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From threats to solutions: A literature review of climate adaptation in anadromous salmon and trout

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Supporting information

Appendix S1 Contents

Supporting information

Table S1. Description of the criteria used to assign each label

List of labels within categories assigned to all papers, with brief definition of labels. Papers were assigned multiple labels within a category, as appropriate to papers covering multiple species, life stages, etc.

Category/labels	Description
Species	
Oncorhynchus clarkii	Cutthroat trout
Oncorhynchus gorbuscha	Pink salmon
Oncorhynchus keta	Chum salmon
Oncorhynchus kisutch	Coho salmon
Oncorhynchus masou	Masu salmon
Oncorhynchus mykiss	Rainbow trout/steelhead
Oncorhynchus nerka	Sockeye salmon
Oncorhynchus tshawytscha	Chinook salmon
Salmo salar	Atlantic salmon
Salvelinus confluentus	Bull trout
Salvelinus fontinalis	Brook trout
Salvelinus malma	Dolly Varden
Salmo trutta	Brown trout
Other fish	Other fish species
Other species	Other non-fish species
General	Non-specific species deemed relevant
Life Stage	
Egg	Egg incubation through emergence
Juvenile	Freshwater juvenile rearing
Juvenile migration	Juvenile migration to the ocean as smolt
Marine	Marine rearing, growth, and survival
Adult migration	Adult spawning migration, including pre-spawn holding
Spawning	Spawning
Population	Productivity, demographic trends, or population resiliency—any stage
Evolution	Explicit use of evolutionary methods or perspective,
Freshwater habitat	Freshwater habitat (may not be specific to a life stage)
General	Issues not specific to salmon or life stage, but determined to be relevant
Region	
Africa	Populations from Africa
Alaska	Populations from Alaska
Australia New Zealand	Populations from Australia and New Zealand
British Columbia	Populations from British Columbia, Canada
California	Populations from California, USA
Asia other	Populations from countries in Asia other than Japan and Russia
East North America	Populations from Canada and the U.S. east of the Rocky Mts
Europe	Populations from Europe
Japan	Populations from Japan
Largescale	Encompassing three or more regions (e.g., ocean or large-scale climate)

Table S1. Continued.

Category/labels	Description
Region (continued)	
Mountain west	Populations from the Rocky Mountain or interior basins of U.S./Canada
Northwest	Populations from Northwest region of the U.S.
Russia	Populations from Russia
South America	Populations from South America
Sub-region	
Alaska SE	Southeast Alaska from Yakutat to southern tip of Alaskan panhandle
Alaska S	South Alaska draining into Gulf of Alaska from Aleutians to Yakutat
Alaska W	Western and central Alaska draining into the Bering Sea or the Arctic
California N	Northern coastal California from San Francisco Bay to Oregon border
California S	Southern coastal California from Mexican border to San Francisco Bay
California CV	Central Valley CA from San Joaquin and Sacramento Basins to SF Bay
BC non Fraser	Areas of British of Columbia outside Fraser River watershed
Northwest Coastal	Coastal Oregon and Washington State
British Columbia Fraser	Areas of British of Columbia, Canada within Fraser R watershed
Northwest Columbia	Columbia River watershed, U.S. Pacific Northwest
Northwest Puget Sound	Puget Sound watershed, Washington State
Study type	
Field remote sensing	Data collected in the field and/or by remote transmitted data
Lab experimental	Lab experiments or field experimental designs
Model	Model as focus (e.g., methods, life cycle models) or those used to make future projections. Statistical models describing relationships excluded
Projections ecosystem	Climate change projections for ecosystems deemed relevant to salmon but not specifically projecting salmon
Projections physical	Physical climate change projections deemed relevant to salmon
Projections salmon	Climate change projections for salmon populations
Review meta-analysis	Reviews and meta-analyses
Theory/opinion	Theoretical and opinion
Study duration	
1	Study or time-series of 1 year or less
2-5	Study or time-series of 2-5 years
6-10	Study or time-series of 6-10 years
10+	Study or time-series of over 10 years
NA	No applicable study period or time-series (often theoretical)

Table S1. Continued.

Category/labels	Description	Process category
Driver		
		Environment
Acidity	Ocean and freshwater acidification	
Climate indices	Large-scale climate indices (PDO, ENSO)	
Contaminants	Contaminants such as heavy metals and PCBs	
Dissolved oxygen	Dissolved oxygen concentrations, hypoxic waters	
Environment	Other environmental drivers (e.g., salinity, upwelling)	
Flow	Freshwater flow levels	
Habitat	Physical habitat characteristics	
Temperature_marine	Marine water temperatures	
Temperature_freshwater	Freshwater water temperatures	
		Species interaction
Density and available food	Density, competition, and food availability	
Disease	Impacts of disease	
Ecosystem	Relevant ecosystem interactions not focused on salmon	
Invasives	Invasive species competing or preying on salmon	
Predators	Salmon predators	
Prey	Salmon prey	
		Evolution
Genetics	Genetically derived traits or genetic diversity	
		Management
Fisheries	Impacts from fisheries	
Management	Management levers (e.g., water, fisheries, hatchery)	
Restoration	Habitat restoration as a driver	
Methods	Methodologies for science or management	
Response		
		Physiology
Growth	Salmon growth	
Immune	Immune system responses	
Maturation	Sexual maturation	
Morphology	Physical morphology	
Performance	Fish performance metrics (e.g., swim speed)	
Physiology_condition	Internal physiological responses/fish condition metrics	
		Demography
Carryover	Carryover impacts from one life stage to another	
Life history	Life history changes, often demographic	
Mortality	Mortality rates	
Phenology	Timing of life history events (e.g., spawning, migration)	
Population resilience	Resilience of entire populations	
Productivity	Population productivity	
		Dispersal
Behavior	Changes in behavior	
Habitat and distribution	Distribution within available habitat	
		Species interaction
Diet	Diet composition as a response	
		Evolution
Genetics_adaptation	Change in genotype or adaptive response (phenotype)	
		Management
Livelihood	Human economic or subsistence	

Table S2. The number of papers assigned to each label across all life stages and within each life stage.

Counts of papers that received the labels listed in Table S1. "All life stages" column shows the number and proportion of unique papers with the label in the corresponding row from all papers in the evolutionary process (driver and response combined) database. Subsequent columns show the number of papers from the "All life stages" column that were also assigned a life history or population label. Note that a single paper could be assigned multiple labels if, for example, multiple regions or life stages were explicitly addressed in that paper

	All life stages								
Category/Label	N	(%)	Egg	Juvenile	Juvenile migration	Marine	Adult migration	Spawning	Population
All									
Evolution Process	199	0.11	20	48	8	18	32	21	31
Process driver									
Environment	119	0.6	17	35	4	9	16	9	13
Spp. interactions	22	0.11	0	10	1	1	4	2	2
Management	35	0.18	0	8	2	3	9	5	11
Evolution	140	0.7	16	33	6	13	21	16	23
Process response									
Demography	88	0.44	14	21	4	6	21	17	15
Physiology	77	0.39	13	32	3	8	8	9	4
Dispersal	25	0.13	0	2	1	5	2	1	7
Spp. interactions	0	0	0	0	0	0	0	0	0
Evolution	143	0.72	13	28	4	11	25	15	23
Driver									
Freshwater temp	78	0.39	13	27	2	3	11	7	6
Flow	16	0.08	0	3	1	0	6	0	4
Dissolved oxygen	5	0.03	1	3	1	0	0	0	1
Contaminants	2	0.01	0	1	0	0	0	0	2
Marine temp	8	0.04	0	1	1	3	0	0	3
Acidity	3	0.01	0	0	0	3	0	0	0
Climate indices	1	0	0	0	0	0	1	1	0
Environment	8	0.04	1	0	1	1	0	0	2
Disease	9	0.04	0	5	0	0	3	0	0
Predators	2	0.01	0	0	0	0	1	0	0
Invasives	2	0.01	0	0	0	0	0	0	1
Prey	0	0	0	0	0	0	0	0	0
Density/food constraint	6	0.03	0	5	1	0	0	2	1
Ecosystem	3	0.01	0	0	0	1	0	0	0
Management	27	0.14	0	7	2	1	6	4	9
Restoration	2	0.01	0	0	0	0	0	0	1
Fisheries	10	0.05	0	1	0	2	5	1	2
Genetics	140	0.7	16	33	6	13	21	16	23

Table S2. Continued.

Category/Label	All life stages N	(%)	Egg	Juvenile	Juvenile migration	Marine	Adult migration	Spawning	Population
Response									
Phenology	36	0.18	5	11	4	3	17	7	2
Mortality	18	0.09	7	8	1	1	4	5	1
Life_history	22	0.11	2	4	1	2	1	2	4
Pop. resilience	19	0.1	1	2	0	1	1	2	9
Productivity	6	0.03	0	0	0	1	1	1	3
Carryover	5	0.03	5	2	0	0	0	3	0
Performance	22	0.11	3	9	0	1	2	1	0
Physiol/Condition	37	0.19	9	17	2	1	5	2	0
Morphology	10	0.05	3	1	0	0	1	3	1
Immune	5	0.03	1	3	0	0	1	0	0
Growth	21	0.11	6	10	1	5	1	2	2
Maturation	14	0.07	0	4	0	4	2	3	4
Behaviour	3	0.01	0	0	0	0	1	0	0
Habitat/Distribution	22	0.11	0	2	1	5	1	1	7
Diet	0	0	0	0	0	0	0	0	0
Genetics/ Adaptation	143	0.72	13	28	4	11	25	15	23
Species									
O_tshawytscha	37	0.19	4	12	2	2	9	10	1
O_mykiss	45	0.23	3	10	1	2	2	1	6
O_nerka	14	0.07	3	3	1	1	7	1	0
O_kisutch	12	0.06	3	1	0	0	0	4	1
O_keta	7	0.04	0	0	1	1	1	1	2
O_gorbuscha	8	0.04	1	1	1	1	4	2	0
O_clarkii	7	0.04	0	1	0	0	0	0	2
O_masou	4	0.02	1	3	0	0	0	1	0
S_salar	30	0.15	1	6	1	4	5	1	10
S_trutta	9	0.04	1	4	1	0	1	0	3
S_fontinalis	4	0.02	1	2	0	0	0	0	1
S_confluentus	2	0.01	0	0	0	0	0	0	1
S_malma	0	0	0	0	0	0	0	0	0
Salmonids gen.	5	0.03	0	0	0	0	0	0	0
Other fish	13	0.06	2	2	0	2	1	1	4
Other spp	7	0.04	0	4	0	3	0	0	0
General	20	0.1	0	2	1	3	3	1	3

Table S2. Continued

Category/Label	All N	All (%)	Egg	Juvenile	Juvenile migration	Marine	Adult migration	Spawning	Population
Region									
Northwest	483	0.26	18	155	55	133	75	48	39
Europe	299	0.16	22	130	40	76	27	15	40
California	237	0.13	11	98	36	65	25	13	18
British_Columbia	205	0.11	14	51	21	70	57	15	14
East_No_America	179	0.10	15	70	13	46	24	13	14
Alaska	149	0.08	6	28	6	61	27	18	16
Largescale	118	0.06	0	6	1	93	2	1	12
Mountain_west	53	0.03	4	25	0	0	4	1	8
Japan	34	0.02	2	10	4	17	4	1	1
Asia_other	22	0.01	2	9	4	3	2	1	2
Australia_NZealand	21	0.01	1	6	1	12	2	2	0
Russia	15	0.01	0	0	0	10	1	0	3
South_America	10	0.01	2	2	0	2	0	1	0
Antarctica	2	<0.01	0	0	0	2	0	0	0
Africa	1	<0.01	0	0	0	0	0	0	0
Sub-region									
Columbia	26	0.13	1	3	1	2	5	3	1
Fraser	11	0.06	5	5	0	0	3	1	0
Northwest Coastal	3	0.01	0	0	0	0	1	0	0
N California	7	0.04	0	1	0	0	1	1	2
Central California	10	0.05	0	4	0	0	2	3	1
BC not Fraser	11	0.06	4	5	1	0	0	4	0
Puget Sound	8	0.04	0	2	0	0	1	3	3
W Alaska	10	0.05	1	0	1	2	5	0	1
S Alaska	9	0.04	1	2	1	2	4	1	1
S California	2	0.01	0	0	0	0	0	0	0
SE Alaska	7	0.04	1	1	1	1	4	1	0
Study duration									
Lab/Experimental	68	0.34	16	27	3	3	8	8	1
Field/RemoteSensing	100	0.5	5	18	4	10	18	12	23
Review/MetaAnalysis	23	0.12	0	2	1	6	3	0	3
Theoretical/Opinion	12	0.06	0	1	1	0	3	1	2
Model	9	0.04	0	2	0	1	2	1	5
Projections: salmon	5	0.03	0	1	0	0	2	1	2
Duration									
1 year	96	0.48	15	28	3	7	22	14	10
2-5 years	39	0.2	3	13	4	5	2	3	8
6-10 years	6	0.03	0	1	0	0	2	1	1
over 10 years	30	0.15	2	5	1	5	11	7	7

Table S3. Complete list of literature quantified by category.

Index	Citation
1	Abadia-Cardoso, A., D. E. Pearse, S. Jacobson, J. Marshall, D. Dalrymple, F. Kawasaki, G. Ruiz-Campos, and J. C. Garza. 2016. Population genetic structure and ancestry of steelhead/rainbow trout (*Oncorhynchus mykiss*) at the extreme southern edge of their range in North America. Conservation Genetics 17:675-689.
2	Abadia-Cardoso, A., R. Hernandez-Guzman, A. Varela-Romero, J. C. Garza, and F. J. Garcia-De Leon. 2021. Population genetics and species distribution modeling highlight conservation needs of the endemic trout from the Northern Sierra Madre Occidental. Conservation Genetics 22:629-643.
3	Akbarzadeh, A., A. L. S. Houde, B. G. Sutherland, O. P. Gunther, and K. M. Miller. 2020. Identification of hypoxia-specific biomarkers in salmonids Using RNA-sequencing and validation using high-throughput qPCR. G3-Genes Genomes Genetics 10:3321-3336.
4	Akbarzadeh, A., O. P. Gunther, A. L. Houde, S. R. Li, T. J. Ming, K. M. Jeffries, S. G. Hinch, and K. M. Miller. 2018. Developing specific molecular biomarkers for thermal stress in salmonids. Bmc Genomics 19:749.
5	Almodovar, A., S. Leal, G. G. Nicola, J. L. Horreo, E. Garcia-Vazquez, and B. Elvira. 2020. Long-term stocking practices threaten the original genetic diversity of the southernmost European populations of Atlantic salmon *Salmo salar*. Endangered Species Research 41:303-317.
6	Alshwairikh, Y. A., S. L. Kroeze, J. Olsson, S. A. Stephens-Cardenas, W. L. Swain, L. P. Waits, R. L. Horn, S. R. Narum, and T. Seaborn. 2021. Influence of environmental conditions at spawning sites and migration routes on adaptive variation and population connectivity in Chinook salmon. Ecology and Evolution 11:16890-16908.
7	Amin, M. H. F., J. H. Lee, A. R. Kim, J. K. Kim, C. I. Lee, and H. W. Kim. 2021. Development of a Quantitative PCR assay for four salmon species inhabiting the Yangyangnamdae River using environmental DNA. Biology-Basel 10.
8	Amish, S. J., O. Ali, M. Peacock, M. Miller, M. Robinson, S. Smith, G. Luikart, and H. Neville. 2019. Assessing thermal adaptation using family-based association and F-ST outlier tests in a threatened trout species. Molecular Ecology 28:2573-2593.
9	Anttila, K., E. J. Eliason, K. H. Kaukinen, K. M. Miller, and A. P. Farrell. 2014. Facing warm temperatures during migration: cardiac mRNA responses of two adult *Oncorhynchus nerka* populations to warming and swimming challenges. Journal of Fish Biology 84:1439-1456.
10	Araneda, C., N. F. Diaz, G. Gomez, M. E. Lopez, and P. Iturra. 2012. Comparative mapping reveals quantitative trait loci that affect spawning time in coho salmon (*Oncorhynchus kisutch*). Genetics and Molecular Biology 35:515-521.
11	Araujo, H. A., W. D. P. Duguid, R. Withler, J. Supernault, A. D. Schulze, J. L. Mckenzie, K. Pellett, T. D. Beacham, K. Jonsen, and A. Gummer. 2021. Chinook and Coho salmon hybrids linked to habitat and climatic changes on Vancouver Island, British Columbia. Ecology and Evolution 11:16874-16889.
12	Archer, L. C., S. A. Hutton, L. Harman, W. R. Poole, P. Gargan, P. McGinnity, and T. E. Reed. 2020. Metabolic traits in brown trout (*Salmo trutta*) vary in response to food restriction and intrinsic factors. Conservation Physiology 8.
13	Arciniega, M., A. J. Clemento, M. R. Miller, M. Peterson, J. C. Garza, and D. E. Pearse. 2016. Parallel evolution of the summer steelhead ecotype in multiple populations from Oregon and Northern California. Conservation Genetics 17:165-175.
14	Arevalo, E., A. Maire, S. Tetard, E. Prevost, F. Lange, F. Marchand, Q. Josset, and H. Drouineau. 2021. Does global change increase the risk of maladaptation of Atlantic salmon migration through joint modifications of river temperature and discharge? Proceedings of the Royal Society B-Biological Sciences 288.
15	Asheim, E. R., J. M. Prokkola, S. Morozov, T. Aykanat, and C. R. Primmer. 2021. Standard metabolic rate does not associate with age-at-maturity genotype in juvenile Atlantic salmon. Ecology and Evolution.

Table S3: Continued

16 Audzijonyte, A., A. Kuparinen, and E. A. Fulton. 2013. How fast is fisheries-induced evolution? Quantitative analysis of modelling and empirical studies. Evol Appl 6:585-595.

17 Austin, C. S., T. E. Essington, and T. P. Quinn. 2021. In a warming river, natural-origin Chinook salmon spawn later but hatchery-origin conspecifics do not. Canadian Journal of Fisheries and Aquatic Sciences 78:68-77.

18 Ayllon, D., G. G. Nicola, B. Elvira, and A. Almodovar. 2021. Climate change will render size-selective harvest of cold-water fish species unsustainable in Mediterranean freshwaters. Journal of Applied Ecology 58:562-575.

19 Beever, E. A., J. O'Leary, C. Mengelt, J. M. West, S. Julius, N. Green, D. Magness, L. Petes, B. Stein, A. B. Nicotra, J. J. Hellmann, A. L. Robertson, M. D. Staudinger, A. A. Rosenberg, E. Babij, J. Brennan, G. W. Schuurman, and G. E. Hofmann. 2016. Improving conservation outcomes with a new paradigm for understanding species' fundamental and realized adaptive capacity. Conservation Letters 9:131-137.

20 Bernas, R., A. Was-Barcz, M. Arnyasi, P. Debowski, G. Radtke, A. Pocwierz-Kotus, and P. Berrebi. 2021. Evidence of unidirectional gene flow in a fragmented population of *Salmo trutta* L. Scientific Reports 11.

21 Bohling, J., J. Von Bargen, and P. Bahls. 2020. Genomic characterization of Coho salmon spawning populations from the Hood Canal. Transactions of the American Fisheries Society 149:3-13.

22 Bowerman, T. E., M. L. Keefer, and C. C. Caudill. 2021. Elevated stream temperature, origin, and individual size influence Chinook salmon prespawn mortality across the Columbia River Basin. Fisheries Research 237.

23 Bowersox, B. J., M. P. Corsi, J. L. McCormick, T. Copeland, and M. R. Campbell. 2019. Examining Life History Shifts and Genetic Composition in a Hatchery Steelhead Population, with Implications for Fishery and Ocean Selection. Transactions of the American Fisheries Society 148:1056-1068.

24 Camak, D. T., M. J. Osborne, and T. F. Turner. 2021. Population genomics and conservation of Gila Trout (*Oncorhynchus gilae*). Conservation Genetics 22:729-743.

25 Carlson, S. M., and T. R. Seamons. 2008. A review of quantitative genetic components of fitness in salmonids: Implications for adaptation to future change. Evolutionary Applications 1:222-238.

26 Chaparro-Pedraza, P. C. 2021. Fast environmental change and eco-evolutionary feedbacks can drive regime shifts in ecosystems before tipping points are crossed. Proceedings of the Royal Society B-Biological Sciences 288.

27 Chapman, J. M., R. J. Lennox, W. M. Twardek, A. K. Teffer, M. J. Robertson, K. M. Miller, and S. J. Cooke. 2021. Serial sampling reveals temperature associated response in transcription profiles and shifts in condition and infectious agent communities in wild Atlantic salmon. Freshwater Biology 66:2086-2104.

28 Chen, Z. Q., A. P. Farrell, A. Matala, N. Hoffman, and S. R. Narum. 2018. Physiological and genomic signatures of evolutionary thermal adaptation in redband trout from extreme climates. Evolutionary Applications 11:1686-1699.

29 Chen, Z. Q., and S. R. Narum. 2021. Whole genome resequencing reveals genomic regions associated with thermal adaptation in redband trout. Molecular Ecology 30:162-174.

30 Christensen, C., M. W. Jacobsen, R. Nygaard, and M. M. Hansen. 2018. Spatiotemporal genetic structure of anadromous Arctic char (*Salvelinus alpinus*) populations in a region experiencing pronounced climate change. Conservation Genetics 19:687-700.

31 Collins, E. E., J. S. Hargrove, T. A. Delomas, and S. R. Narum. 2020. Distribution of genetic variation underlying adult migration timing in steelhead of the Columbia River basin. Ecology and Evolution 10:9486-9502.

32 Conover, D. O., T. A. Duffy, and L. A. Hice. 2009. The covariance between genetic and environmental influences across ecological gradients reassessing the evolutionary significance of countergradient and cogradient Variation. Pages 100-129 Year in Evolutionary Biology 2009.

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Table S3: Continued

34 Cook, C. J., G. Burness, and C. C. Wilson. 2018. Metabolic rates of embryos and alevin from a cold-adapted salmonid differ with temperature, population and family of origin: Implications for coping with climate change. Conservation Physiology 6.

35 Cote, J., J. M. Roussel, S. Cam, G. Bal, and G. Evanno. 2012. Population differences in response to hypoxic stress in Atlantic salmon. Journal of Evolutionary Biology 25:2596-2606.

36 Crichigno, S. A., M. Orellana, R. Larraza, G. Mirenna, and V. E. Cussac. 2021. Thermal effects in rainbow trout (*Oncorhynchus mykiss*) F1 embryos (farmed female x wild thermal-resistant male). Journal of Fish Biology 99:197-205.

37 Crozier, L. G., and J. A. Hutchings. 2014. Plastic and evolutionary responses to climate change in fish. Evolutionary Applications 7:68-87.

38 Czorlich, Y., T. Aykanat, J. Erkinaro, P. Orell, and C. R. Primmer. 2018. Rapid sex-specific evolution of age at maturity is shaped by genetic architecture in Atlantic salmon. Nature Ecology & Evolution 2:1800-1807.

39 D'Ambrosio, J., R. Morvezen, S. Brard-Fudulea, A. Bestin, A. A. Perez, D. Guemen, C. Poncet, P. Haffray, M. Dupont-Nivet, and F. Phocas. 2020. Genetic architecture and genomic selection of female reproduction traits in rainbow trout. Bmc Genomics 21.

40 Dallaire, X., E. Normandeau, J. Mainguy, J. E. Tremblay, L. Bernatchez, and J. S. Moore. 2021. Genomic data support management of anadromous Arctic Char fisheries in Nunavik by highlighting neutral and putatively adaptive genetic variation. Evolutionary Applications 14:1880-1897.

41 Davis, C. D., C. W. Epps, R. L. Flitcroft, and M. A. Banks. 2018. Refining and defining riverscape genetics: How rivers influence population genetic structure. Wiley Interdisciplinary Reviews-Water 5:e1269.

42 de Eyto, E., P. McGinnity, J. Huisman, J. Coughlan, S. Consuegra, K. Farrell, C. O'Toole, J. Tufto, H. J. Megens, W. Jordan, T. Cross, and R. J. M. Stet. 2011. Varying disease-mediated selection at different life-history stages of Atlantic salmon in fresh water. Evolutionary Applications 4:749-762.

43 Debes, P. V., M. F. Solberg, I. H. Matre, L. Dyrhovden, and K. A. Glover. 2021. Genetic variation for upper thermal tolerance diminishes within and between populations with increasing acclimation temperature in Atlantic salmon. Heredity 127:455-466.

44 Debes, P. V., N. Piavchenko, J. Erkinaro, and C. R. Primmer. 2020. Genetic growth potential, rather than phenotypic size, predicts migration phenotype in Atlantic salmon. Proceedings of the Royal Society B-Biological Sciences 287.

45 DeFilippo, L. B., D. E. Schindler, K. Shedd, and K. L. Schaberg. 2020. A Bayesian hierarchical approach to integrating historical and in-season genetic data for real-time assessment of a mixed stock fishery. Canadian Journal of Fisheries and Aquatic Sciences 77:1721-1732.

46 Dionne, M., K. M. Miller, J. J. Dodson, F. Caron, and L. Bernatchez. 2007. Clinal variation in mhc diversity with temperature: Evidence for the role of host-pathogen interaction on local adaptation in Atlantic salmon. Evolution 61:2154-2164.

47 Eliason, E. J., S. M. Wilson, A. P. Farrell, S. J. Cooke, and S. G. Hinch. 2013. Low cardiac and aerobic scope in a coastal population of sockeye salmon *Oncorhynchus nerka* with a short upriver migration. Journal of Fish Biology 82:2104-2112.

48 Evans, M. L., B. D. Neff, and D. D. Heath. 2010. Quantitative genetic and translocation experiments reveal genotype-by-environment effects on juvenile life-history traits in two populations of Chinook salmon (*Oncorhynchus tshawytscha*). Journal of Evolutionary Biology 23:687-698.

49 Everett, M. V., and J. E. Seeb. 2014. Detection and mapping of QTL for temperature tolerance and body size in Chinook salmon (*Oncorhynchus tshawytscha*) using genotyping by sequencing. Evolutionary Applications 7:480-492.

50 Faber, M., S. Shaw, S. Yoon, E. D. Alves, B. Wang, Z. T. Qi, B. Okamura, H. Hartikainen, C. J. Secombes, and J. W. Holland. 2021. Comparative transcriptomics and host-specific parasite gene expression profiles inform on drivers of proliferative kidney disease. Scientific Reports 11.

Table S3: Continued

51 Finlay, R., R. Poole, J. Coughlan, K. P. Phillips, P. Prodohl, D. Cotter, P. McGinnity, and T. E. Reed. 2020. Telemetry and genetics reveal asymmetric dispersal of a lake-feeding salmonid between inflow and outflow spawning streams at a microgeographic scale. Ecology and Evolution 10:1762-1783.

52 Ford, M. D., K. M. Nichols, R. S. Waples, E. C. Anderson, M. Kardos, I. Koch, G. McKinney, M. R. Miller, J. Myers, K. Naish, S. R. Narum, K. G. O'Malley, D. Pearse, T. R. Seamons, A. Spidle, P. Swanson, T. Q. Thompson, K. I. Warheit, and S. Willis. 2020. Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28 February 2020.

53 Fraik, A. K., J. R. McMillan, M. Liermann, T. Bennett, M. L. McHenry, G. J. McKinney, A. H. Wells, G. Winans, J. L. Kelley, G. R. Pess, and K. M. Nichols. 2021. The Impacts of Dam Construction and Removal on the Genetics of Recovering Steelhead (*Oncorhynchus mykiss*) Populations across the Elwha River Watershed. Genes 12.

54 Fraser, D. J. 2014. Evolutionary hypotheses for a constraint to life-history resilience in depleted S*almo salar* populations. Journal of Fish Biology 85:119-131.

55 Fraser, G. S., P. W. DeHaan, C. T. Smith, J. F. Von Bargen, M. R. Cooper, and T. J. Desgrosseillier. 2020. Overlap of Spatial and Temporal Spawning Distributions of Spring and Summer Chinook Salmon Results in Hybridization in the Upper Columbia River. Transactions of the American Fisheries Society 149:517-531.

56 Gallardo-Hidalgo, J., A. Barria, G. M. Yoshida, and J. M. Yanez. 2021. Genetics of growth and survival under chronic heat stress and trade-offs with growth- and robustness-related traits in rainbow trout. Aquaculture 531.

57 Garvin, M. R., G. H. Thorgaard, and S. R. Narum. 2015. Differential Expression of Genes that Control Respiration Contribute to Thermal Adaptation in Redband Trout (*Oncorhynchus mykiss gairdneri*). Genome Biology and Evolution 7:1404-1414.

58 Gharrett, A. J., J. Joyce, and W. W. Smoker. 2013. Fine-scale temporal adaptation within a salmonid population: Mechanism and consequences. Molecular Ecology 22:4457-4469.

59 Gilbey, J., K. R. Utne, V. Wennevik, A. C. Beck, K. Kausrud, K. Hindar, C. G. de Leaniz, C. Cherbonnel, J. Coughlan, T. F. Cross, E. Dillane, D. Ensing, E. Garcia-Vazquez, L. R. Hole, M. Holm, J. C. Holst, J. A. Jacobsen, A. J. Jensen, S. Karlsson, N. O. Maoileidigh, K. A. Mork, E. E. Nielsen, L. Nottestad, C. R. Primmer, P. Prodohl, S. Prusov, J. R. Stevens, K. Thomas, K. Whelan, P. McGinnity, and E. Verspoor. 2021. The early marine distribution of Atlantic salmon in the North-east Atlantic: A genetically informed stock-specific synthesis. Fish and Fisheries 22:1274-1306.

60 Glasgow, J., J. D. De Groot, and M. P. Small. 2020. Genetic composition and conservation status of coastal cutthroat trout (*Oncorhynchus clarki clarki*) in the San Juan Islands, Washington. Conservation Genetics 21:181-186.

61 Gosselin, J. L., and J. J. Anderson. 2020. Step-patterned survivorship curves: Mortality and loss of equilibrium responses to high temperature and food restriction in juvenile rainbow trout (*Oncorhynchus mykiss*). Plos One 15.

62 Goulding, A. T., and A. P. Farrell. 2020. The effect of temperature acclimation on the force-frequency relationship and adrenergic sensitivity of the ventricle of two populations of juvenile sockeye salmon. Journal of Comparative Physiology B-Biochemical Systems and Environmental Physiology 190:717-730.

63 Grainger, T. N., and J. M. Levine. 2022. Rapid evolution of life-history traits in response to warming, predation and competition: A meta-analysis. Ecology Letters 25:541-554.

64 Hand, B. K., C. C. Muhlfeld, A. A. Wade, R. P. Kovach, D. C. Whited, S. R. Narum, A. P. Matala, M. W. Ackerman, B. A. Garner, J. S. Kimball, J. A. Stanford, and G. Luikart. 2016. Climate variables explain neutral and adaptive variation within salmonid metapopulations: the importance of replication in landscape genetics. Molecular Ecology 25:689-705.

65 Hartman, K. J., and M. A. Porto. 2014. Thermal performance of three rainbow trout strains at above-optimal temperatures. Transactions of the American Fisheries Society 143:1445-1454.

Table S3: Continued

66 Hecht, B. C., A. P. Matala, J. E. Hess, and S. R. Narum. 2015. Environmental adaptation in Chinook salmon (O*ncorhynchus tshawytscha*) throughout their North American range. Molecular Ecology 24:5573-5595.

67 Heim, K. C., T. E. McMahon, S. T. Kalinowski, B. D. Ertel, and T. M. Koel. 2020. Abiotic conditions are unlikely to mediate hybridization between invasive rainbow trout and native Yellowstone cutthroat trout in a high-elevation metapopulation. Canadian Journal of Fisheries and Aquatic Sciences 77:1433-1445.

68 Hess, J. E., and S. R. Narum. 2011. Single-Nucleotide Polymorphism (SNP) loci correlated with run timing in adult Chinook salmon from the Columbia River Basin. Transactions of the American Fisheries Society 140:855-864.

69 Hirsch, S. L., and J. Long. 2021. Adaptive Epistemologies: Conceptualizing Adaptation to Climate Change in Environmental Science. Science Technology & Human Values 46:298-319.

70 Horita, J., Y. Iwasa, and Y. Tachiki. 2021. Eco-evolutionary dynamics may show an irreversible regime shift, illustrated by salmonids facing climate change. Theoretical Ecology 14:345-357.

71 Horreo, J. L., A. M. Griffiths, G. Machado-Schiaffino, J. R. Stevens, and E. Garcia-Vazquez. 2019. Northern areas as refugia for temperate species under current climate warming: Atlantic salmon (*Salmo salar* L.) as a model in northern Europe. Journal of Fish Biology 95:304-310.

72 Hotaling, S., A. A. Shah, K. L. McGowan, L. M. Tronstad, J. J. Giersch, D. S. Finn, H. A. Woods, M. E. Dillon, and J. L. Kelley. 2020. Mountain stoneflies may tolerate warming streams: Evidence from organismal physiology and gene expression. Global Change Biology 26:5524-5538.

73 Hurst, T. P., S. B. Munch, and K. A. Lavelle. 2012. Thermal reaction norms for growth vary among cohorts of Pacific cod (*Gadus macrocephalus*). Marine Biology 159:2173-2183.

74 Janhunen, M., J. Piironen, and N. Peuhkuri. 2010. Parental effects on embryonic viability and growth in Arctic charr *Salvelinus alpinus* at two incubation temperatures. Journal of Fish Biology 76:2558-2570.

75 Jarque, S., E. Gallego, M. Bartrons, J. Catalan, J. O. Grimalt, and B. Pina. 2010. Altitudinal and thermal gradients of hepatic Cyp1A gene expression in natural populations of *Salmo trutta* from high mountain lakes and their correlation with organohalogen loads. Environmental Pollution 158:1392-1398.

76 Jensen, A. J., S. Karlsson, P. Fiske, L. P. Hansen, G. M. Ostborg, and K. Hindar. 2014. Origin and life history of Atlantic salmon (*Salmo salar*) near their northernmost oceanic limit. Canadian Journal of Fisheries and Aquatic Sciences 71:1740-1746.

77 Johnson, B. M., B. M. Kemp, and G. H. Thorgaard. 2018. Increased mitochondrial DNA diversity in ancient Columbia River basin Chinook salmon *Oncorhynchus tshawytscha*. Plos One 13:e0190059.

78 Johnson, J. R., J. Baumsteiger, J. Zydlewski, J. M. Hudson, and W. Ardren. 2010. Evidence of panmixia between sympatric life history forms of coastal cutthroat trout in two Lower Columbia River tributaries. North American Journal of Fisheries Management 30:691-701.

79 Kannry, S. H., S. M. O'Rourke, S. J. Kelson, and M. R. Miller. 2020. On the Ecology and Distribution of Steelhead (*Oncorhynchus mykiss*) in California's Eel River. Journal of Heredity 111:548-563.

80 Kardos, M., and G. Luikart. 2021. The genetic architecture of fitness drives population viability during rapid environmental change. The American Naturalist 197:511-525.

81 Kardos, M., E. E. Armstrong, S. W. Fitzpatrick, S. Hauser, P. W. Hedrick, J. M. Miller, D. A. Tallmon, and W. C. Funk. 2021. The crucial role of genome-wide genetic variation in conservation. Proceedings of the National Academy of Sciences 118:e2104642118.

82 Kavanagh, K. D., T. O. Haugen, F. Gregersen, J. Jernvall, and L. A. Vollestad. 2010. Contemporary temperature-driven divergence in a Nordic freshwater fish under conditions commonly thought to hinder adaptation. Bmc Evolutionary Biology 10:Available at: http://www.biomedcentral.com/1471-2148/1410/1350.

83 Kelly, M. W., and G. E. Hofmann. 2013. Adaptation and the physiology of ocean acidification. Functional Ecology 27:980-990.

Table S3: Continued

84 Kelly, M. W., J. L. Padilla-Gamino, and G. E. Hofmann. 2013. Natural variation and the capacity to adapt to ocean acidification in the keystone sea urchin Strongylocentrotus purpuratus. Global Change Biology 19:2536-2546.

85 Kelson, S. J., M. R. Miller, T. Q. Thompson, S. M. O'Rourke, and S. M. Carlson. 2020. Temporal dynamics of migration-linked genetic variation are driven by streamflows and riverscape permeability. Molecular Ecology 29:870-885.

86 King, R. A., B. Stockley, and J. R. Stevens. 2020. Small coastal streams-Critical reservoirs of genetic diversity for trout (*Salmo trutta* L.) in the face of increasing anthropogenic stressors. Ecology and Evolution 10:5651-5669.

87 Kitada, S., and H. Kishino. 2021. Population structure of chum salmon and selection on the markers collected for stock identification. Ecology and Evolution 11:13972-13985.

88 Kodama, M., J. J. Hard, and K. A. Naish. 2012. Temporal variation in selection on body length and date of return in a wild population of coho salmon, *Oncorhynchus kisutch*. Bmc Evolutionary Biology 12.

89 Kovach, R. P., A. J. Gharrett, and D. A. Tallmon. 2012. Genetic change for earlier migration timing in a pink salmon population. Proceedings of the Royal Society B-Biological Sciences 279:3870-3878.

90 Kovach, R. P., A. J. Gharrett, and D. A. Tallmon. 2013. Temporal patterns of genetic variation in a salmon population undergoing rapid change in migration timing. Evolutionary Applications 6:795-807.

91 Kovach, R. P., C. C. Muhlfeld, A. A. Wade, B. K. Hand, D. C. Whited, P. W. DeHaan, R. Al-Chokhachy, and G. Luikart. 2015. Genetic diversity is related to climatic variation and vulnerability in threatened bull trout. Global Change Biology 21:2510-2524.

92 Kuzishschin, K. V., A. V. Semenova, M. A. Gruzdeva, and D. S. Pavlov. 2021. Regularities of Formation of Diversity of Life Strategy and Genetic Variability of The Kamchatka Rainbow Trout Parasalmo mykiss in a Local Population. Journal of Ichthyology 60:839-857.

93 Laramie, M. B., D. S. Pilliod, and C. S. Goldberg. 2015. Characterizing the distribution of an endangered salmonid using environmental DNA analysis. Biological Conservation 183:29-37.

94 Larson, W. A., J. E. Seeb, T. H. Dann, D. E. Schindler, and L. W. Seeb. 2014. Signals of heterogeneous selection at an MHC locus in geographically proximate ecotypes of sockeye salmon. Molecular Ecology 23:5448-5461.

95 Layton, K. K. S., P. V. R. Snelgrove, J. B. Dempson, T. Kess, S. J. Lehnert, P. Bentzen, S. J. Duffy, A. M. Messmer, R. R. E. Stanley, C. DiBacco, S. J. Salisbury, D. E. Ruzzante, C. M. Nugent, M. M. Ferguson, J. S. Leong, B. F. Koop, and I. R. Bradbury. 2021. Genomic evidence of past and future climate-linked loss in a migratory Arctic fish. Nature Climate Change 11.

96 Lee, H. J., S. Y. Lee, and Y. K. Kim. 2021. Molecular characterization of transient receptor potential vanilloid 4 (TRPV4) gene transcript variant mRNA of chum salmon *Oncorhynchus keta* in response to salinity or temperature changes. Gene 795.

97 Lehnert, S. J., S. M. Baillie, J. MacMillan, I. G. Paterson, C. F. Buhariwalla, I. R. Bradbury, and P. Bentzen. 2020. Multiple decades of stocking has resulted in limited hatchery introgression in wild brook trout (*Salvelinus fontinalis*) populations of Nova Scotia. Evolutionary Applications 13:1069-1089.

98 Lehnert, S. J., T. Kess, P. Bentzen, M. Clement, and I. R. Bradbury. 2020. Divergent and linked selection shape patterns of genomic differentiation between European and North American Atlantic salmon (*Salmo salar*). Molecular Ecology 29:2160-2175.

99 Lehnert, S. J., T. Kess, P. Bentzen, M. P. Kent, S. Lien, J. Gilbey, M. Clement, N. W. Jeffery, R. S. Waples, and I. R. Bradbury. 2019. Genomic signatures and correlates of widespread population declines in salmon. Nature Communications 10:10.

100 Li, J. J., S. H. Huang, Z. Y. Liu, and Y. X. Bi. 2020. Climate-Driven Range Shifts of Brown Seaweed Sargassum horneri in the Northwest Pacific. Frontiers in Marine Science 7.

101 Liedvogel, M., S. Akesson, and S. Bensch. 2011. The genetics of migration on the move. Trends in Ecology & Evolution 26:561-569.

Table S3: Continued

102 Limborg, M. T., S. M. Blankenship, S. F. Young, F. M. Utter, L. W. Seeb, M. H. H. Hansen, and J. E. Seeb. 2012. Signatures of natural selection among lineages and habitats in *Oncorhynchus mykiss*. Ecology and Evolution 2:1-18.

103 Lin, J. E., J. J. Hard, R. Hilborn, and L. Hauser. 2017. Modeling local adaptation and gene flow in sockeye salmon. Ecosphere 8.

104 Lohmus, M., L. F. Sundstrom, M. Bjorklund, and R. H. Devlin. 2010. Genotype-temperature interaction in the regulation of development, growth, and morphometrics in wild-type, and growth-hormone transgenic coho salmon. Plos One 5:e9980.

105 Lohmus, M., M. Bjorklund, L. F. Sundstrom, and R. H. Devlin. 2010. Effects of temperature and growth hormone on individual growth trajectories of wild-type and transgenic coho salmon *Oncorhynchus kisutch*. Journal of Fish Biology 76:641-654.

106 Macqueen, D. J., and I. A. Johnston. 2014. A well-constrained estimate for the timing of the salmonid whole genome duplication reveals major decoupling from species diversification. Proceedings of the Royal Society B-Biological Sciences 281.

107 Madsen, R. P. A., M. W. Jacobsen, K. G. O'Malley, R. Nygaard, K. Praebel, B. Jonsson, J. M. Pujolar, D. J. Fraser, L. Bernatchez, and M. M. Hansen. 2020. Genetic population structure and variation at phenologyrelated loci in anadromous Arctic char (*Salvelinus alpinus*). Ecology of Freshwater Fish 29.

108 Magerhans, A., and G. Horstgen-Schwark. 2010. Selection experiments to alter the sex ratio in rainbow trout (*Oncorhynchus mykiss*) by means of temperature treatment. Aquaculture 306:63-67.

109 Manhard, C. V., J. E. Joyce, and A. J. Gharrett. 2017. Evolution of phenology in a salmonid population: a potential adaptive response to climate change. Canadian Journal of Fisheries and Aquatic Sciences 74:1519-1527.

110 Manhard, C. V., M. D. Adkison, J. J. Hard, W. W. Smoker, and A. J. Gharrett. 2018. Local adaptation of phenology revealed in outcrosses between spawning segments of a salmonid population. Molecular Ecology 27:4698-4710.

111 Martinez, A. S., J. R. Willoughby, and M. R. Christie. 2018. Genetic diversity in fishes is influenced by habitat type and life-history variation. Ecology and Evolution 8:12022-12031.

112 Matala, A. P., M. W. Ackerman, M. R. Campbell, and S. R. Narum. 2014. Relative contributions of neutral and non-neutral genetic differentiation to inform conservation of steelhead trout across highly variable landscapes. Evolutionary Applications 7:682-701.

113 McGaughran, A., R. Laver, and C. Fraser. 2021. Evolutionary Responses to Warming. Trends in Ecology & Evolution 36:591-600.

114 McKenzie, D. J., Y. F. Zhang, E. J. Eliason, P. M. Schulte, G. Claireaux, F. R. Blasco, J. J. H. Nati, and A. P. Farrell. 2021. Intraspecific variation in tolerance of warming in fishes. Journal of Fish Biology 98:1536-1555.

115 McKenzie, J. L., H. A. Araujo, J. L. Smith, D. Schluter, and R. H. Devlin. 2021. Incomplete reproductive isolation and strong transcriptomic response to hybridization between sympatric sister species of salmon. Proceedings of the Royal Society B-Biological Sciences 288.

116 Meek, M. H., M. R. Stephens, A. Goodbla, B. May, and M. R. Baerwald. 2020. Identifying hidden biocomplexity and genomic diversity in Chinook salmon, an imperiled species with a history of anthropogenic influence. Canadian Journal of Fisheries and Aquatic Sciences 77:534-547.

117 Meier, K., M. M. Hansen, E. Normandeau, K.-L. D. Mensberg, J. Frydenberg, P. F. Larsen, D. Bekkevold, and L. Bernatchez. 2014. Local adaptation at the transcriptome level in brown trout: Evidence from early life history temperature genomic reaction norms. Plos One 9.

118 Miller, D. D., Y. Ota, U. R. Sumaila, A. M. Cisneros-Montemayor, and W. W. L. Cheung. 2018. Adaptation strategies to climate change in marine systems. Global Change Biology 24:E1-E14.

119 Miller, M., J. Brunelli, P. Wheeler, S. Liu, C. Rexroad, Y. Palti, C. Doe, and G. Thorgaard. 2012. A conserved haplotype controls parallel adaptation in geographically distant salmonid populations. Molecular Ecology 21:237-249.

Table S3: Continued

120 Mitchell, C. J., E. Lawrence, V. R. Chu, M. J. Harris, W. G. Landis, K. E. von Stackelberg, and J. D. Stark. 2021. Integrating Metapopulation Dynamics into a Bayesian Network Relative Risk Model: Assessing Risk of Pesticides to Chinook Salmon (*Oncorhynchus tshawytscha*) in an Ecological Context. Integrated Environmental Assessment and Management 17:95-109.

121 Moran, P., D. J. Teel, M. A. Banks, T. D. Beacham, M. R. Bellinger, S. M. Blankenship, J. R. Candy, J. C. Garza, J. E. Hess, S. R. Narum, L. W. Seeb, W. D. Templin, C. G. Wallace, and C. T. Smith. 2013. Divergent life-history races do not represent Chinook salmon coast-wide: The importance of scale in Quaternary biogeography. Canadian Journal of Fisheries and Aquatic Sciences 70:415-435.

122 Morita, K. 2019. Earlier migration timing of salmonids: an adaptation to climate change or maladaptation to the fishery? Canadian Journal of Fisheries and Aquatic Sciences 76:475-479.

123 Muhlfeld, C. C., R. P. Kovach, L. A. Jones, R. Al-Chokhachy, M. C. Boyer, R. F. Leary, W. H. Lowe, G. Luikart, and F. W. Allendorf. 2014. Invasive hybridization in a threatened species is accelerated by climate change. Nature Climate Change 4:620-624.

124 Muñoz, N. J., A. P. Farrell, J. W. Heath, and B. D. Neff. 2015. Adaptive potential of a Pacific salmon challenged by climate change. Nature Climate Change 5:163-166.

125 Muñoz, N. J., K. Anttila, Z. Chen, J. W. Heath, A. P. Farrell, and B. D. Neff. 2014. Indirect genetic effects underlie oxygen-limited thermal tolerance within a coastal population of chinook salmon. Proceedings of the Royal Society B-Biological Sciences 281.

126 Narum, S. R., and N. R. Campbell. 2015. Transcriptomic response to heat stress among ecologically divergent populations of redband trout. Bmc Genomics 16.

127 Narum, S. R., N. R. Campbell, C. C. Kozfkay, and K. A. Meyer. 2010. Adaptation of redband trout in desert and montane environments. Molecular Ecology 19:4622-4637.

128 Narum, S. R., N. R. Campbell, K. A. Meyer, M. R. Miller, and R. W. Hardy. 2013. Thermal adaptation and acclimation of ectotherms from differing aquatic climates. Molecular Ecology 22:3090-3097.

129 Nguyen, D. T., D. Marancik, C. Ware, M. J. Griffin, and E. Soto. 2021. *Mycobacterium salmoniphilum* and *M. chelonae* in captive populations of Chinook Salmon. Journal of Aquatic Animal Health 33:107-115.

130 Nielsen, J. L., G. T. Ruggerone, and C. E. Zimmerman. 2013. Adaptive strategies and life history characteristics in a warming climate: Salmon in the Arctic? Environmental Biology of Fishes 96:1187-1226.

131 O'Malley, K. G., D. P. Jacobson, R. Kurth, A. J. Dill, and M. A. Banks. 2013. Adaptive genetic markers discriminate migratory runs of Chinook salmon (*Oncorhynchus tshawytscha*) amid continued gene flow. Evolutionary Applications 6:1184-1194.

132 O'Malley, K. G., M. J. Ford, and J. J. Hard. 2010. Clock polymorphism in Pacific salmon: Evidence for variable selection along a latitudinal gradient. Proceedings of the Royal Society B-Biological Sciences 277:3703-3714.

133 Ocalewicz, K., A. Gurgul, M. Polonis, and S. Dobosz. 2020. Preliminary identification of candidate genes related to survival of gynogenetic Rainbow Trout (*Oncorhynchus mykiss*) based on comparative transcriptome analysis. Animals 10.

134 Oke, K. B., C. J. Cunningham, T. P. Quinn, and A. P. Hendry. 2019. Independent lineages in a common environment: the roles of determinism and contingency in shaping the migration timing of even- versus odd-year pink salmon over broad spatial and temporal scales. Ecology Letters 22:1547-1556.

135 Oku, H., M. Tokuda, H. Matsunari, H. Furuita, K. Murashita, and T. Yamamoto. 2014. Characterization of differentially expressed genes in liver in response to the rearing temperature of rainbow trout *Oncorhynchus mykiss* and their heritable differences. Fish Physiology and Biochemistry 40:1757-1769.

136 Olsen, J. B., P. Walsh, A. M. Benson, C. J. Schwanke, and J. K. Wenburg. 2021. Genetic divergence and diversity reflect a predominant freshwater resident life history in rainbow trout from Southwestern Alaska. Transactions of the American Fisheries Society: 151(2):202-214

Table S3: Continued

137 Ostergren, J., S. Palm, J. Gilbey, G. Spong, J. Dannewitz, H. Konigsson, J. Persson, and A. Vasemagi. 2021. A century of genetic homogenization in Baltic salmon-evidence from archival DNA. Proceedings of the Royal Society B-Biological Sciences 288.

138 Pearse, D. E., and M. A. Campbell. 2018. Ancestry and adaptation of rainbow trout in Yosemite National Park. Fisheries 43:472-484.

139 Piou, C., and E. Prevost. 2013. Contrasting effects of climate change in continental vs. oceanic environments on population persistence and microevolution of Atlantic salmon. Global Change Biology 19:711-723.

140 Pulkkinen, K., L. R. Suomalainen, A. F. Read, D. Ebert, P. Rintamaki, and E. T. Valtonen. 2010. Intensive fish farming and the evolution of pathogen virulence: The case of columnaris disease in Finland. Proceedings of the Royal Society B-Biological Sciences 277:593-600.

141 Quinn, T. P. 2021. Differential migration in Pacific salmon and trout: Patterns and hypotheses. Animal Migration 8:1-18.

142 Quinn, T. P., M. J. Unwin, and M. T. Kinnison. 2011. Contemporary divergence in migratory timing of naturalized populations of chinook salmon, *Oncorhynchus tshawytscha*, in New Zealand. Evolutionary Ecology Research 13:45-54.

143 Raymond, C. L., D. L. Peterson, and R. M. Rochefort, editors. 2014. Climate change vulnerability and adaptation in the North Cascades region, Washington. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

144 Reed, T. E., D. E. Schindler, M. J. Hague, D. A. Patterson, E. Meir, R. S. Waples, and S. G. Hinch. 2011. Time to evolve? Potential evolutionary responses of Fraser River sockeye salmon to climate change and effects on persistence. Plos One 6:e20380.

145 Reed, T. E., P. Prodohl, C. Bradley, J. Gilbey, P. McGinnity, C. R. Primmer, and P. J. Bacon. 2019. Heritability estimation via molecular pedigree reconstruction in a wild fish population reveals substantial evolutionary potential for sea age at maturity, but not size within age classes. Canadian Journal of Fisheries and Aquatic Sciences 76:790-805.

146 Rougemont, Q., and L. Bernatchez. 2018. The demographic history of Atlantic salmon (*Salmo salar*) across its distribution range reconstructed from approximate Bayesian computations. Evolution 72:1261-1277.

147 Satterthwaite, W. H., M. P. Beakes, E. M. Collins, D. R. Swank, J. E. Merz, R. G. Titus, S. M. Sogard, and M. Mangel. 2010. State-dependent life history models in a changing (and regulated) environment: Steelhead in the California Central Valley. Evolutionary Applications 3:221-243.

148 Schade, F. M., L. N. S. Shama, and K. M. Wegner. 2014. Impact of thermal stress on evolutionary trajectories of pathogen resistance in three-spined stickleback (Gasterosteus aculeatus). Bmc Evolutionary Biology 14.

149 Scribner, K. T., C. Soiseth, J. McGuire, G. K. Sage, L. Thorsteinson, J. L. Nielsen, and E. Knudsen. 2017. Genetic assessment of the effects of streamscape succession on coho salmon *Oncorhynchus kisutch* colonization in recently deglaciated streams. J Fish Biol 91:195-218.

150 Seeb, L. W., J. E. Seeb, C. Habicht, E. V. Farley, and F. M. Utter. 2011. Single-nucleotide polymorphic genotypes reveal patterns of early juvenile migration of sockeye salmon in the eastern Bering Sea. Transactions of the American Fisheries Society 140:734-748.

151 Shitova, M. V., Y. N. Khokhlov, A. I. Nikiforov, P. K. Afanasyev, S. Y. Orlova, A. N. Elnikov, A. V. Bugaev, T. A. Rakitskaya, V. D. Prohorovskaya, T. V. Malinina, D. V. Politov, K. I. Afanasyev, G. A. Rubtsova, and L. A. Zhivotovsky. 2020. Differentiation of asian north Chum Salmon (*Oncorhynchus keta W.*) based on microsatellite markers. Russian Journal of Genetics 56:706-717.

152 Siegel, J. E., M. D. Adkison, and M. V. McPhee. 2018. Changing maturation reaction norms and the effects of growth history in Alaskan Chinook salmon. Marine Ecology Progress Series 595:187-202.

153 Sinnatamby, R. N., A. Cantin, and J. R. Post. 2019. Threats to at-risk salmonids of the Canadian Rocky Mountain region. Ecology of Freshwater Fish:18.

Table S3: Continued

154 Sparks, M. M., P. A. H. Westley, J. A. Falke, and T. P. Quinn. 2017. Thermal adaptation and phenotypic plasticity in a warming world: Insights from common garden experiments on Alaskan sockeye salmon. Glob Chang Biol 23:5203-5217.

155 Stelkens, R. B., G. Jaffuel, M. Escher, and C. Wedekind. 2012. Genetic and phenotypic population divergence on a microgeographic scale in brown trout. Molecular Ecology 21:2896-2915.

156 Stitt, B. C., G. Burness, K. A. Burgomaster, S. Currie, J. L. McDermid, and C. C. Wilson. 2014. Intraspecific variation in thermal tolerance and acclimation capacity in brook trout (*Salvelinus fontinalis*): Physiological implications for climate change. Physiological and Biochemical Zoology 87:15-29.

157 Strait, J. T., L. A. Eby, R. P. Kovach, C. C. Muhlfeld, M. C. Boyer, S. J. Amish, S. Smith, W. H. Lowe, and G. Luikart. 2021. Hybridization alters growth and migratory life-history expression of native trout. Evolutionary Applications 14:821-833.

158 Strowbridge, N., S. L. Northrup, M. L. Earhart, T. S. Blanchard, and P. M. Schulte. 2021. Acute measures of upper thermal and hypoxia tolerance are not reliable predictors of mortality following environmental challenges in rainbow trout (*Oncorhynchus mykiss*). Conservation Physiology 9.

159 Sturrock, A. M., S. M. Carlson, J. D. Wikert, T. Heyne, S. Nussle, J. E. Merz, H. J. W. Sturrock, and R. C. Johnson. 2020. Unnatural selection of salmon life histories in a modified riverscape. Global Change Biology 26:1235-1247.

160 Sullivan, A. P., D. W. Bird, and G. H. Perry. 2017. Human behaviour as a long-term ecological driver of non-human evolution. Nat Ecol Evol 1:65.

161 Sullivan, R. M., and J. P. Hileman. 2019. Effects of managed flows on Chinook Salmon (*Oncorhynchus tshawytscha*) in relation to run-timing, fertility, and fluctuations in water temperature and flow volume. California Fish and Game 105:132-176.

162 Sutcliffe, R. L., S. R. Li, M. J. H. Gilbert, P. M. Schulte, K. M. Miller, and A. P. Farrell. 2020. A rapid intrinsic heart rate resetting response with thermal acclimation in rainbow trout, *Oncorhynchus mykiss*. Journal of Experimental Biology 223.

163 Sylvester, E. V. A., R. G. Beiko, P. Bentzen, I. Paterson, J. B. Horne, B. Watson, S. Lehnert, S. Duffy, M. Clement, M. J. Robertson, and I. R. Bradbury. 2018. Environmental extremes drive population structure at the northern range limit of Atlantic salmon in North America. Molecular Ecology 27:4026-4040.

164 Syrova, E., M. Palikova, J. Mendel, V. Seidlova, I. Papezikova, H. Schmidt-Posthaus, K. Somerlikova, H. Minarova, L. Mares, I. Mikulikova, J. Pikula, and J. Mares. 2020. Field study indicating susceptibility differences between salmonid species and their lineages to proliferative kidney disease. Journal of Fish Diseases 43:1201-1211.

165 Tan, E. K., C. Wongwarangkana, S. Kinoshita, Y. Suzuki, K. Oshima, M. Hattori, T. Ineno, K. Tamaki, A. Kera, K. Muto, T. Yada, S. Kitamura, S. Asakawa, and S. Watabe. 2012. Global gene expression analysis of gill tissues from normal and thermally selected strains of rainbow trout. Fisheries Science 78:1041-1049.

166 Thompson, N. F., E. C. Anderson, A. J. Clemento, M. A. Campbell, D. E. Pearse, J. W. Hearsey, A. P. Kinziger, and J. C. Garza. 2020. A complex phenotype in salmon controlled by a simple change in migratory timing. Science 370:609.

167 Thorn, M. W., and Y. E. Morbey. 2018. Egg size and the adaptive capacity of early life history traits in Chinook salmon (*Oncorhynchus tshawytscha*). Evolutionary Applications 11:205-219.

168 Thraya, M., M. Hammoud, D. Heath, and P. Karpowicz. 2019. Testing the expression of circadian clock genes in the tissues of Chinook salmon, *Oncorhynchus tshawytscha*. Chronobiology International 36:1088-1102.

169 Tillotson, M. D., and T. P. Quinn. 2018. Selection on the timing of migration and breeding: A neglected aspect of fishing-induced evolution and trait change. Fish and Fisheries 19:170-181.

170 Tillotson, M. D., H. K. Barnett, M. Bhuthimethee, M. E. Koehler, and T. P. Quinn. 2019. Artificial selection on reproductive timing in hatchery salmon drives a phenological shift and potential maladaptation to climate change. Evolutionary Applications 12:1344-1359.

Table S3: Continued

171 Tonteri, A., A. Vasemagi, J. Lumme, and C. R. Primmer. 2010. Beyond MHC: Signals of elevated selection pressure on Atlantic salmon (*Salmo salar*) immune-relevant loci. Molecular Ecology 19:1273-1282.

172 Tuor, K. M. F., D. D. Heath, and J. M. Shrimpton. 2020. Spatial and environmental effects on Coho Salmon life history trait variation. Ecology and Evolution 10:13198-13210.

173 Turrero, P., J. L. Horreo, and E. Garcia-Vazquez. 2012. Same old *Salmo*? Changes in life history and demographic trends of North Iberian salmonids since the Upper Palaeolithic as revealed by archaeological remains and beast analyses. Molecular Ecology 21:2318-2329.

174 Vainikka, A., I. Kallio-Nyberg, M. Heino, and M. L. Koljonen. 2010. Divergent trends in life-history traits between Atlantic salmon *Salmo salar* of wild and hatchery origin in the Baltic Sea. Journal of Fish Biology 76:622-640.

175 Valiente, A. G., E. Beall, and E. Garcia-Vazquez. 2010. Population genetics of south European Atlantic salmon under global change. Global Change Biology 16:36-47.

176 Van Doorslaer, W., J. Vanoverbeke, C. Duvivier, S. Rousseaux, M. Jansen, B. Jansen, H. Feuchtmayr, D. Atkinson, B. Moss, R. Stoks, and L. De Meester. 2009. Local adaptation to higher temperatures reduces immigration success of genotypes from a warmer region in the water flea Daphnia. Global Change Biology 15:3046-3055.

177 Van Doorslaer, W., R. Stoks, C. Duvivier, A. Bednarska, and L. De Meester. 2009. Population dynamics determine genetic adaptation to temperature in Daphnia. Evolution 63:1867-1878.

178 Van Doorslaer, W., R. Stoks, I. Swillen, H. Feuchtmayr, D. Atkinson, B. Moss, and L. De Meester. 2010. Experimental thermal microevolution in community-embedded Daphnia populations. Climate Research 43:81-89.

179 Veilleux, H. D., J. M. Donelson, and P. L. Munday. 2018. Reproductive gene expression in a coral reef fish exposed to increasing temperature across generations. Conservation Physiology 6:12.

180 Venney, C. J., O. P. Love, E. J. Drown, and D. D. Heath. 2020. DNA methylation profiles suggest intergenerational transfer of maternal effects. Molecular Biology and Evolution 37:540-548.

181 Verhille, C. E., K. K. English, D. E. Cocherell, A. P. Farrell, and N. A. Fangue. 2016. High thermal tolerance of a rainbow trout population near its southern range limit suggests local thermal adjustment. Conserv Physiol 4:cow057.

182 Vincent, B., M. Dionne, M. P. Kent, S. Lien, and L. Bernatchez. 2013. Landscape genomics in Atlantic Salmon (*Salmo salar*): Searching for gene-environment interactions driving local adaptation. Evolution 67:3469-3487.

183 Waples, R. S., A. Elz, B. D. Arnsberg, J. R. Faulkner, J. J. Hard, E. Timmins-Schiffman, and L. K. Park. 2017. Human-mediated evolution in a threatened species? Juvenile life-history changes in Snake River salmon. Evol Appl 10:667-681.

184 Waples, R. S., and A. Audzijonyte. 2016. Fishery-induced evolution provides insights into adaptive responses of marine species to climate change. Frontiers in Ecology and the Environment 14:217-224.

185 Waters, C. D., J. J. Hard, D. E. Fast, C. M. Knudsen, W. J. Bosch, and K. A. Naish. 2020. Genomic and phenotypic effects of inbreeding across two different hatchery management regimes in Chinook salmon. Molecular Ecology 29:658-672.

186 Watson, K. B., S. J. Lehnert, P. Bentzen, T. Kess, A. Einfeldt, S. Duffy, B. Perriman, S. Lien, M. Kent, and I. R. Bradbury. 2021. Environmentally associated chromosomal structural variation influences fine-scale population structure of Atlantic Salmon (*Salmo salar*). Molecular Ecology.

187 Weise, E. M., N. M. Sard, A. Nehfer, and K. T. Scribner. 2020. Adaptive genetic management: assessing the benefits of translocations. Conservation Genetics 21:277-287.

188 Weitkamp, L. A., D. J. Teel, M. Liermann, S. A. Hinton, D. M. Van Doornik, and P. J. Bentley. 2015. Stock-Specific Size and Timing at Ocean Entry of Columbia River Juvenile Chinook Salmon and Steelhead: Implications for Early Ocean Growth. Marine and Coastal Fisheries 7:370-392.

189 Wellband, K. W., and D. D. Heath. 2013. Environmental associations with gene transcription in Babine Lake rainbow trout: Evidence for local adaptation. Ecology and Evolution 3:1194-1208.

Table S3: Continued

190 Wellband, K. W., and D. D. Heath. 2013. The relative contribution of drift and selection to transcriptional divergence among Babine Lake tributary populations of juvenile rainbow trout. Journal of Evolutionary Biology 26:2497-2508.

191 Whitney, C. K., S. G. Hinch, and D. A. Patterson. 2013. Provenance matters: Thermal reaction norms for embryo survival among sockeye salmon *Oncorhynchus nerka* populations. Journal of Fish Biology 82:1159-1176.

192 Whitney, C. K., S. G. Hinch, and D. A. Patterson. 2014. Population origin and water temperature affect development timing in embryonic sockeye salmon. Transactions of the American Fisheries Society 143:1316-1329.

193 Williams, J. G., R. W. Zabel, R. S. Waples, J. A. Hutchings, and W. P. Connor. 2008. Potential for anthropogenic disturbances to influence evolutionary change in the life history of a threatened salmonid. Evolutionary Applications 1:271-285.

194 Winans, G. A., J. Baker, M. McHenry, L. Ward, and J. Myers. 2017. Genetic Characterization of *Oncorhynchus mykiss* Prior to Dam Removal with Implications for Recolonization of the Elwha River Watershed, Washington. Transactions of the American Fisheries Society 146:160-172.

195 Winsor, S., S. Blumenshine, P. Adelizi, and M. Bigelow. 2021. Precocious Maturation in Spring-Run Chinook Salmon Is Affected by Incubation Temperature, Feeding Regime, and Parentage. Transactions of the American Fisheries Society 150:578-592.

196 Wong, J. M., K. M. Johnson, M. W. Kelly, and G. Hofmann. 2018. Transcriptomics reveal transgenerational effects in purple sea urchin embryos: Adult acclimation to upwelling conditions alters the response of their progeny to differential pCO2 levels. Molecular Ecology 27:1120-1137.

197 Yamada, H., and S. Wada. 2021. Morphological evolution reduces downstream displacement in juvenile landlocked salmon. Evolution 75:1850-1861.

198 Yamamoto, T., S. Kitanishi, M. Sato, M. Yagisawa, and D. Kishi. 2021. Links between paternal life history and offspring metabolic rate and body size during early life in masu salmon *Oncorhynchus masou*. Ecology of Freshwater Fish 30:296-305.

199 Zillig, K. W., R. A. Lusardi, P. B. Moyle, and N. A. Fangue. 2021. One size does not fit all: variation in thermal eco-physiology among Pacific salmonids. Reviews in Fish Biology and Fisheries 31:95-114.