State of Salmon Program:

Fraser River Sockeye: Chasing Predictions in a Rapidly Changing Climate

Sue C.H. Grant & Bronwyn L. MacDonald,
Catherine G.J. Michielsens, M.Lapointe, A-M.Huang, M.Trudel,
J.King, D.Patterson, K.Robinson, D.Selbie, L.Pon, C.Neville,
K.Benner, J. Boldt, I.Perry, J.Tadey, S.Latham, S.Decker, B.Leaf

PSC Environmental Indicators Workshop May 11 2021

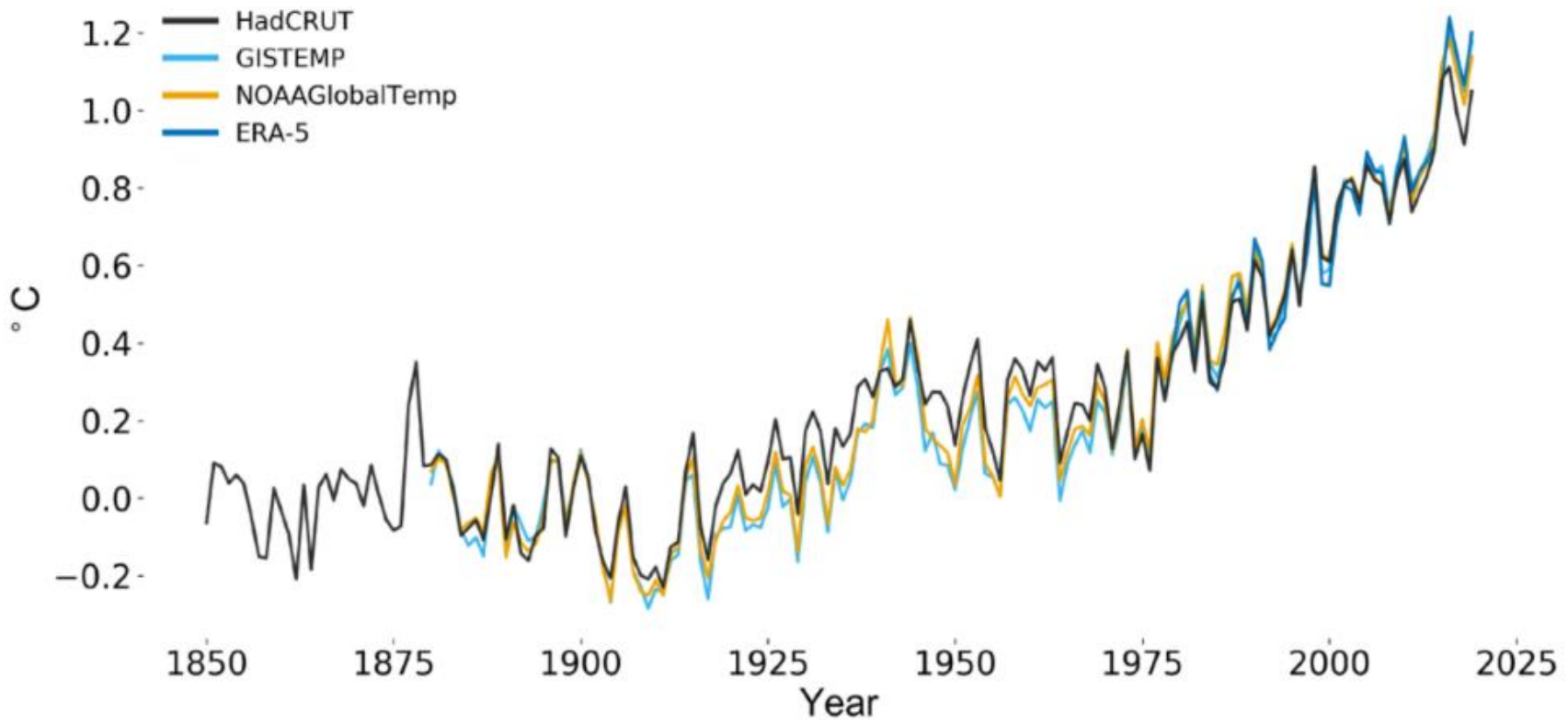
Videographer: DFO Matt Townsend

Human Induced Global Climate Change

Emerging as a key driver of current & future salmon trends

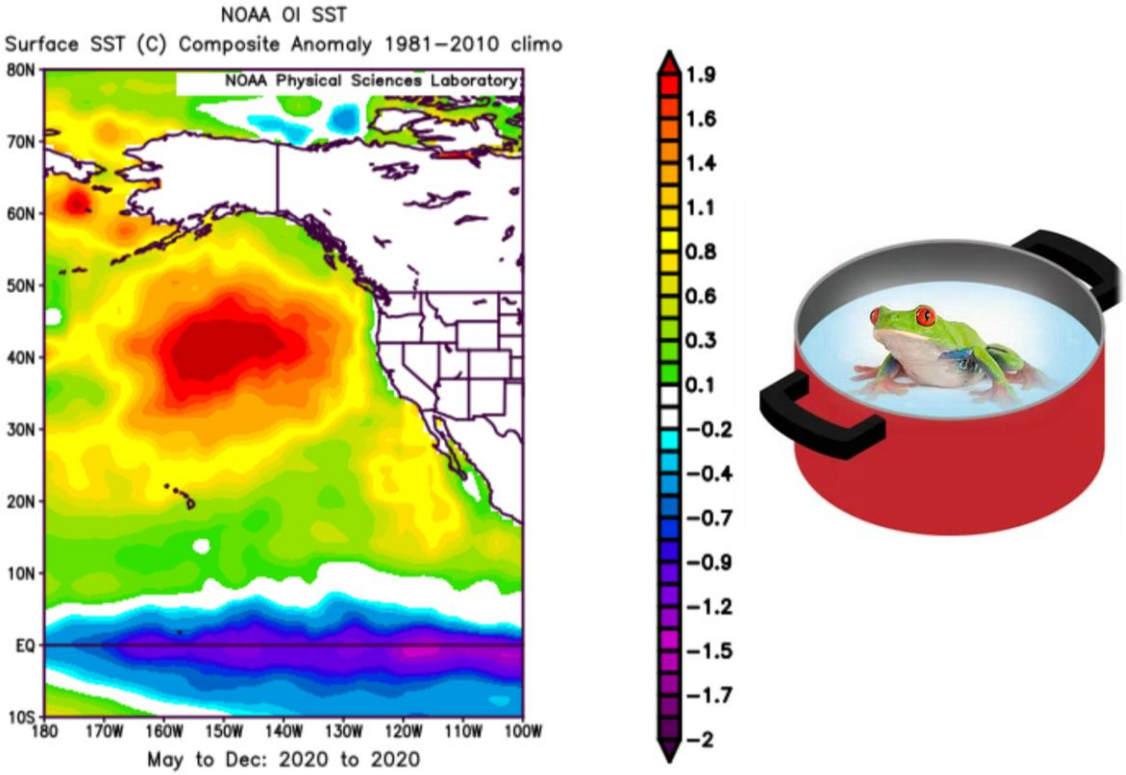
Grant, S. C. H., MacDonald, B. L., & Winston, M. L. (2019). State of the Canadian Pacific Salmon: Responses to Changing Climate and Habitats. Can. Tech. Rep. Fish. Aquat. Sci., 3332, ix + 50 pp. http://www.dfo-mpo.gc.ca/species-especes/publications/salmon-saumon/state-etat-2019/abstract-resume/index-eng.html

A Changing Global Climate



Source: Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia, UK (HadCRU) presented in World Meteorological Organization, 2020. WMO Statement on the State of Global Climate Change in 2019 (WMO-No. 1248), Figure 1, Page 6).

Heatwaves are exacerbating climate change impacts on fisheries

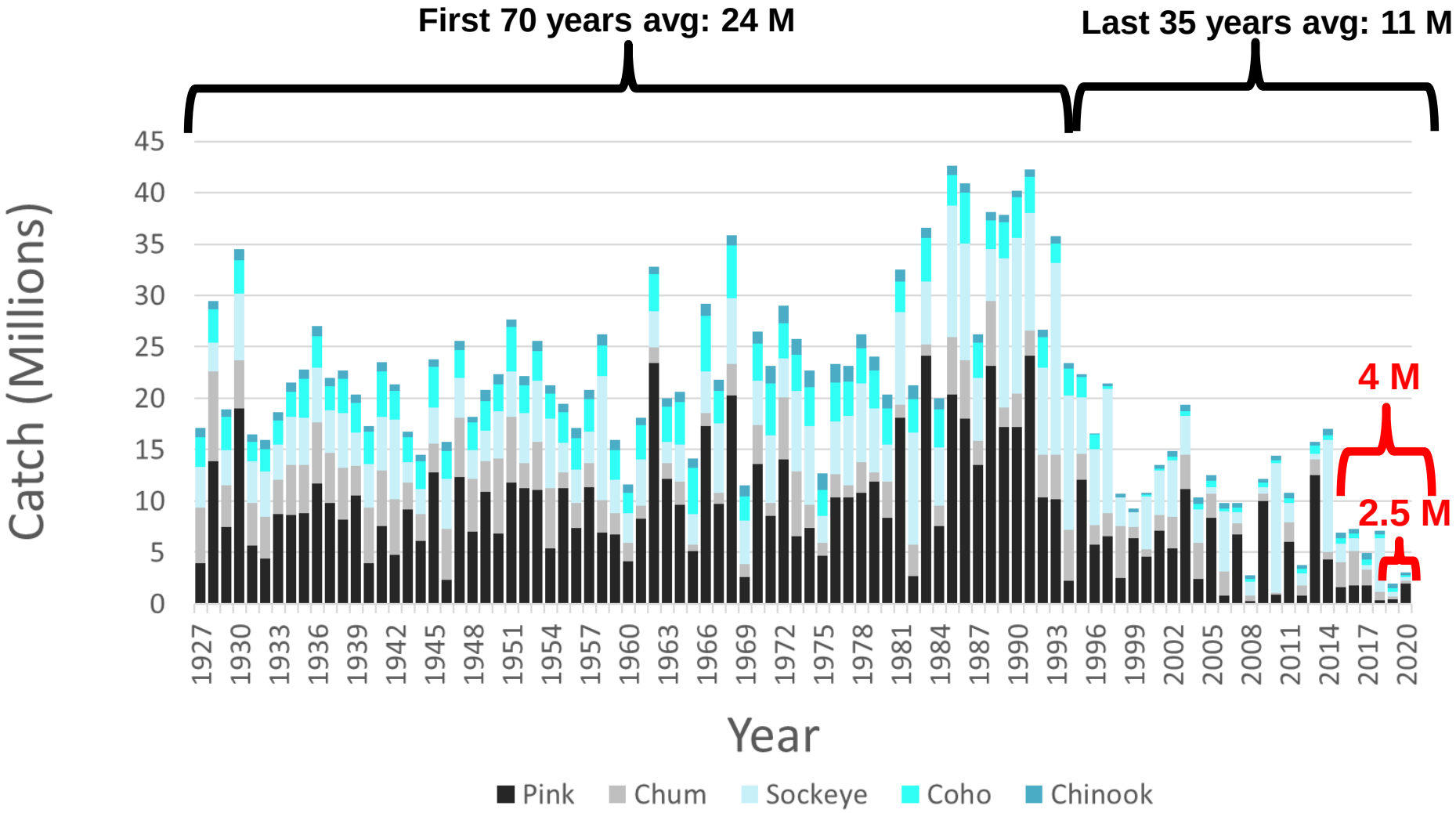


Cheung, W. W. L., & Frölicher, T. L. (2020). **Marine heatwaves exacerbate climate change impacts for fisheries in the northeast Pacific**. Scientific Reports, 10(1), 1–10. https://doi.org/10.1038/s41598-020-63650-z

Laufkötter, C., Zscheischler, J., & Frölicher, T. L. (2020). **High-impact marine heatwaves attributable to human-induced global warming.** Science (New York, N.Y.), 369(6511), 1621–1625. https://doi.org/10.1126/science.aba0690

Frölicher, T. L., Fischer, E. M., & Gruber, N. (2018). **Marine heatwaves under global warming**. Nature, 560(7718), 360–364. https://doi.org/10.1038/s41586-018-0383-9

Canadian Pacific Salmon Catch



Data source NPAFC: https://npafc.org/statistics/

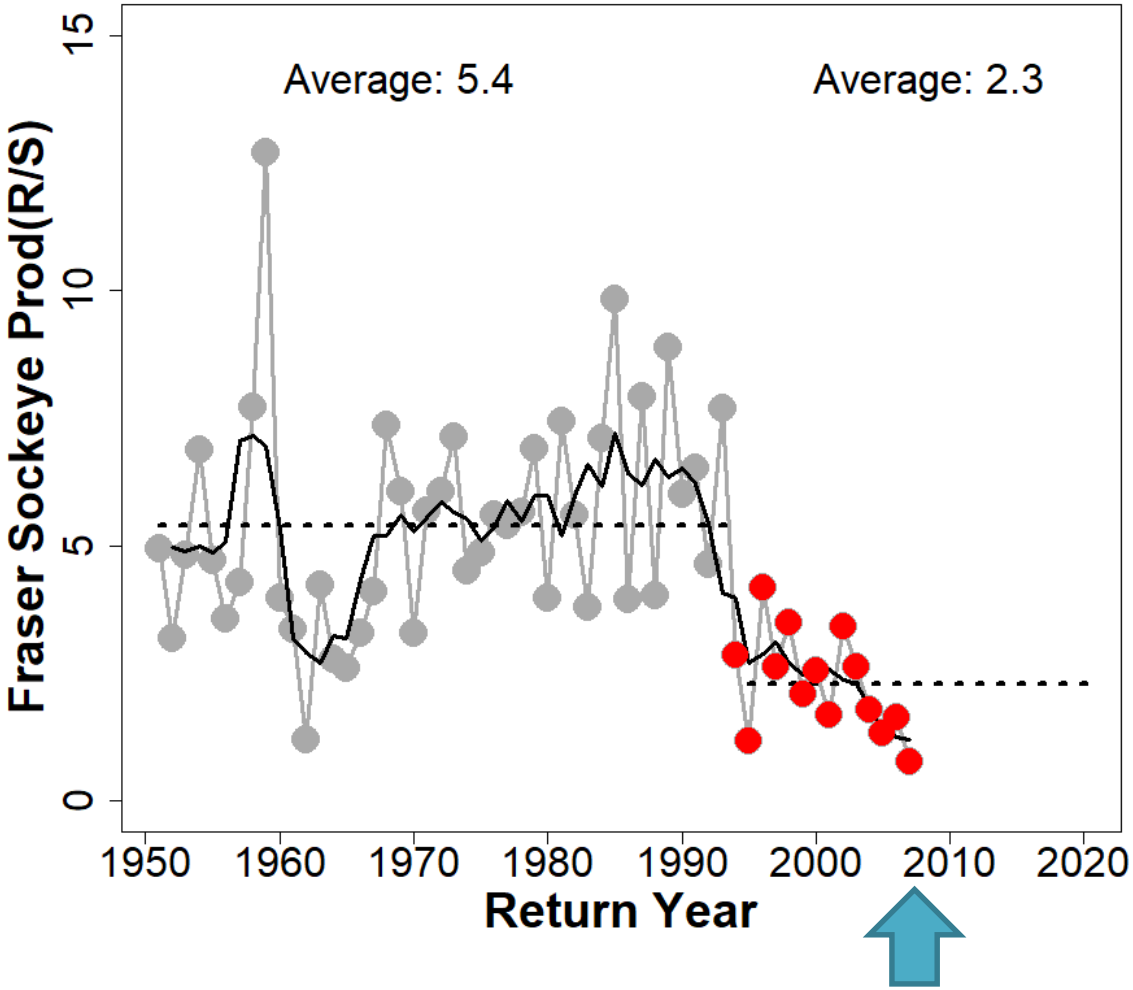
Compiled over the years by many DFO staff in recent years by A. Velez-Espino

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021

Forecasting in Times of Large Environmental Change

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021

Fraser Sockeye Forecasts in 2007

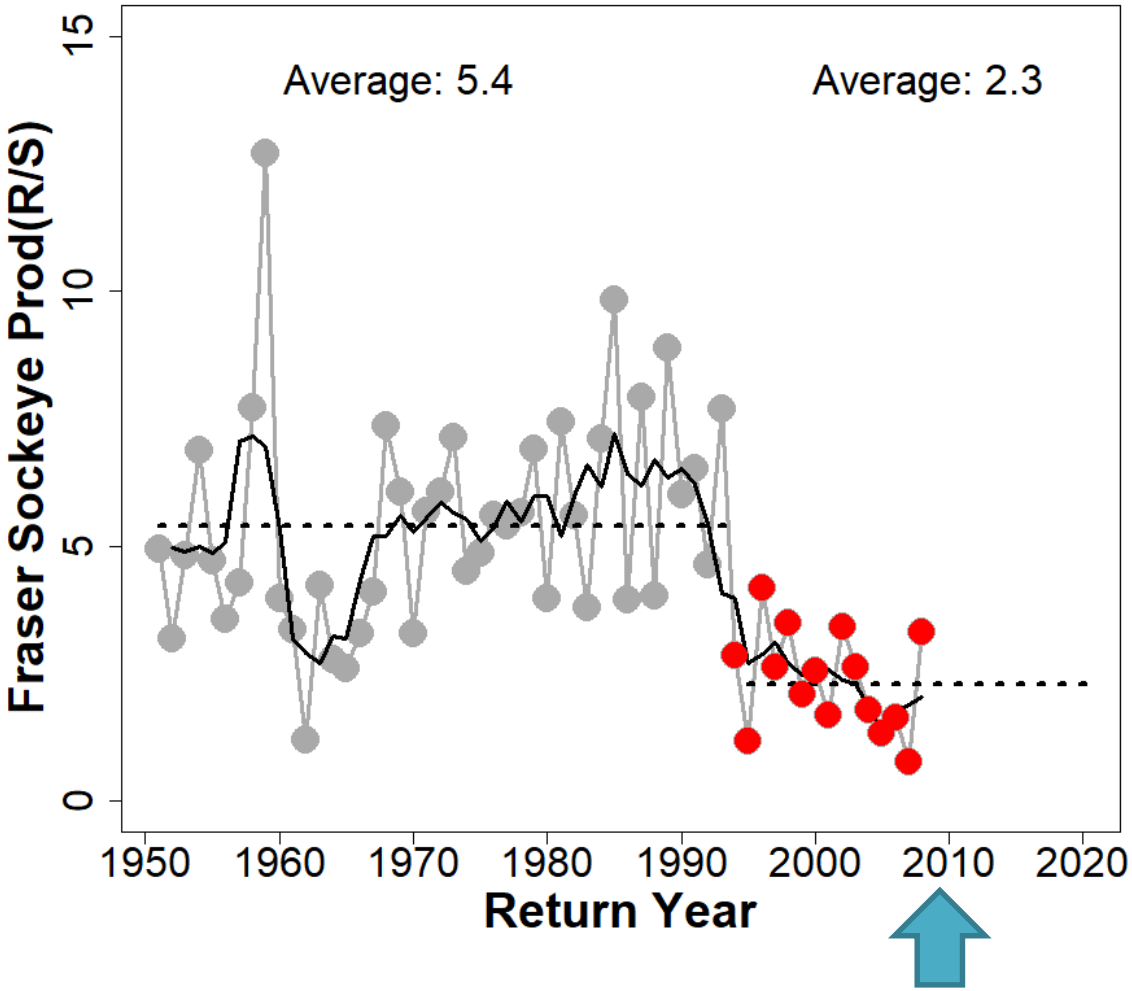


2007 Cass & Grant

- **'turning the crank'** exercise
- Models **include environmental variables: ocean & Fraser discharge during smolt outmigration**
- **We were not tracking or accounting for this productivity change in modelling**
- **High uncertainty**

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021

Fraser Sockeye Forecasts in 2008

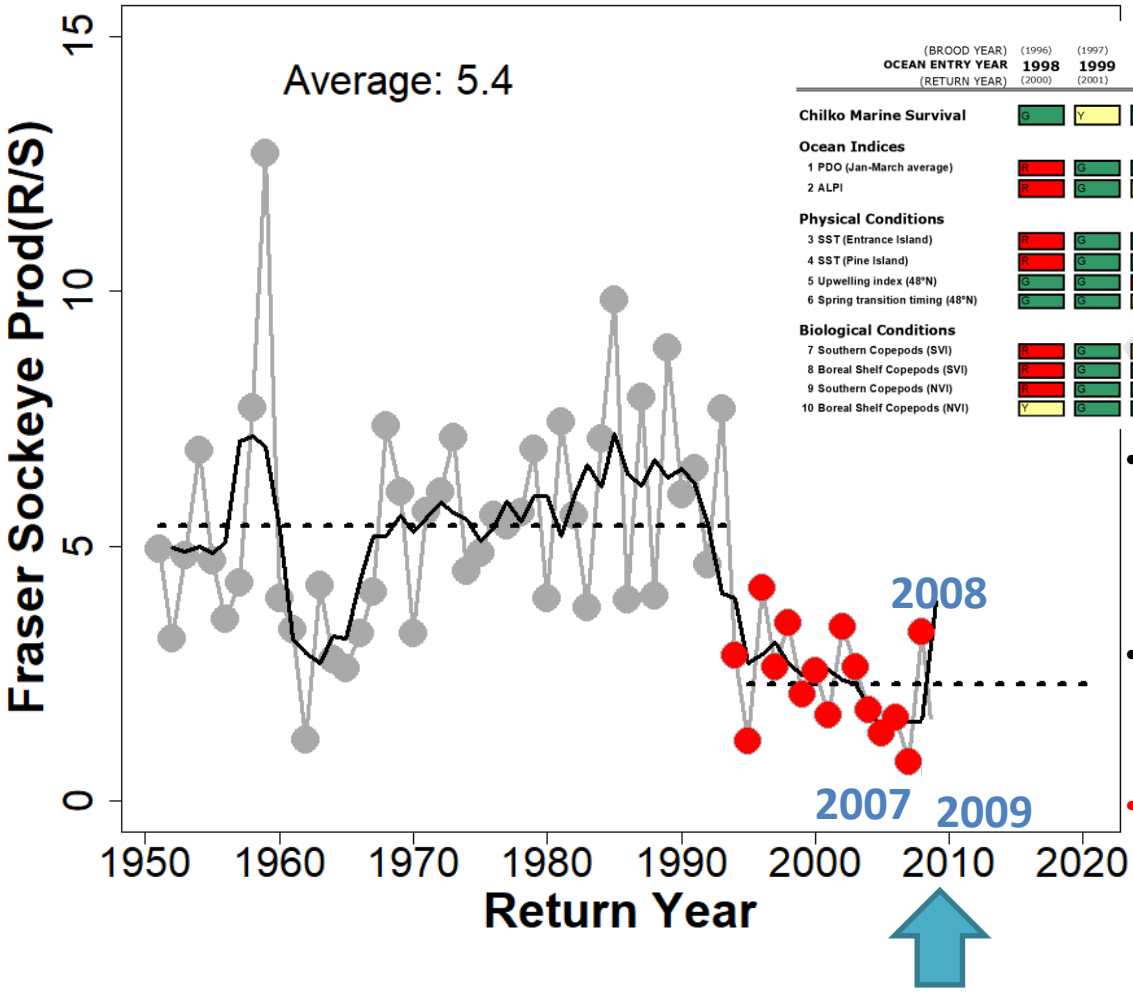


- **Started to use expert judgement**
- **More emphasis on marine environmental conditions** and suggested identifying previous years with similar environmental conditions
- High uncertainty

2008 Sue forecasts with input from Mike Lapointe and others

Fraser Sockeye Forecasts in 2009

2007 2008

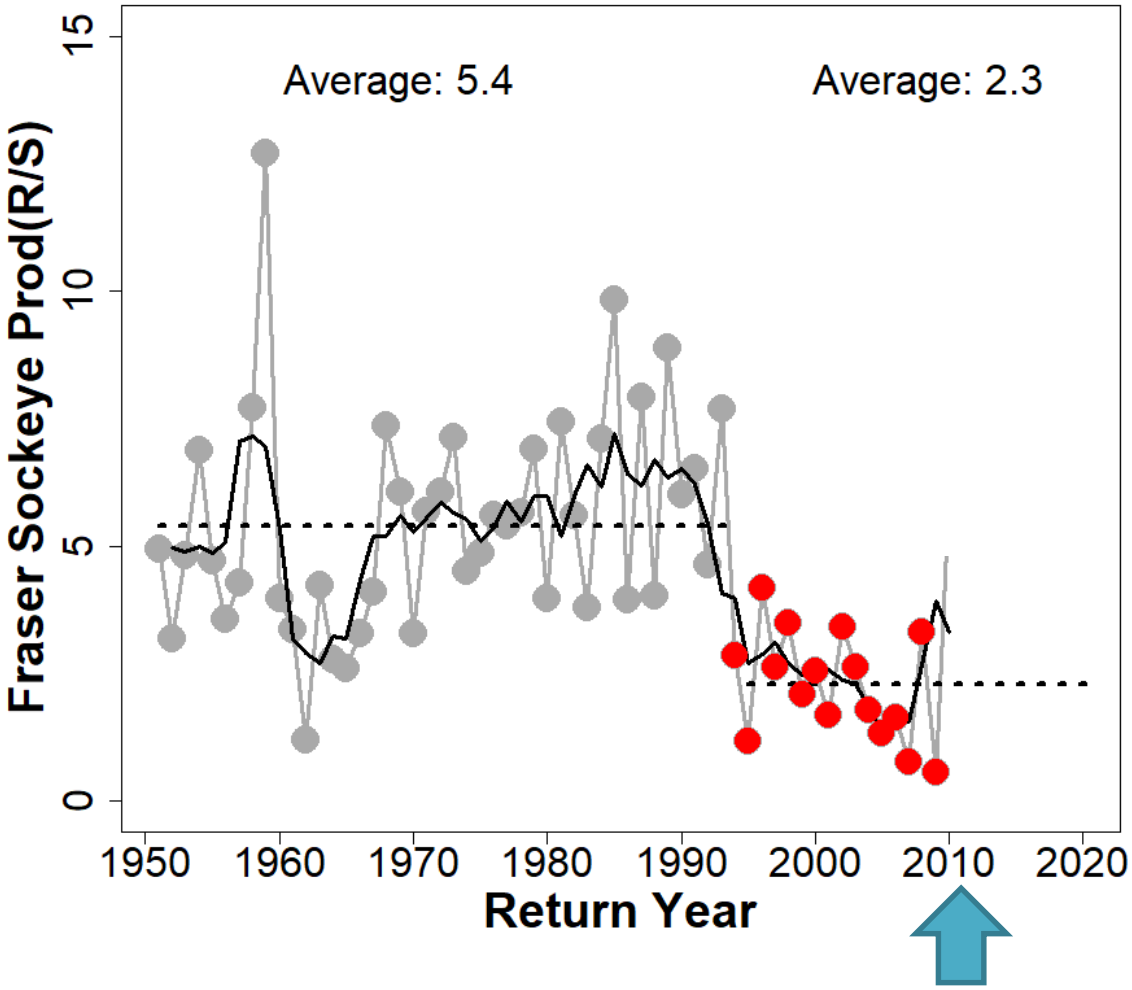


- Used the Bill Peterson (NOAA) stop light approach (marine focused) indicated good conditions for 2009 returns
- In 2009, there was no warning from marine/freshwater scientists in advance of the return year.
- **Unexpected near record low returns of 1.6 M**

2009 Sue forecasts lots of input from Mike Lapointe from the PSC and then goes through a Cohen Inquiry

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSG Workshop 2021

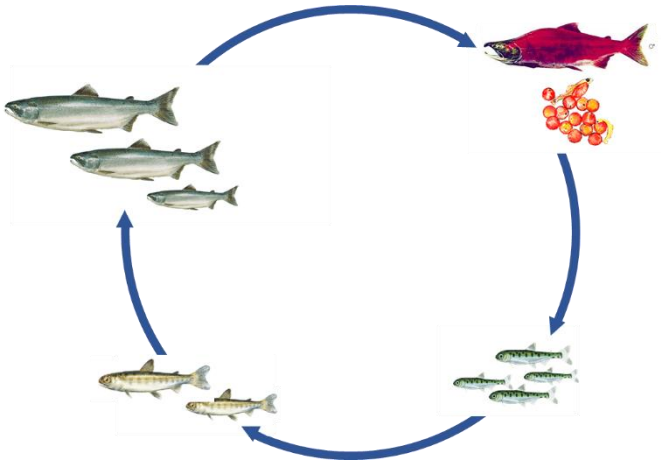
Fraser Sockeye Forecasts in 2010



- **Added new models & approach to explicitly account for this recent low productivity**
- In 2010, again no advance warning by marine or freshwater experts.
- **Unexpected Record High return year of 28 million Sockeye**

2010 Sue & Erin Porszt gets lots of support from Catherine & Mike from the PSC

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021



Fraser Sockeye Science Integration: Qualitative Indicators

2020 Life-History

Most Fraser Sockeye Mature as Four Year Olds

Marine
2 Winters

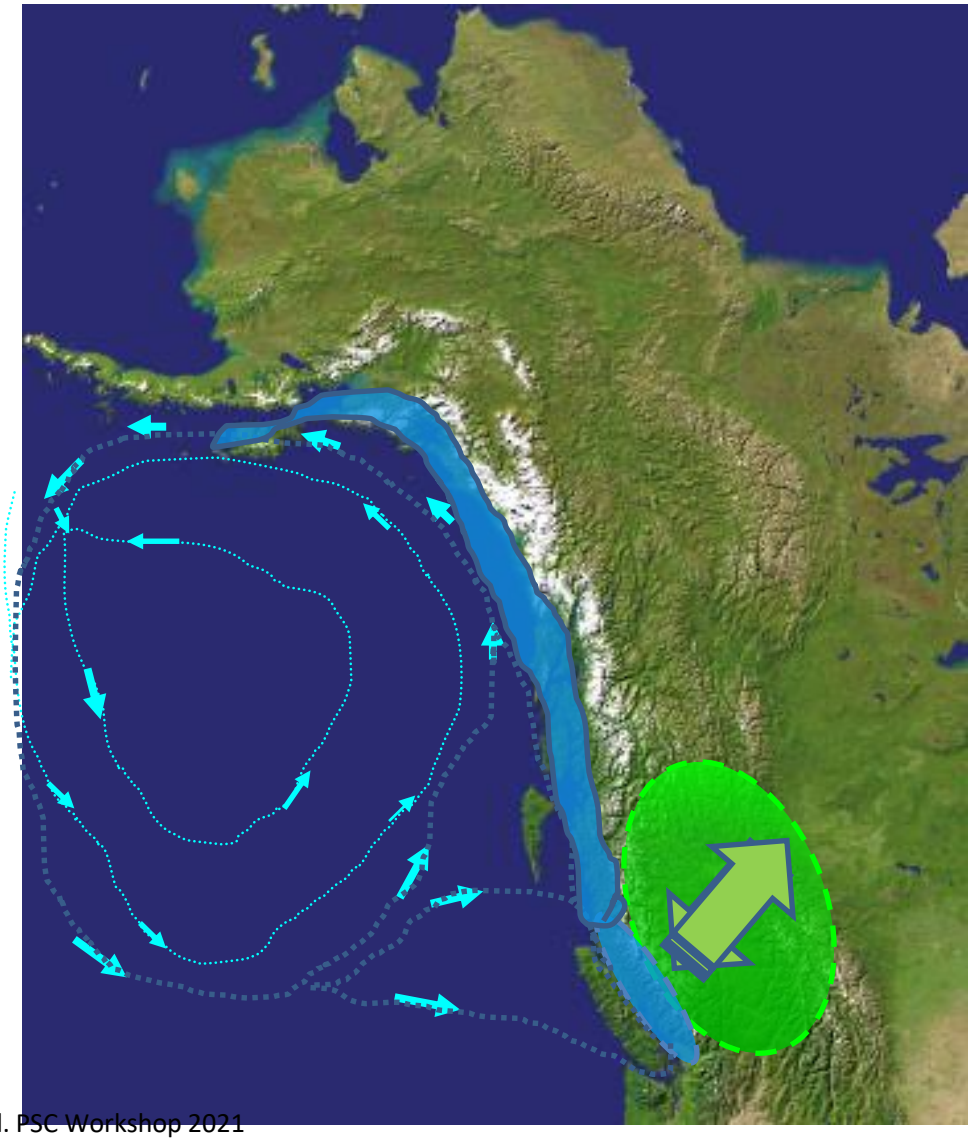
May-June 2018

June-October 2018

First Winter 2019

Second Winter 2020

July-Oct 2020



Freshwater
2 Winters

Brood Year
July-Oct 2016

April-May 2017

April-May 2018

Return: 4 yrs

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021





Overall	Effect	Confidence
Fraser Sockeye Survival	Negative	Likely

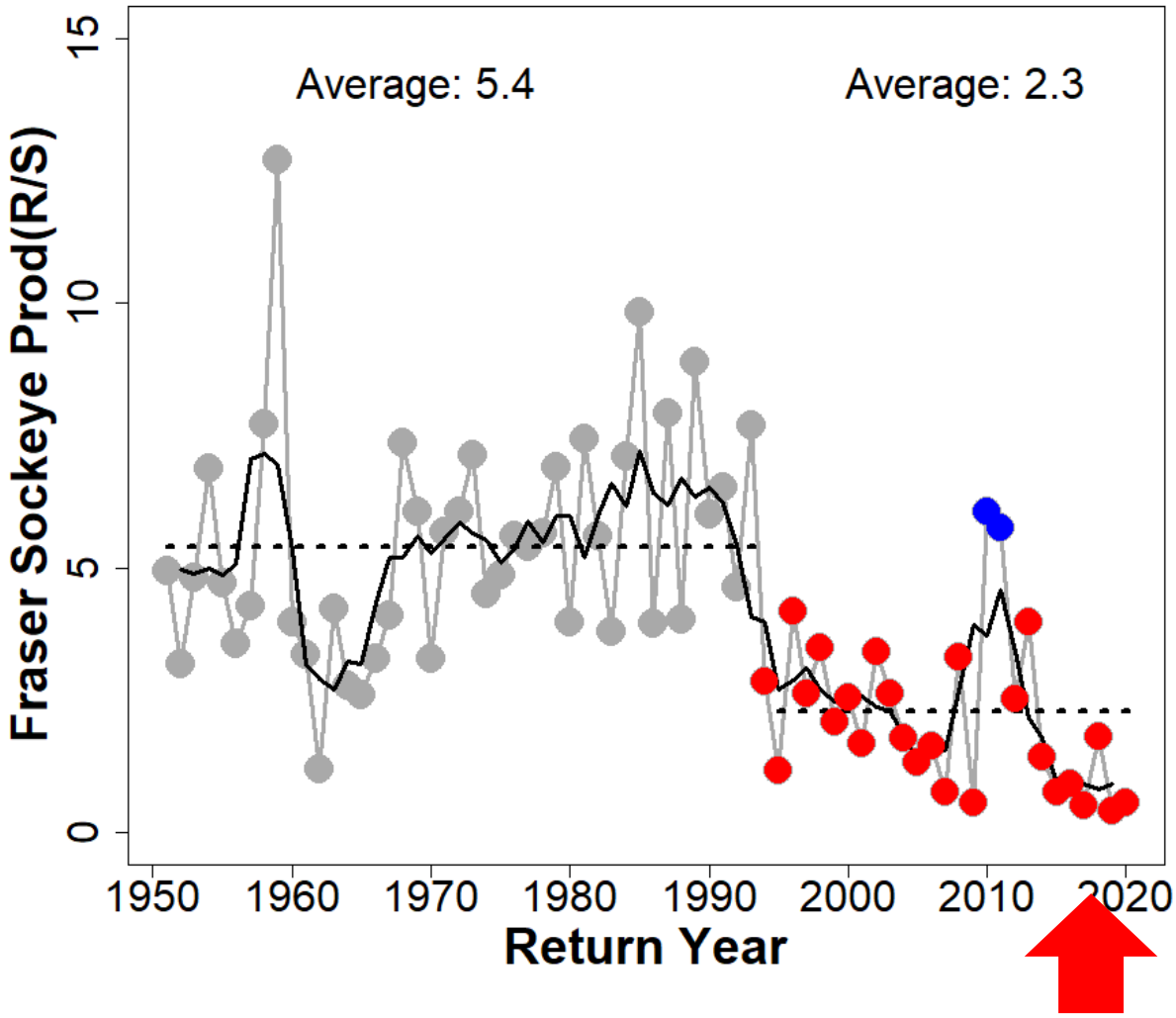
Brood Year Spawners and Egg Stage (Summer/Fall 2016-Spring 2017)	Effect	Confidence	Potential impact on survival
• Lower Fraser River temperatures were predominately above average during adult migration: Summer and Late Sockeye populations experienced conditions above 19°C during mainstem migration	Negative	Very Likely	Low
• Spawning ground water temperatures and stream flows for most populations were within normal ranges during spawning, with some exceptions	Neutral	Likely	Low
• Fraser River discharge at Hell's Gate, a migration barrier during high flows, was below average during adult migration of all run-timing groups in 2016	Neutral	Very Likely	Low
• Sockeye were reported to be in good condition on spawning grounds in most areas, with some stream-specific exceptions	Neutral	Likely	Low
• November air temperatures were very warm, with anomalies at least 4-5°C above normal in 2016; this has the potential to influence egg incubation conditions	Negative	Possible	Low
BROOD YEAR SPAWNER STAGE - summary	**NEUTRAL**	**LIKELY**	**LOW**

Juvenile Freshwater Rearing (Spring 2017-Spring 2018)	Effect	Confidence	Potential impact on survival
• Normal timing of Fraser River spring freshet, with above average early June flow	Neutral	Possible	Low
• Extensive fire season and hot summer air temperatures with unknown impacts	Unknown	Unknown	Unknown
• Warm fall likely lengthened the growing season in some areas	Positive	Possible	Low
• Overall winter 2017-2018 air temperatures below normal, transitioning to a very warm May	Neutral	Possible	Low
JUVENILE FRESHWATER REARING STAGE - summary	**NEUTRAL**	**LIKELY**	**LOW**

Smolt Downstream Migration (Spring 2018)	Effect	Confidence	Potential impact on survival
• Early-timed peak freshet with day-of-year record flows in May; mainstem temperatures were average	Neutral	Possible	Low
• Populations experienced different levels of discharge based on their migration timing	Variable	Possible	Low
• Migration timing past Mission was slightly earlier than average, however, there may be some bias in this timing estimate	Neutral	Possible	Low
• Smolts at Mission varied in average length by stock	Neutral	Possible	Low
SMOLT DOWNSTREAM MIGRATION - summary	**NEUTRAL**	**POSSIBLE**	**LOW**

• 2018 juvenile Sockeye CPUE in Queen Charlotte Strait/Southern Queen Charlotte Sound trawl surveys was above average for non-dominant cycle years	Positive	Possible	Low
• 2018 juvenile Sockeye condition in Queen Charlotte Strait/Southern Queen Charlotte Sound trawl surveys was average	Neutral	Possible	Low
• In late 2018 there was a transition from a weak La Nina to a weak El Nino	Neutral	Likely	Low
MARINE RESIDENCE - summary	**NEGATIVE**	**POSSIBLE**	**LOW**

- DFO. (2014). Supplement to the pre-season return forecasts for Fraser River sockeye salmon in 2014. Can. Sci. Adv. Sec. Sci. Resp., 2014/041, 57 pp. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2014/2014_041-eng.html
- DFO. (2015). Supplement to the pre-season return forecasts for Fraser River sockeye salmon in 2015. Can. Sci. Adv. Sec. Sci. Resp., 2015/028, 49 pp. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2015/2015_028-eng.html
- DFO. (2016). Supplement to the pre-season run size forecasts for Fraser River Sockeye *(Oncorhynchus nerka*) in 2016. Can. Sci. Adv. Sec. Proc., 2016/047, 61.
- MacDonald, B. L., Grant, S. C. H., Patterson, D. A., Robinson, K. A., Boldt, J. L., Benner, K., Neville, C. M., Pon, L., Tadey, J. A., Selbie, D. T., & Winston, M. L. (2018). State of the Salmon: informing the survival of Fraser sockeye returning in 2018 through life cycle observations. Can. Tech. Rep. Fish. Aquat. Sci., 3271. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2018/2018_034-eng.html
- MacDonald, B. L., Grant, S. C. H., Patterson, D. A., Robinson, K. A., Boldt, J. L., Benner, K., King, J., Pon, L., Selbie, D. ., Neville, C. M., & Tadey., J. A. (2019). State of Salmon: informing the survival of Fraser sockeye returning in 2019 through life-cycle observations. Can. Tech. Rep. Fish. Aquat. Sci., 3336, vi + 60 pp. http://waves-vagues.dfo-mpo.gc.ca/Library/40819103.pdf
- Macdonald, B. L., Grant, S. C. H., Wilson, N., Patterson, D. A., Robinson, K. A., Boldt, J. L., King, J., Anderson, E., Decker, S., Leaf, B., Pon, L., Xu, Y., Davis, B., & Selbie, D. (2020). State of the Salmon : Informing the survival of Fraser Sockeye returning in 2020 through life cycle observations. Can. Tech. Rep. Fish. Aquat. Sci. 3398 pp. v + 76. https://waves-vagues.dfo-mpo.gc.ca/Library/4088546x.pdf

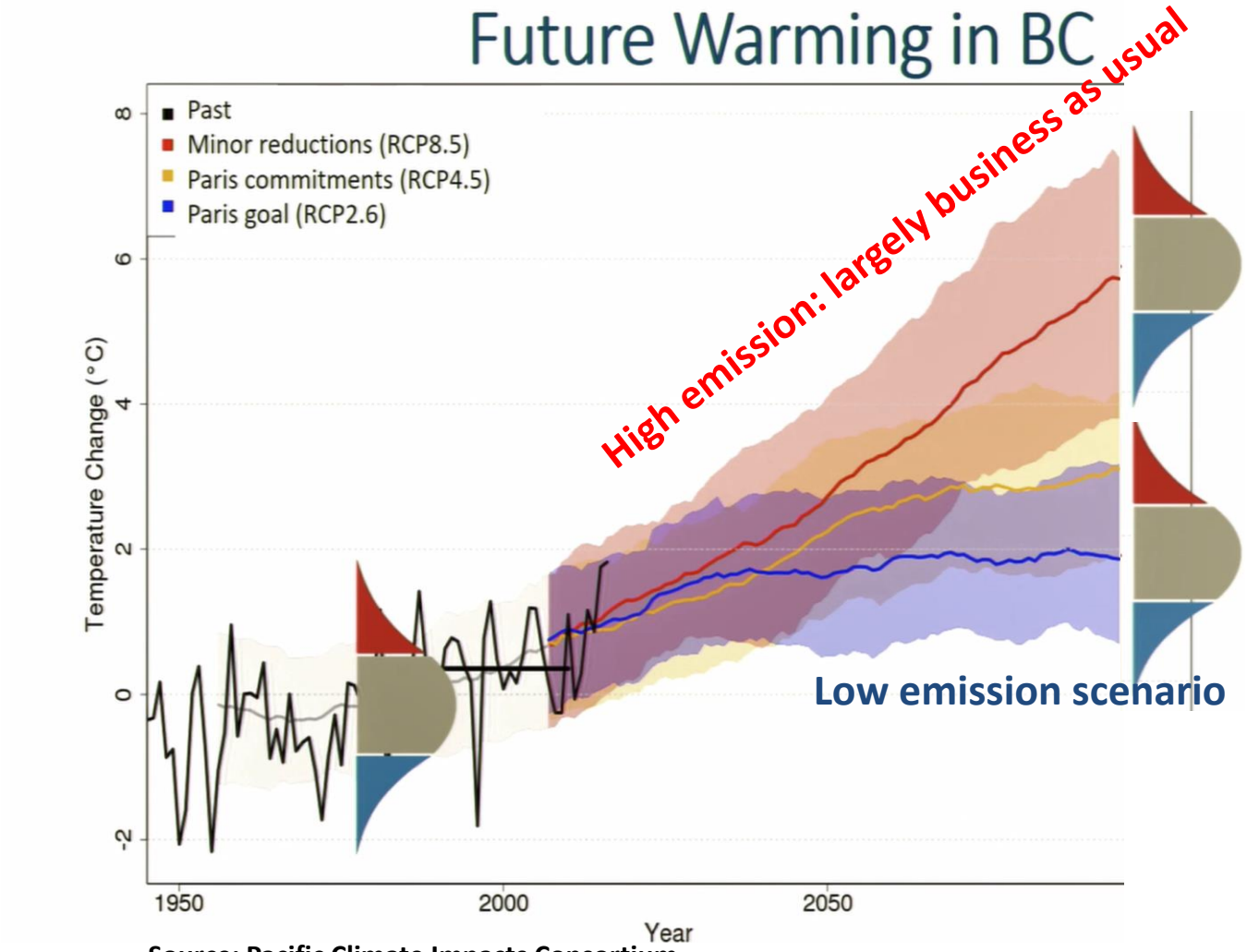


- **On-going learning process; breaking down silos**
- Gaps & therefore more surprises

2017-2020 indicated below average survivals

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021

The future of salmon species in the wild will depend on how successfully we curb greenhouse gas emissions.



Source: Pacific Climate Impacts Consortium

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021

Thoughts on Next Steps

We are seeing environmental conditions not previously observed and more extremes, resulting in increased uncertainty

This requires: more precautionary management approaches

Grant, SCH, Nener, J., MacDonald, B.L., Boldt, J.L., King, J. Patterson, D.A., Robinson, K.A., Wheeler, S. (2021) **Chapter 16. Canadian Fraser River sockeye salmon: a case study 259** in Bahri, T., Vasconcellos, M., Welch, D.J., Johnson, J., Perry, R.I., Ma, X. & Sharma, R., (eds.) *Adaptive management of fisheries in response to climate change.* FAO Fisheries and Aquaculture Technical Paper No. 667. Rome, FAO. http://www.fao.org/documents/card/en/c/cb3095en

Thoughts on Next Steps

We are seeing environmental conditions not previously observed and more extremes, resulting in increased uncertainty

This requires: The use of environmental & biological indicators collected across all life history stages

Freshwater, marine, interactions b/w these ecosystems; disease, fish condition…

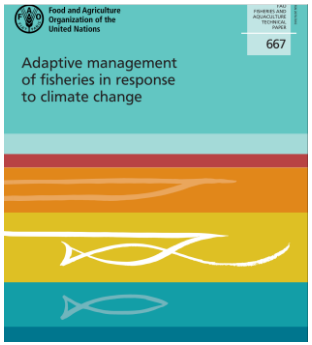
Grant, SCH, Nener, J., MacDonald, B.L., Boldt, J.L., King, J. Patterson, D.A., Robinson, K.A., Wheeler, S. (2021) **Chapter 16. Canadian Fraser River sockeye salmon: a case study 259** in Bahri, T., Vasconcellos, M., Welch, D.J., Johnson, J., Perry, R.I., Ma, X. & Sharma, R., (eds.) *Adaptive management of fisheries in response to climate change.* FAO Fisheries and Aquaculture Technical Paper No. 667. Rome, FAO. http://www.fao.org/documents/card/en/c/cb3095en

Thoughts on Next Steps

Wild salmon numbers are declining and an increasing number of stocks are at risk of extinction

This requires: forward looking science advice

- salmon vulnerability to climate change
- Management strategy evaluations under different projections of climate changes on salmon & their ecosystems

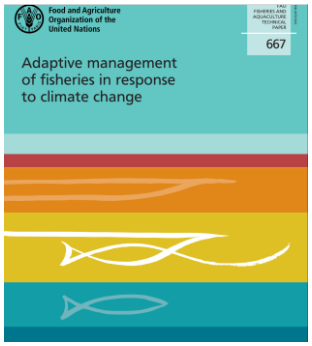


Grant, SCH, Nener, J., MacDonald, B.L., Boldt, J.L., King, J. Patterson, D.A., Robinson, K.A., Wheeler, S. (2021) **Chapter 16. Canadian Fraser River sockeye salmon: a case study 259** in Bahri, T., Vasconcellos, M., Welch, D.J., Johnson, J., Perry, R.I., Ma, X. & Sharma, R., (eds.) *Adaptive management of fisheries in response to climate change.* FAO Fisheries and Aquaculture Technical Paper No. 667. Rome, FAO. http://www.fao.org/documents/card/en/c/cb3095en

Thoughts on Next Steps

Wild salmon numbers are declining and an increasing number of stocks are at risk of extinction

This requires: adaptive & flexible fisheries management required



Grant, SCH, Nener, J., MacDonald, B.L., Boldt, J.L., King, J. Patterson, D.A., Robinson, K.A., Wheeler, S. (2021) **Chapter 16. Canadian Fraser River sockeye salmon: a case study 259** in Bahri, T., Vasconcellos, M., Welch, D.J., Johnson, J., Perry, R.I., Ma, X. & Sharma, R., (eds.) *Adaptive management of fisheries in response to climate change.* FAO Fisheries and Aquaculture Technical Paper No. 667. Rome, FAO. http://www.fao.org/documents/card/en/c/cb3095en

We need to stop managing salmon by looking in the rear view mirror

The future of salmon is going to look very different under climate change

SCH Grant, BL MacDonald, CGJ Michielsens et al. PSC Workshop 2021