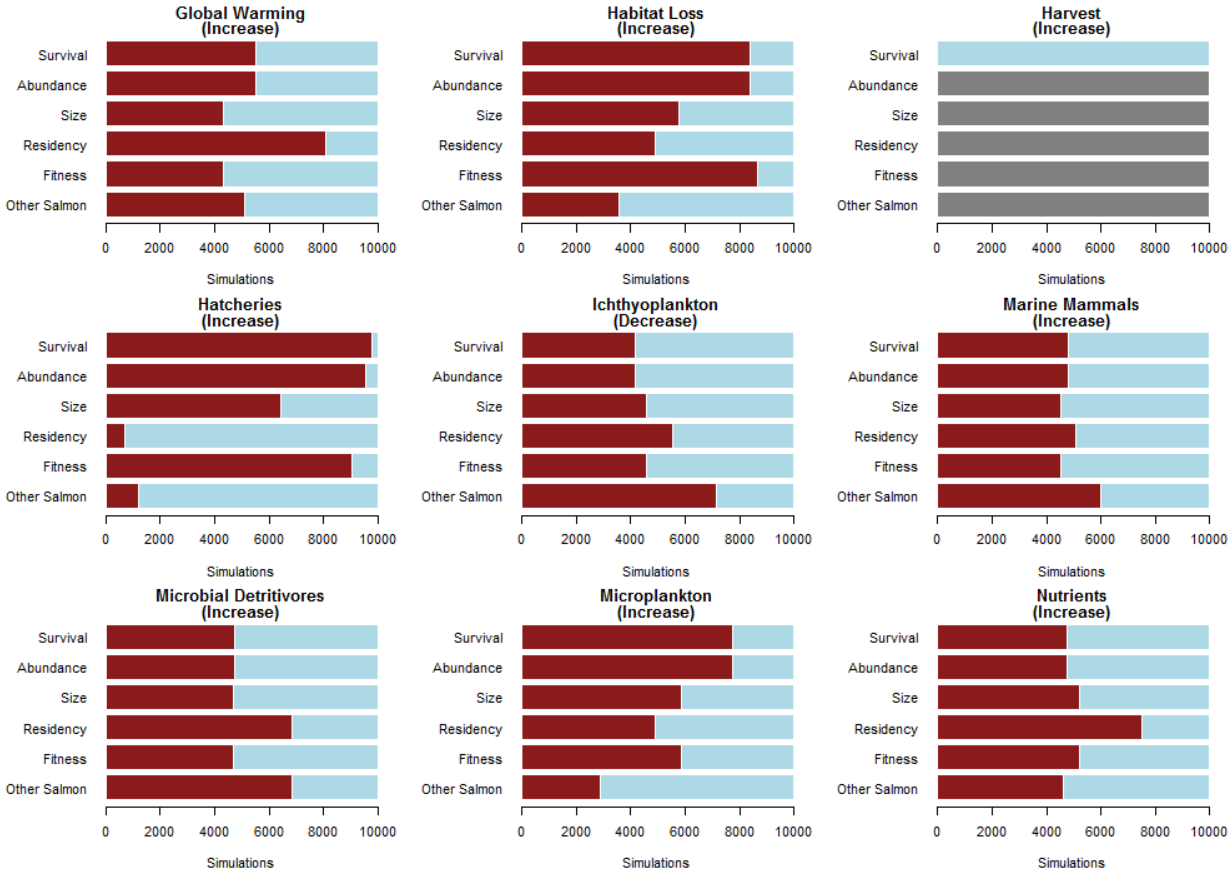
Appendix 4. Model Output for Individual Perturbations

Model output showing 6 model nodes of interest: salmon survival, abundance, size, residency, fitness and other salmon. Other salmon refers to the populations (chum, pink, and sockeye) which have not seen a noticeable decline in survival in recent decades. In each plot box, the model node that was perturbed is shown in the title, with the direction of the press (increase or decrease) shown below. The bar graphs indicate the proportion of model simulations with negative (red bars) and positive (blue bars) outcomes for that model node, given the invoked press perturbation. Where the bars are dark gray, there was no impact to those nodes.




Global Warming (Increase)
Habitat Loss (Increase)
Harvest (Increase)
Hatcheries (Increase)
Ichthyoplankton (Decrease)
Marine Mammals (Increase)
Microbial Detritivores (Increase)
Microplankton (Increase)
Nutrients (Increase)
Survival
Abundance
Size
Residency
Fitness
Other Salmon
0
2000
4000
6000
8000
10000
Simulations

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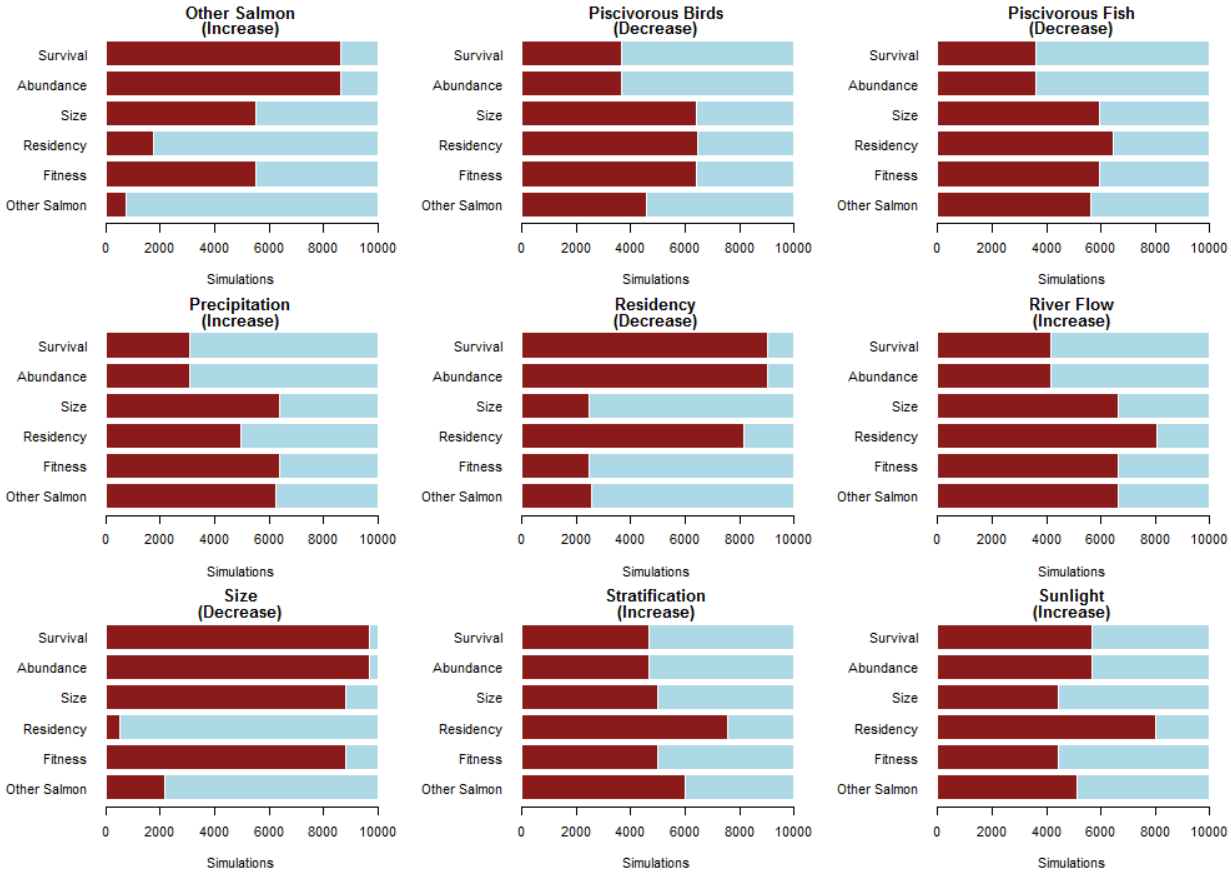

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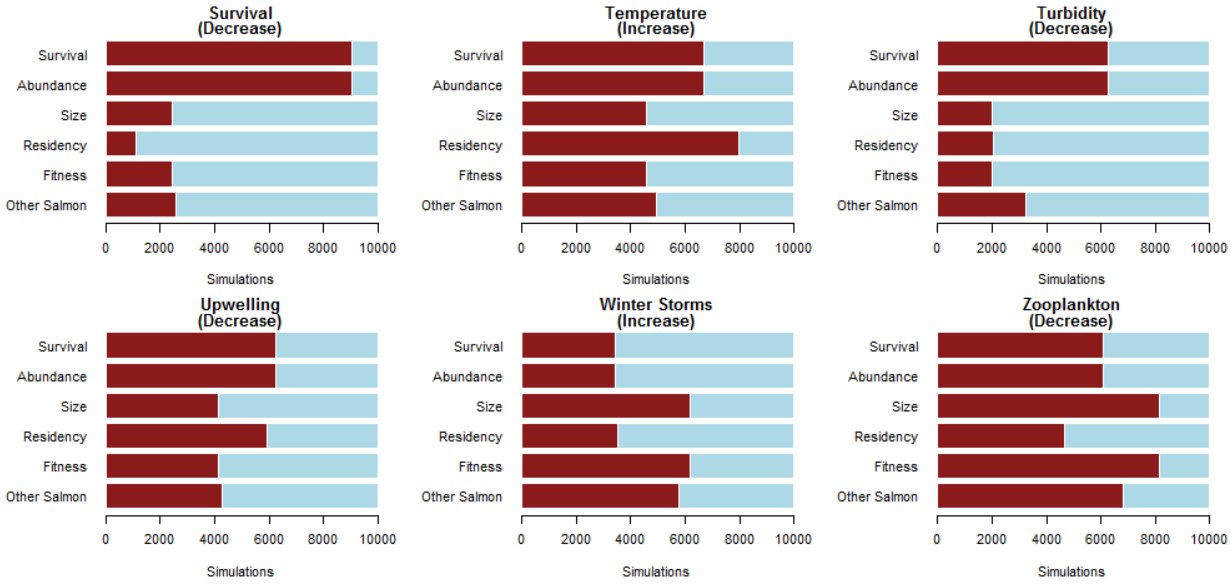

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