Modelling the effects of climate change on the migratory success of Fraser River sockeye salmon

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CLIMATE MODEL

- GISS global coupled atmosphere-ocean-ice model
  - Simulations from followed IPCC's SRES A1B GHG and sulfate scenario; 3ºx4º lat/long resolution; Russell et al. 1995; Ferrari et al. 2007
- Generated annual thermograph in daily time steps for 2081-2100 period

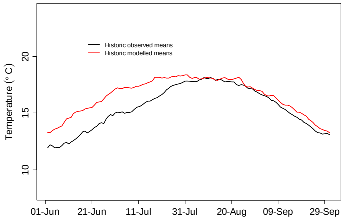

Figure 1. Comparison of modelled and observed lower Fraser River summer water temperatures from 1981 – 2000.

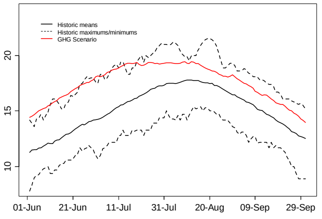

Figure 2. Observed historic mean, max and min daily lower Fraser River water temperatures (1950-2008) and mean future modelled temperatures from the GISS model (2081-2100).

INTRODUCTION

- Climate change models forecast increased Fraser River summer water temperatures
- High water temperatures are associated with salmon migration failures
- Differences in thermal exposure and tolerance suggest that climate change impacts will vary among sockeye salmon populations

TEMPERATURE THRESHOLDS

- Thermal shock occurs at 21ºC (Servizi and Jensen 1977)
- No sockeye salmon populations have mean freshwater spawning migrations temperatures > 19ºC (Hodgson and Quinn 2002)
- The GISS model forecasts an increase in the frequency of extreme daily water temperatures

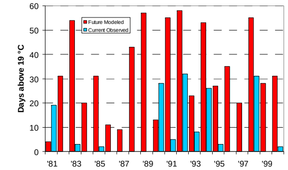

Figure 3. The number of days > 19ºC in the lower Fraser River during historic observed (1981-2000) and GISS modelled (2081-2100) periods.

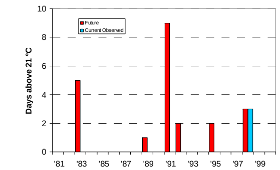

Figure 4. The number of days > 21ºC in the lower Fraser River during historic (1981-2000) and GISS modelled (2081-2100) periods.

LOGISTIC SURVIVAL MODEL

- Survival rates modelled using capture-recapture theory
- Lower-river temperatures experienced by individual fish used to predict survival
- Predict large future decline in survival rates of Shuswap (Late-run) fish
- Future survival of Chilko (Summer-run) fish was not strongly affected by temperature

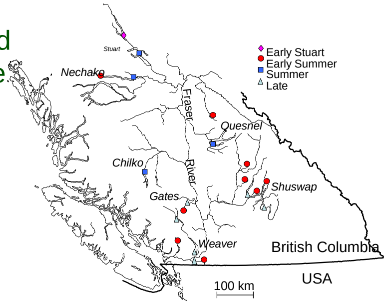

Figure 5. Map of the Fraser River Basin, British Columbia, Canada and locations of key sockeye salmon spawning populations.

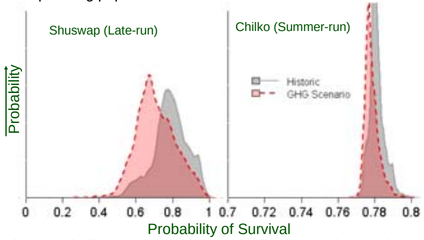

Figure 6. Probability of survival of Shuswap and Chilko sockeye salmon populations under historic (1981-2000) and GISS (2081-2100) Fraser River water temperature scenarios.

MANAGEMENT ADJUSTMENT MODEL

- Management adjustments (MAs) are the difference between lower and upper river escapement estimates; used as a relative index of survival
- Forecasted MAs for 4 different sockeye groups (Early Stuart, Early Summer, Summer, Late) using historic and future river environment scenarios show large difference among groups

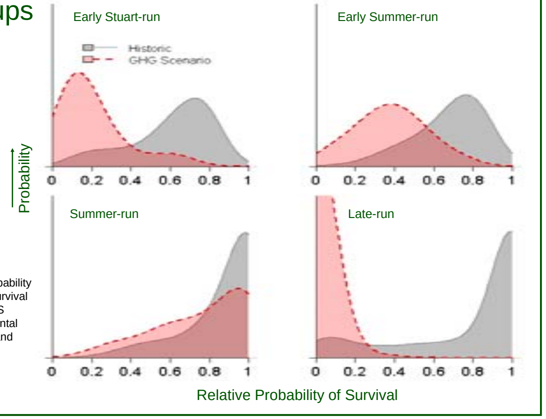

Figure 7. Probability distributions for the probability of relative freshwater survival during historic and GISS Fraser River environmental scenarios (1981-2000 and 2081-2100).

AEROBIC SCOPE MODEL

- Salmon optimise rates of O_2 consumption (i.e. aerobic scope) at temperatures near historic ambient values (Lee et al. 2003; Farrell et al. 2008)
- High rates of mortality are observed at temperatures associated with functional T_{Crit}, approx. 50% max. aerobic scope (Farrell et al. 2008)
- Climate change scenarios suggest only a small proportion of populations are likely to experience $T > T_{Crit}$ in the lower Fraser River

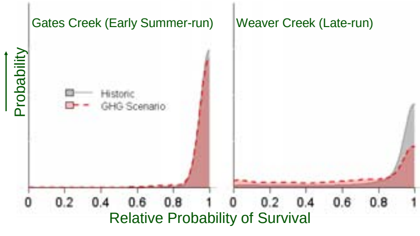

Figure 8. Probability distributions for the proportion of Gates Creek (i.e. Early Summer-run) and Weaver Creek (i.e. Late-run) fish experiencing lower Fraser River temperatures < T_{Crit} (i.e. surviving) in historic (1981-2000) and GISS (2081-2100) scenarios. Gates T_{crit} = 21.6ºC; Weaver T_{Crit} = 18.7ºC.

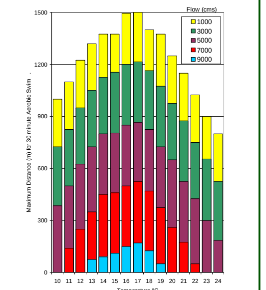

Figure 9. Maximum distance swam in 30 minutes by Gates Creek sockeye under maximum aerobic scope, for different temperature and discharge conditions.

References Servizi, J. A. and J. O. T. Jensen. 1977. Resistance of adult sockeye salmon to acute thermal shock. IPSFC Progress Report 34. Russell, G.L., J.R. Miller and D. Rind. 1995. A coupled atmosphere-ocean model for transient climate change studies. Atmosphere-Ocean 33(4): 683-730. Hodgson, S. and T. P. Quinn. 2002. The timing of adult sockeye salmon migration into fresh water: adaptations by populations to prevailing thermal regimes. Canadian Journal of Zoology 80: 542: 555. Lee. C. G, A. P. Farrell, A. Lotto, M. J. MacNutt, S.G. Hinch, and M. C. Healey. 2003. The effect of temperature on swimming performance and oxygen consumption in adult sockeye (Oncorhynchus nerka) and coho (O. kisutch) salmon stocks. The Journal of Experimental Biology 206: 3239-3251. Ferrari, M.R., J.R. Miller, and G. L. Russell. 2007. Modeling changes in summer temperature of the Fraser River during the next century. Journal of Hydrology 342: 736-746. Farrell, A. P., S. G. Hinch, S. J. Cooke, D.A. Patterson, G. T. Crossin, M. Lapointe, and M. T. Mathes. 2008. Pacific salmon in hot water: applying aerobic scope models and biotelemetry to predict success of spawning migrations. Physiological and Biochemical Zoology 81(6); 697-708.

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