

Salmon Futures:

Climate change, multiple stressors, and resilience of salmon watersheds

Jonathan Moore

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@jon_w_moore 



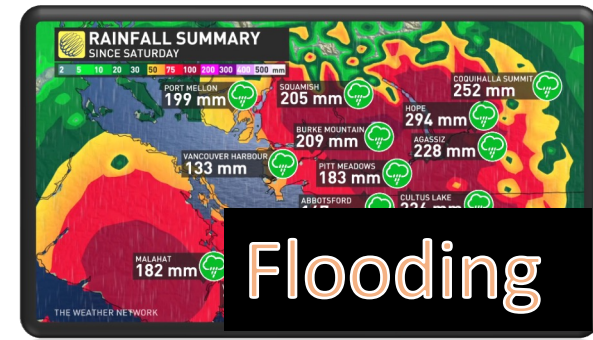
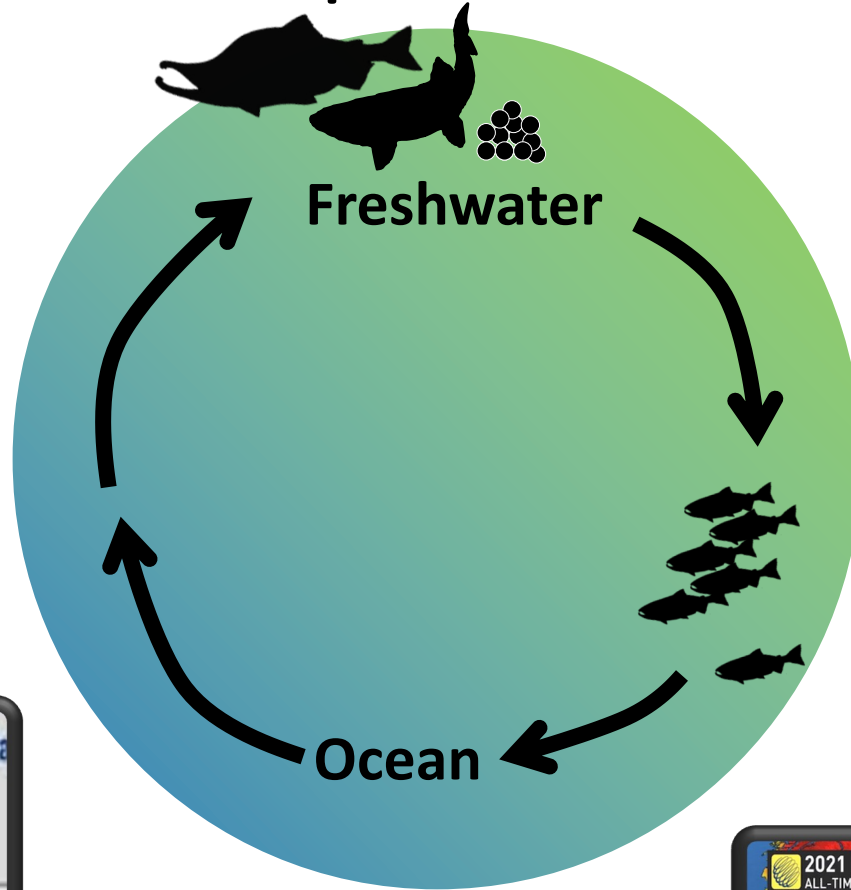
Salmon Watersheds Lab







Climate change & multiple stressors



Flooding



Development



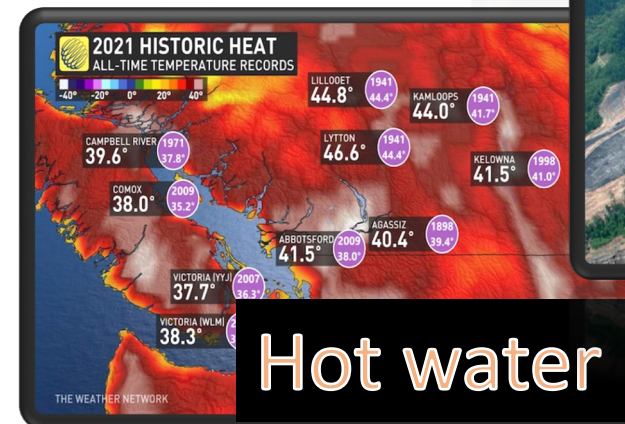
Mining



Ocean heat waves



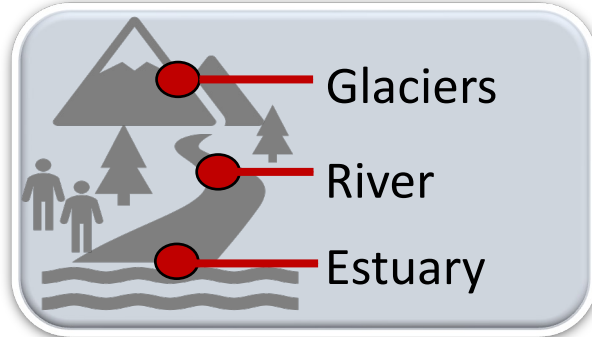
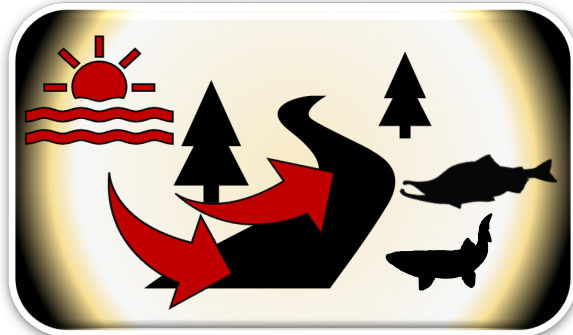
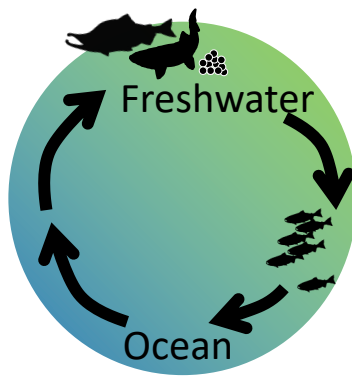
Forestry



Hot water

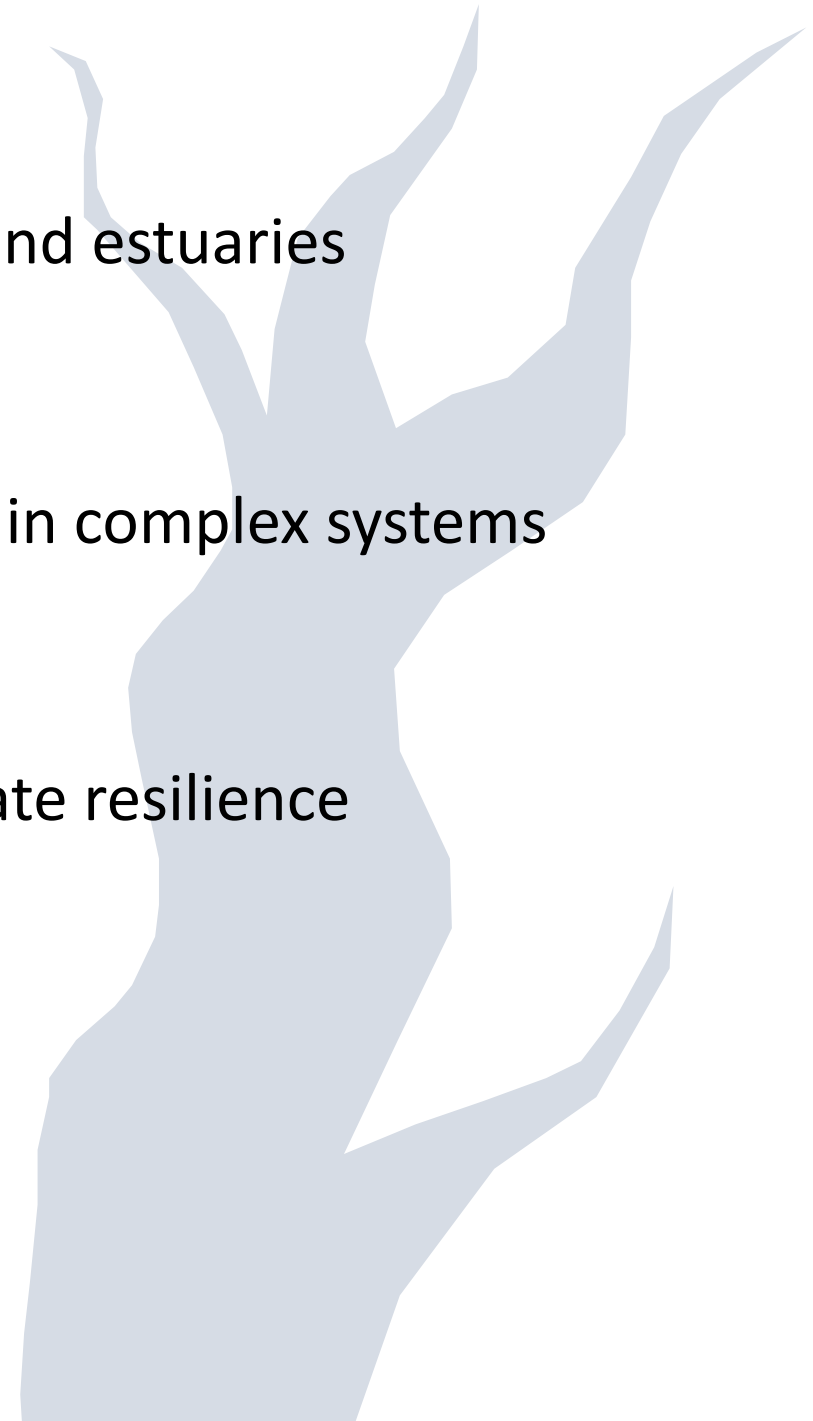
**How can we best steward salmon watersheds,
given climate change and multiple stressors?**

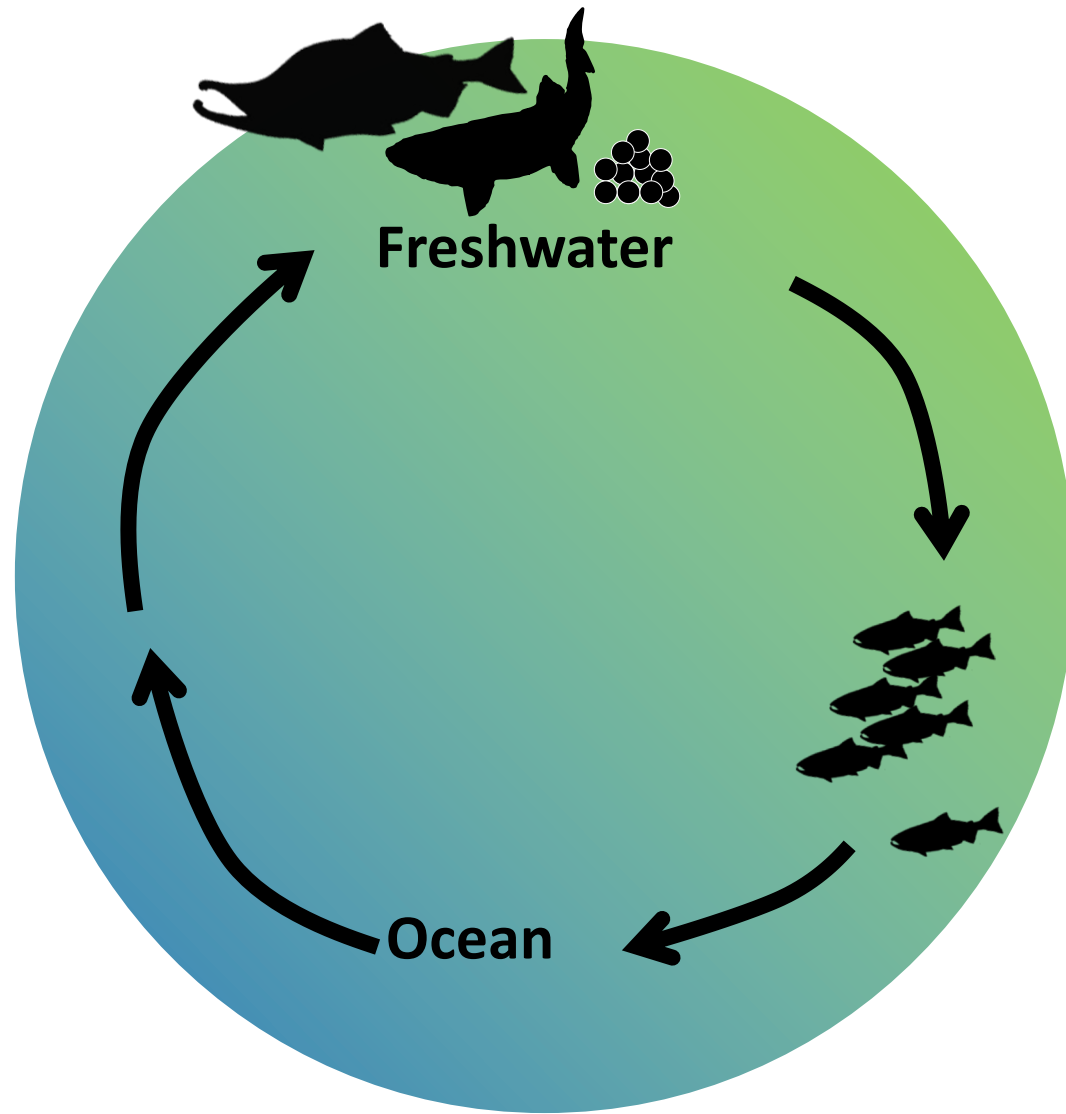




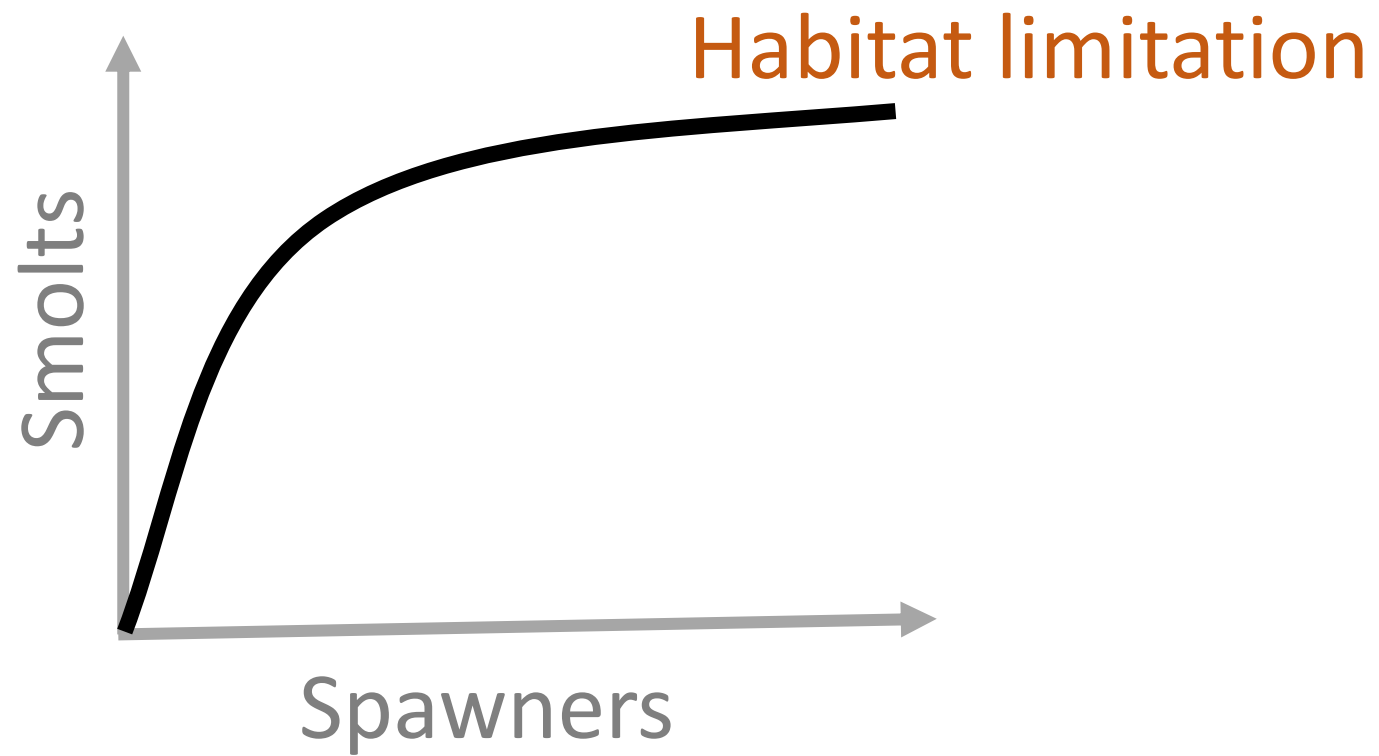
FLOW

- Freshwaters and estuaries
- Rapid change in complex systems
- Towards climate resilience
 - Estuary
 - River
 - Glacier
- Paths forward

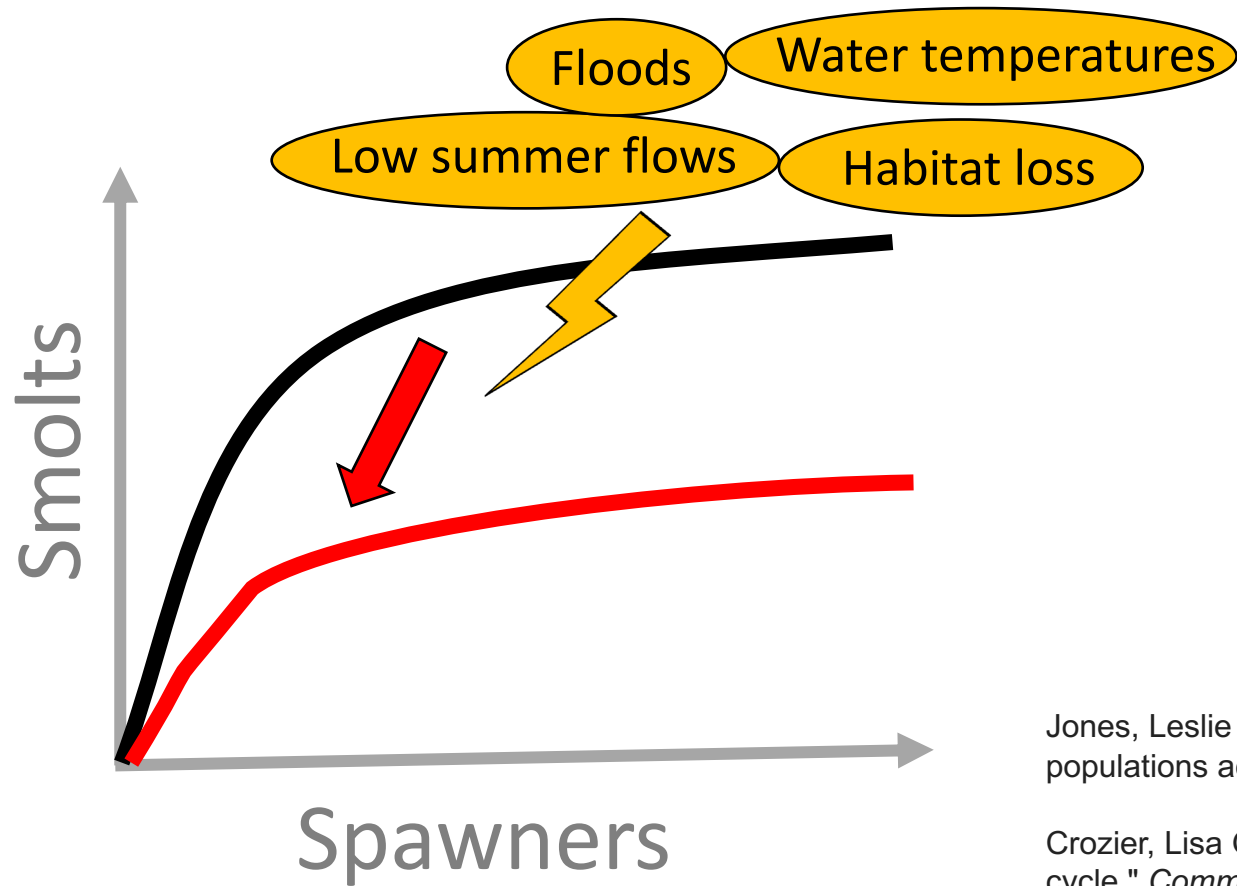




Freshwater matters



Freshwater matters

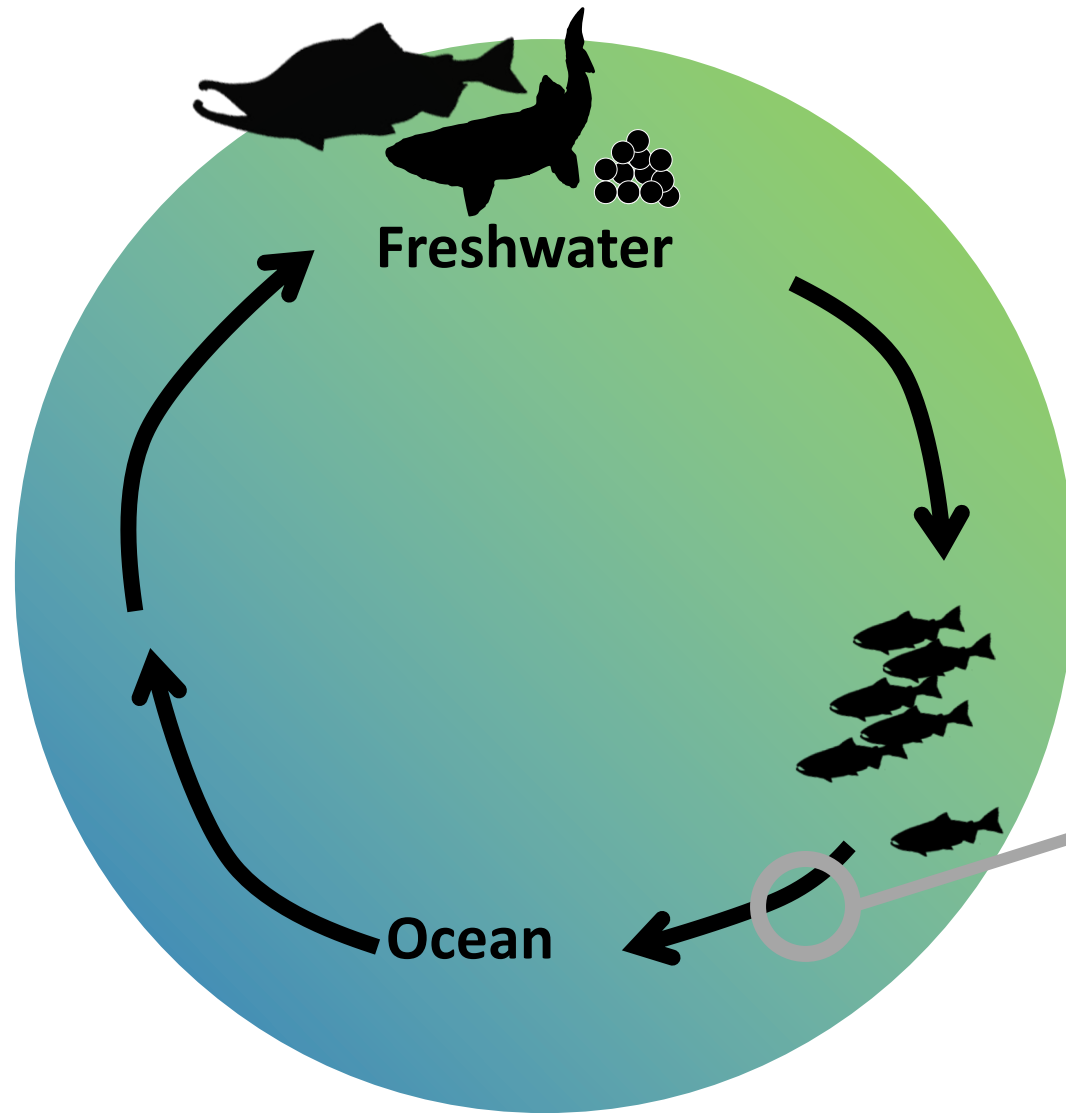


Jones, Leslie A., et al. "Watershed-scale climate influences productivity of Chinook salmon populations across southcentral Alaska." *Global change biology* 26.9 (2020): 4919-4936.

Crozier, Lisa G., et al. "Climate change threatens Chinook salmon throughout their life cycle." *Communications biology* 4.1 (2021): 1-14.

Wilson, Kyle L., et al. "Marine and freshwater regime changes impact a community of migratory Pacific salmonids in decline." *Global Change Biology* 28.1 (2022): 72-85.

Warkentin, Luke, et al. "Low summer river flows associated with low productivity of Chinook salmon in a watershed with shifting hydrology." *Ecological Solutions and Evidence* 3.1 (2022): e12124.





Estuary



What is the importance of estuaries for salmon?

Tagging salmon smolts as they leave freshwater

2015-present

N = 7001 sockeye salmon

N = 7091 coho salmon



Attempting to recapture in estuary and ocean entry





RECAP!

A large shark, likely a sandbar shark, is lying on a sandy beach. The shark is facing right, with its mouth slightly open, showing its teeth. A speech bubble points to the shark's head. In the background, there are blue fishing nets and the legs of people in waders. The scene is outdoors, near the water's edge.

I am not a juvenile salmon



Size-spectra analysis in the estuary: assessing fish nursery function
across a habitat mosaic

KARL M. SEITZ ^{1,2,3,†} WILLIAM I. ATLAS ^{1,2,3} BENJAMIN MILLARD-MARTIN,² JARED REID,³
JULIAN HEAVYSIDE ⁴ BRIAN P. V. HUNT ^{2,5,6} AND JONATHAN W. MOORE ¹

Extensive estuary residency (up to 40 days)

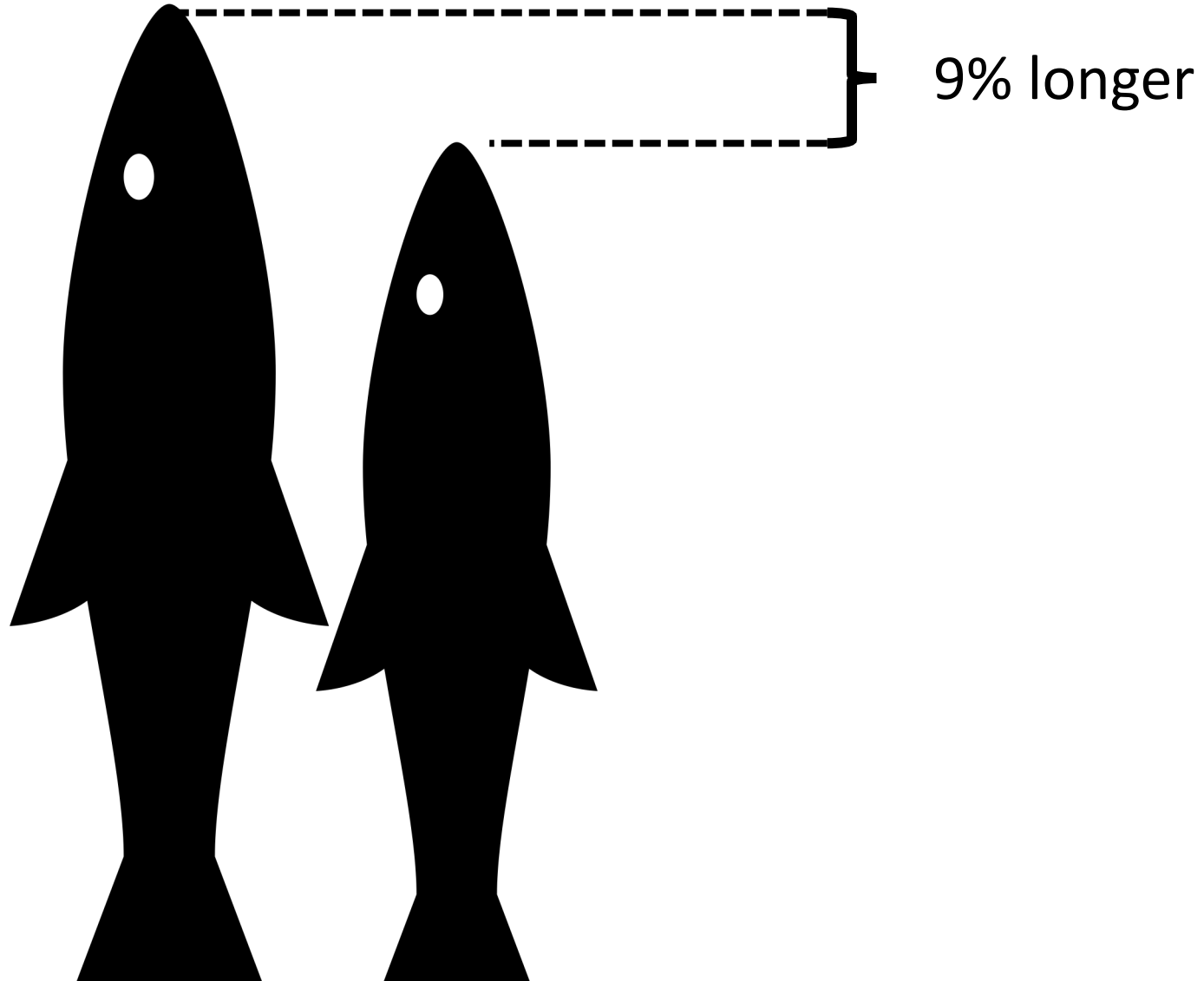
+

Fast estuary growth rates

9% increase (5 - 25%) in length prior to ocean entry



Growth benefits of estuary nursery habitat



Growth benefits of estuary nursery habitat

Lebron James: 6' 7"

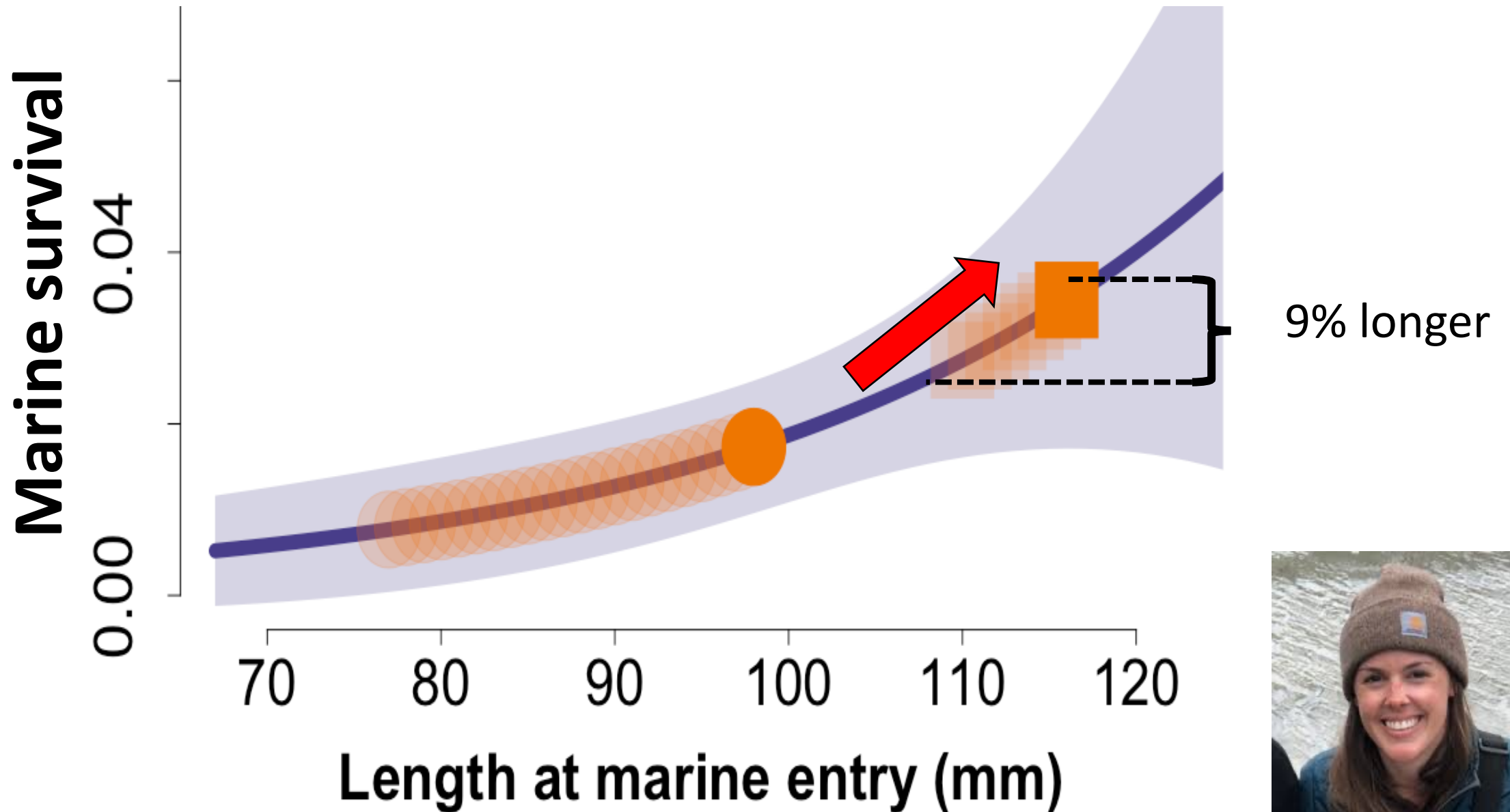
Luka Doncic = 6' 6"

Jon Moore = 6' 1" (on a tall day)

8.2% taller



Growth benefits of estuary nursery habitat



Extensive estuary residency (up to 40 days)

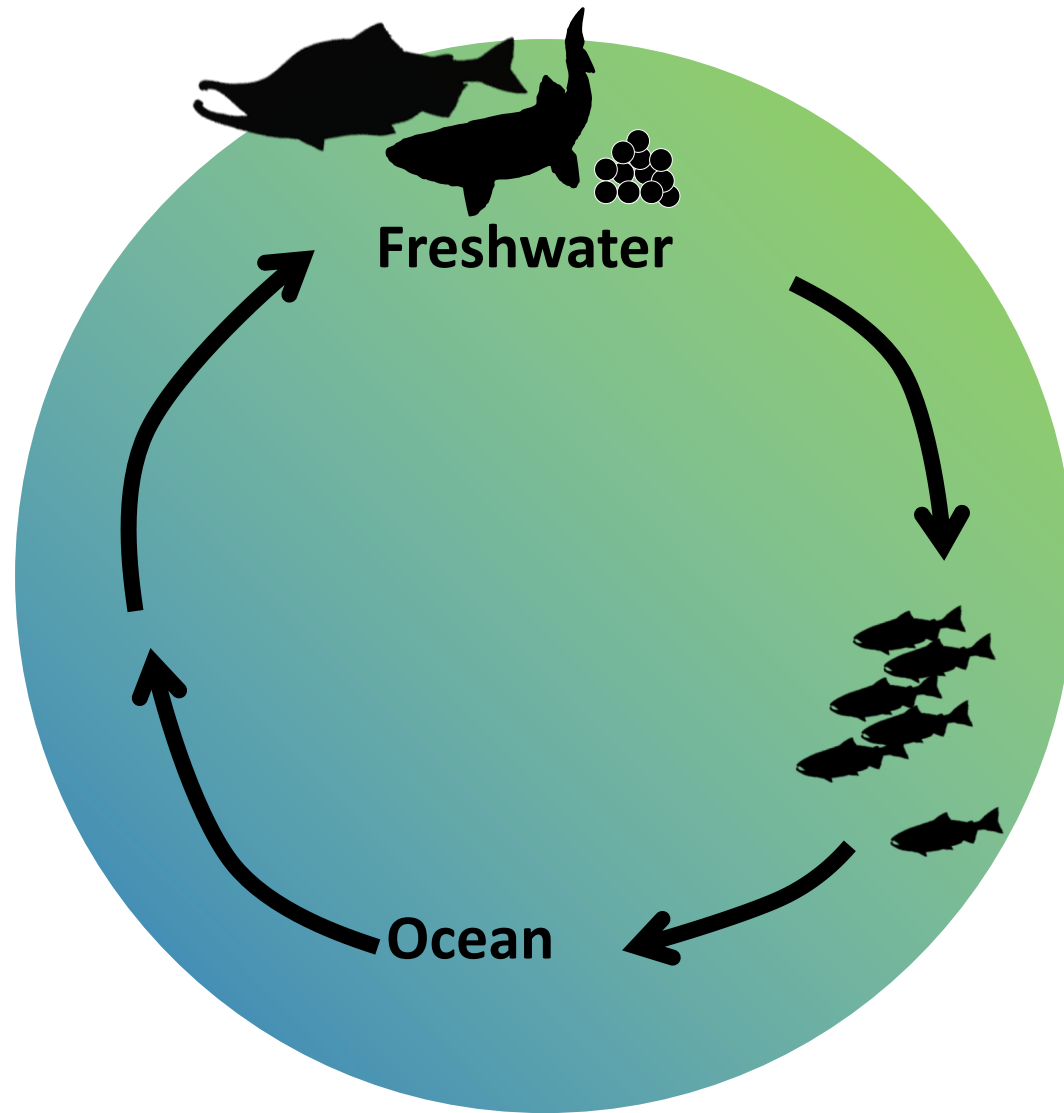
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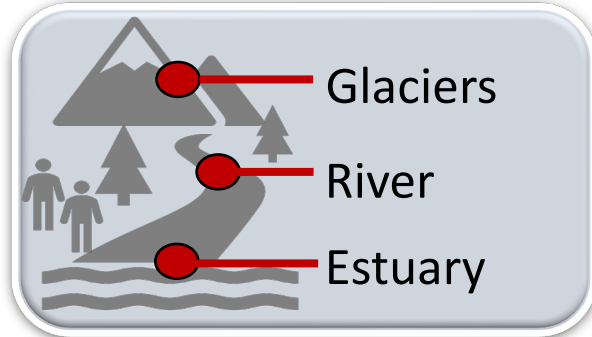
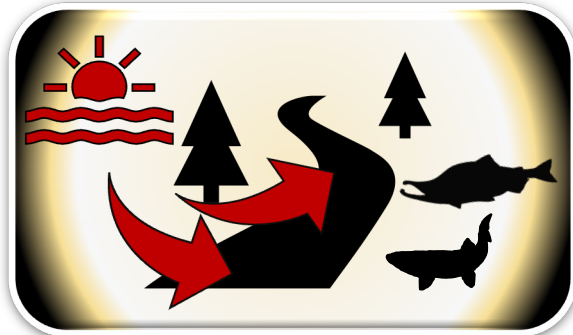
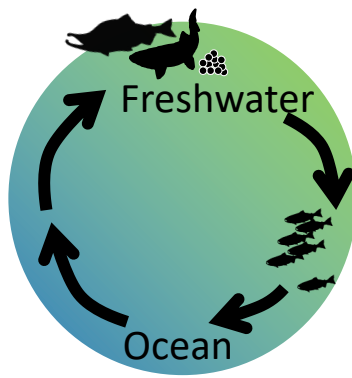
Fast estuary growth rates

9% increase (5 - 25%) in length prior to ocean entry

~35% increase in marine survival!

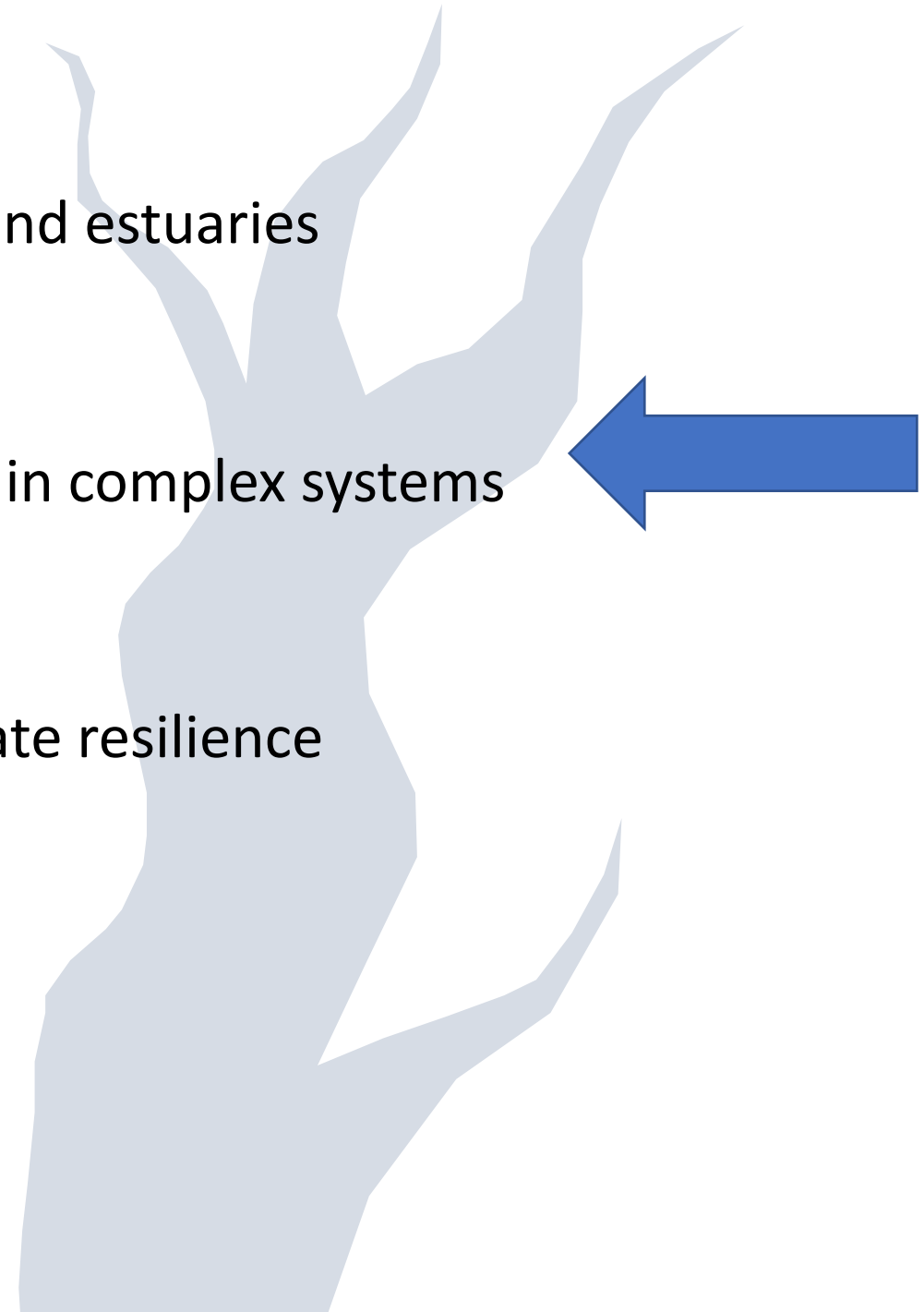






FLOW

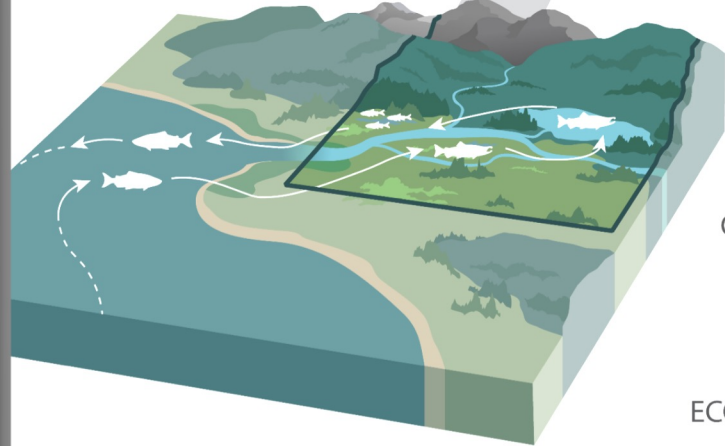
- Freshwaters and estuaries
- Rapid change in complex systems
- Towards climate resilience
 - Estuary
 - River
 - Glacier
- Paths forward



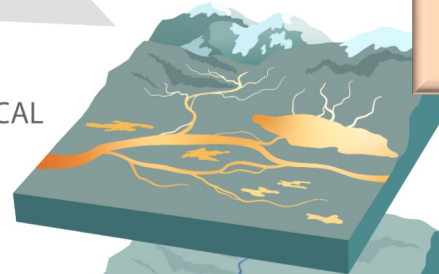
Rapid change in complex systems



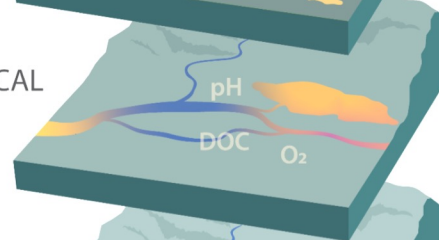
CLIMATE CHANGE



PHYSICAL



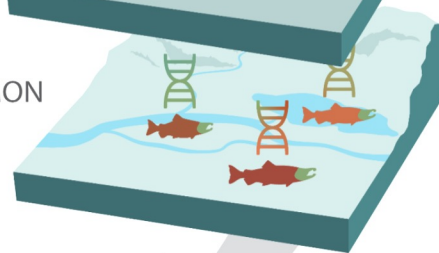
CHEMICAL



ECOLOGICAL



SALMON

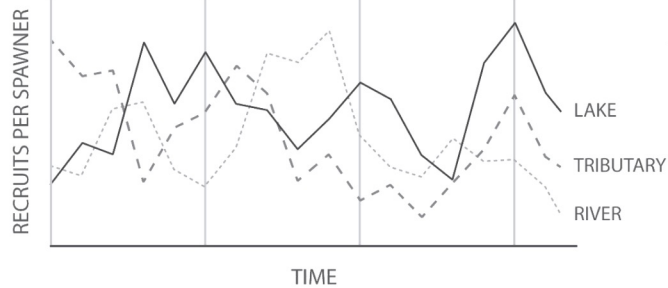


RECRUITS PER SPAWNER

LOW HIGH



YEAR 0 YEAR 5 YEAR 10 YEAR 15

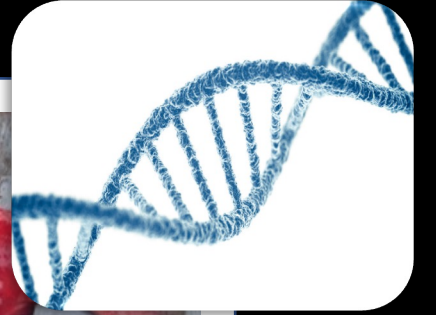
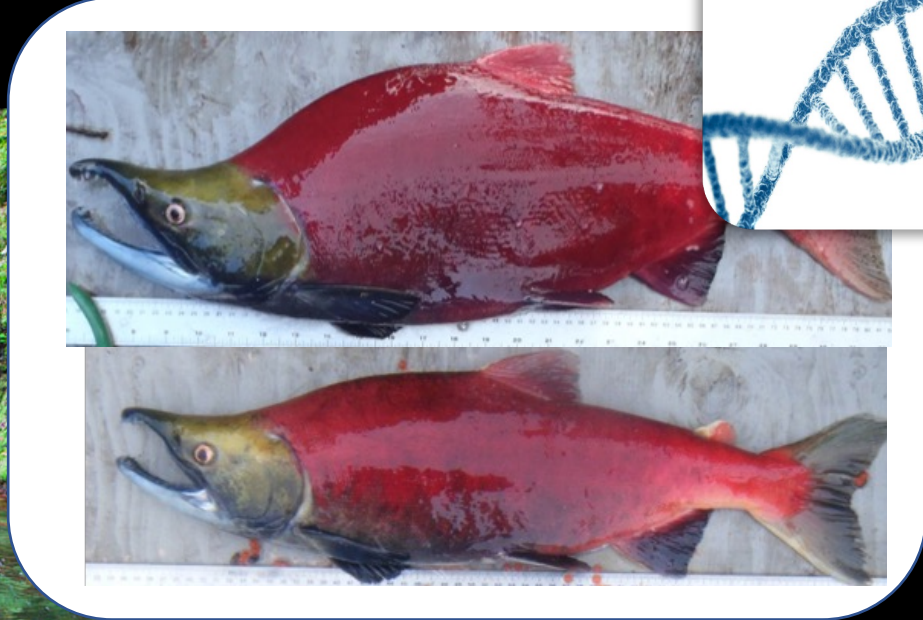


Wilson, Moore, Schindler, Westley
in prep

Shifting habitat mosaics & portfolio effects

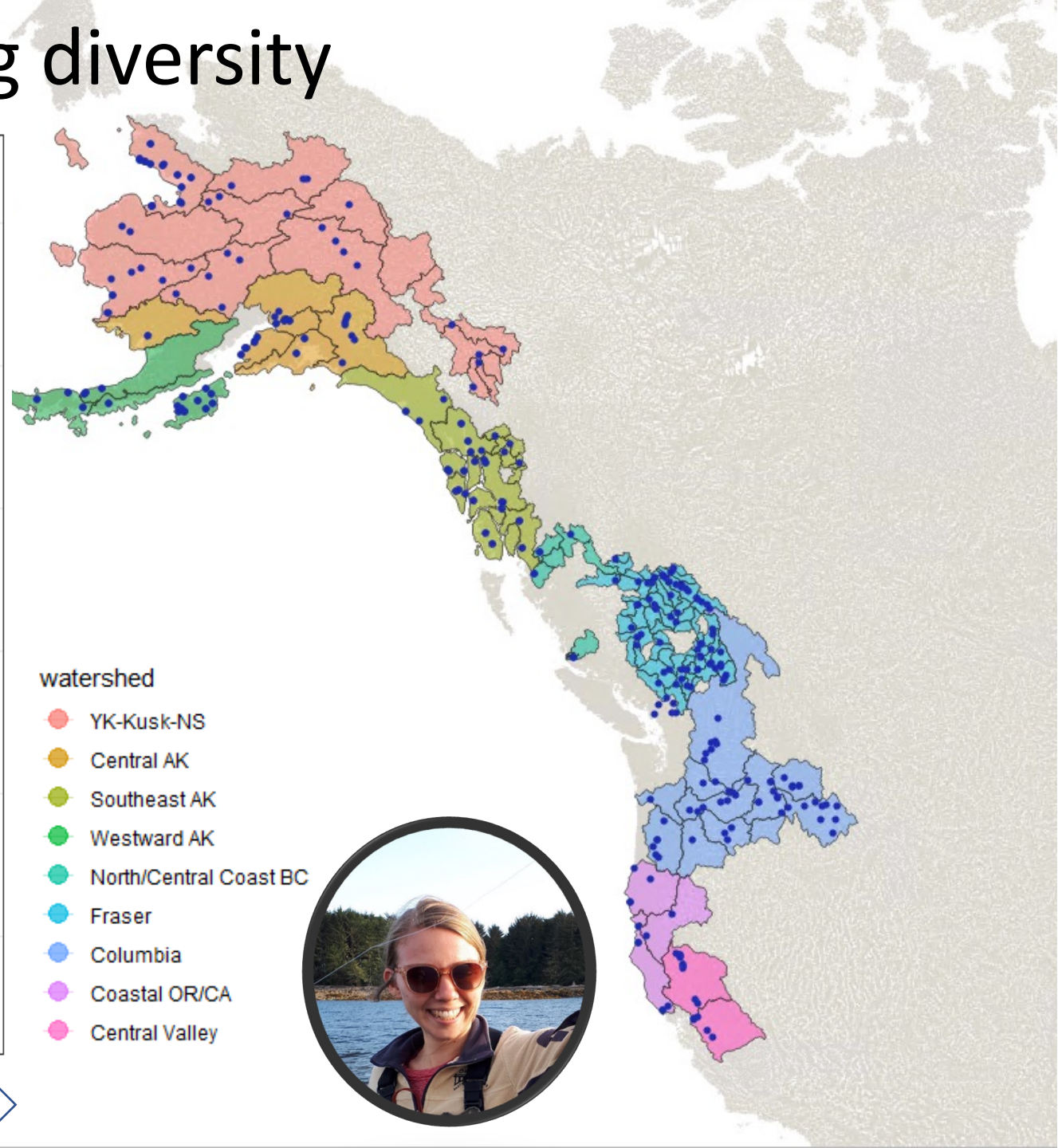
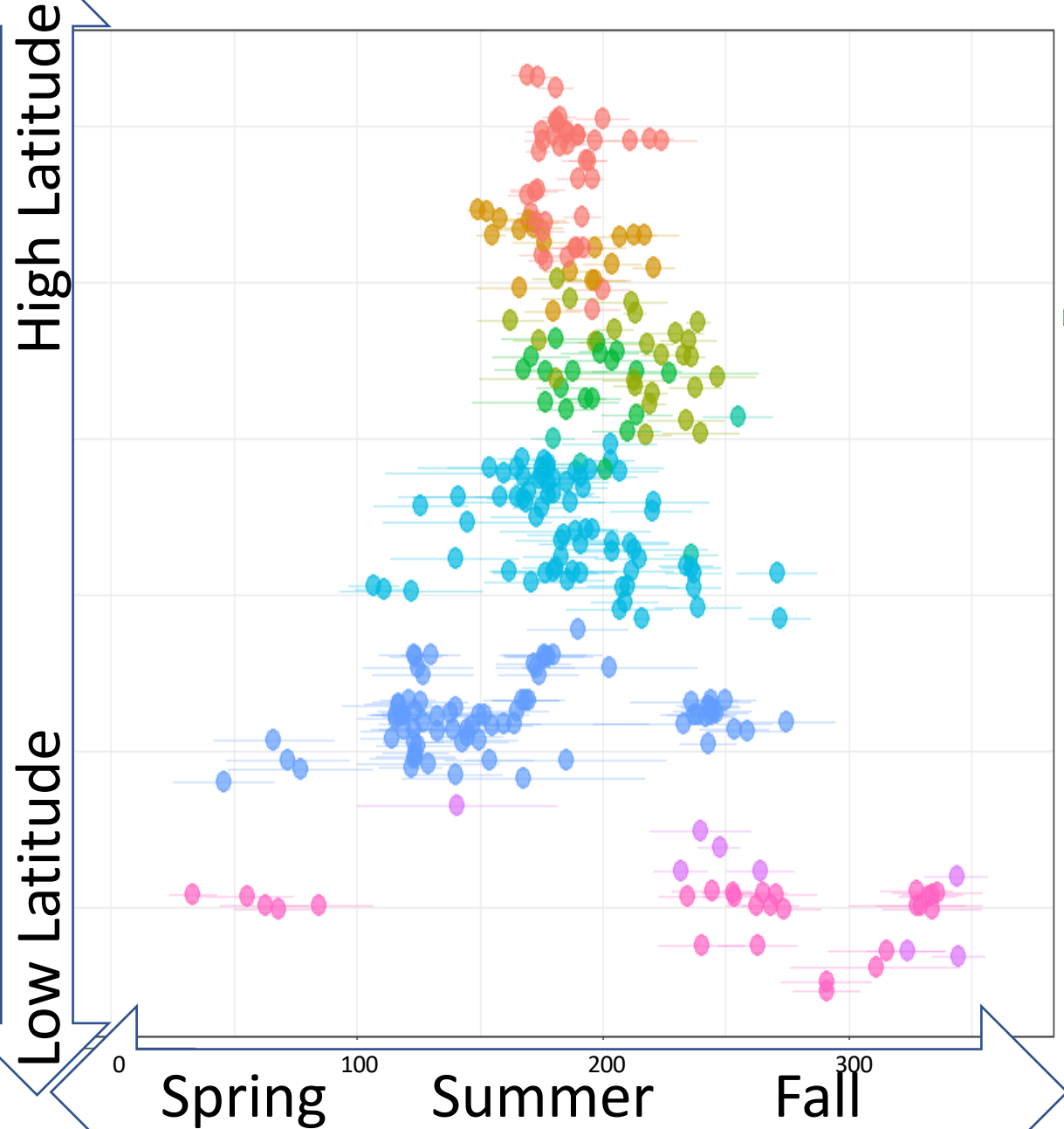


Amazing biodiversity of salmon systems

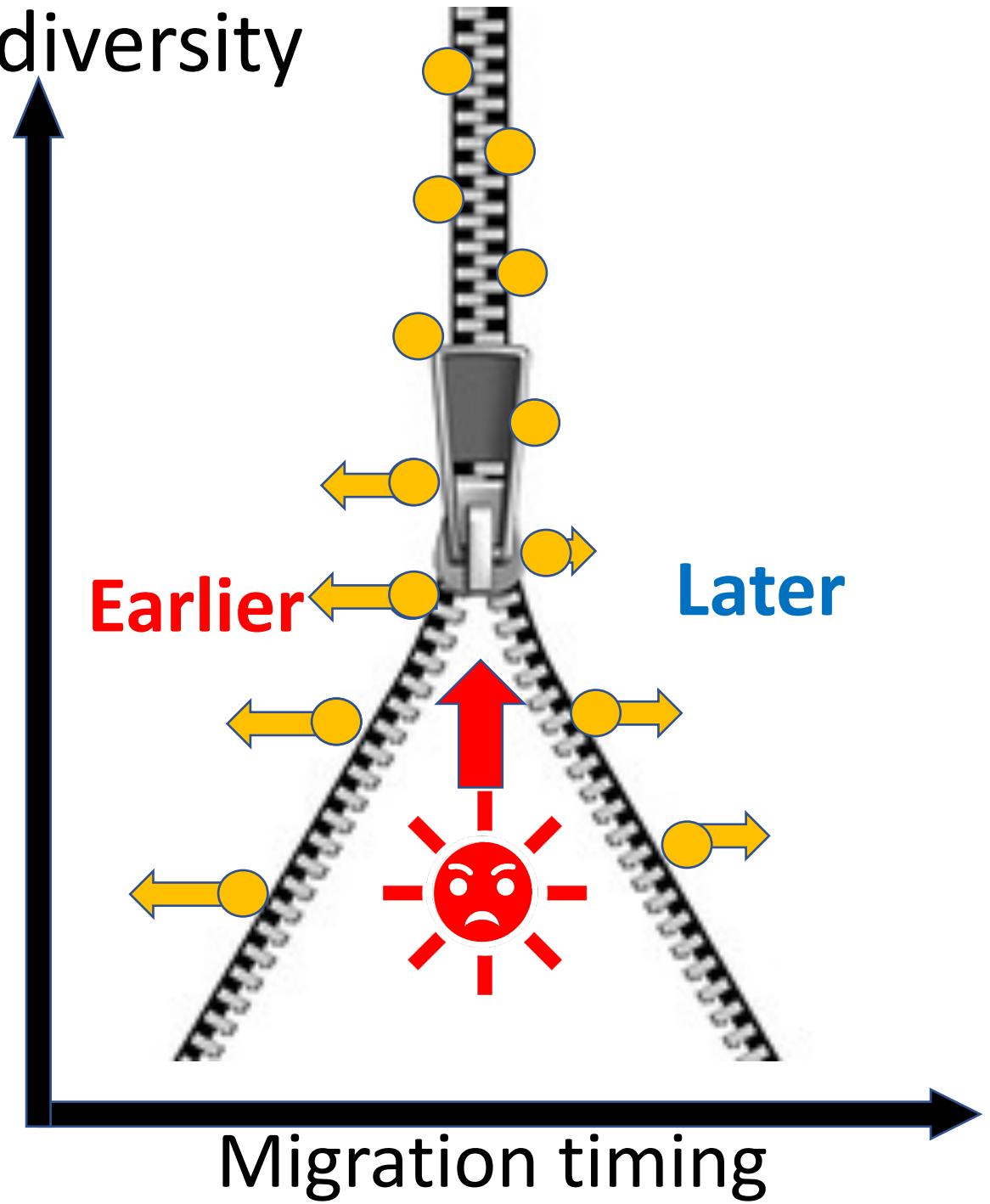
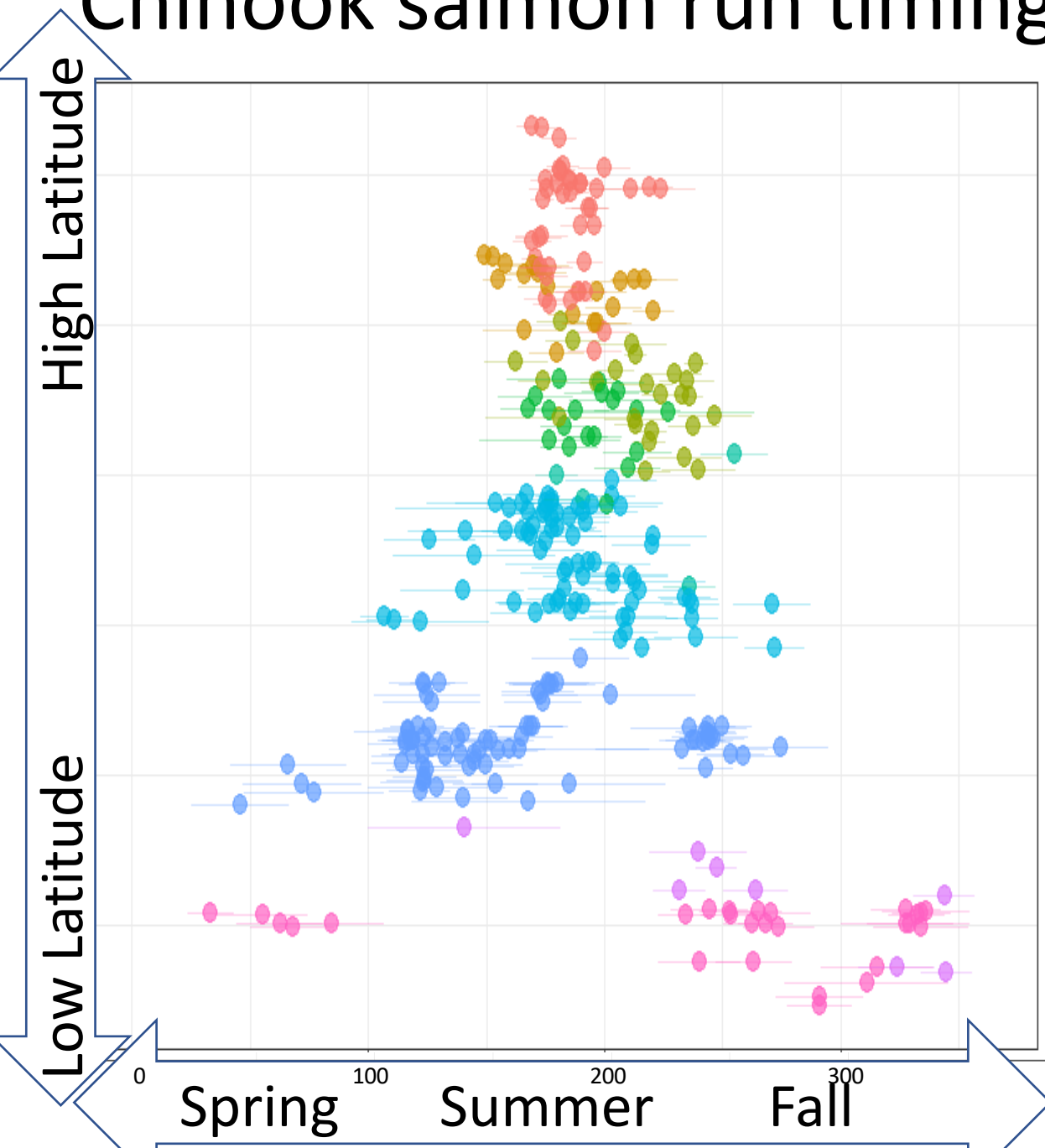




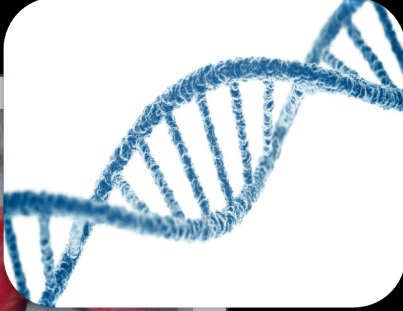
Chinook salmon run timing diversity

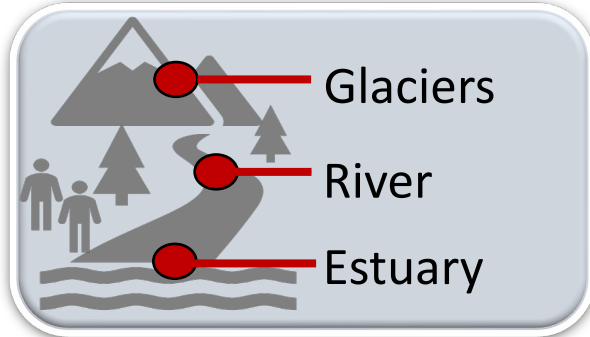
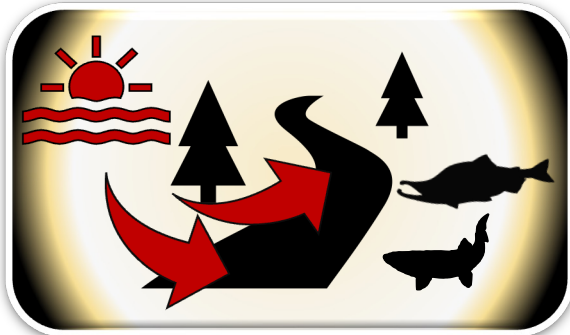
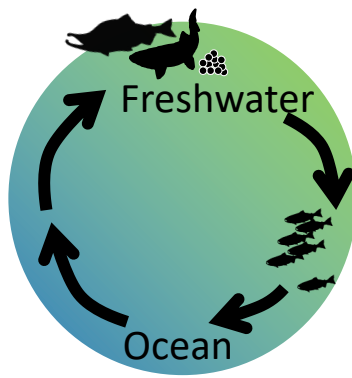


Chinook salmon run timing diversity



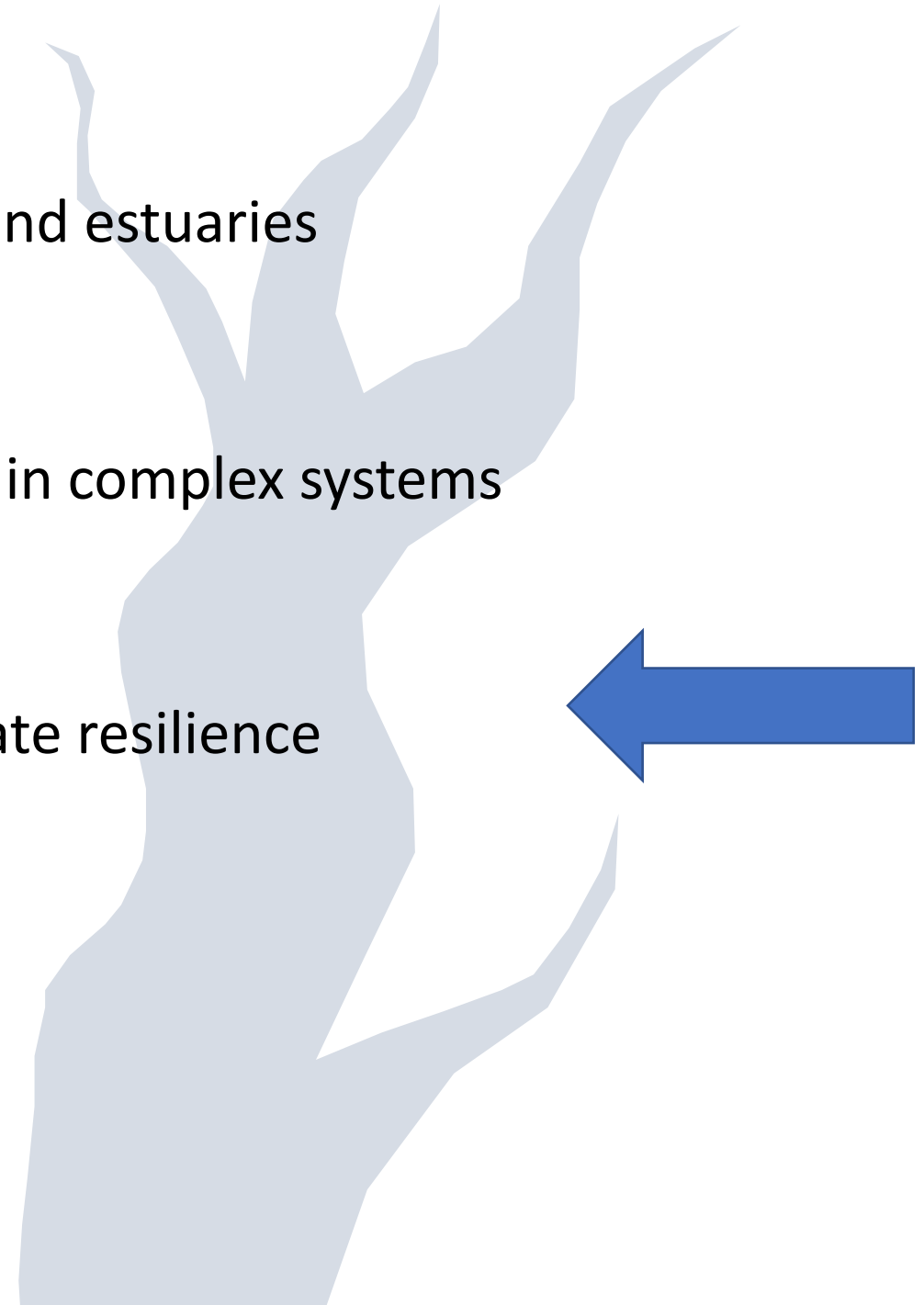
Complexity and diversity of salmon systems



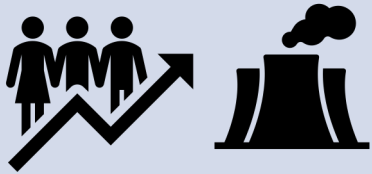


FLOW

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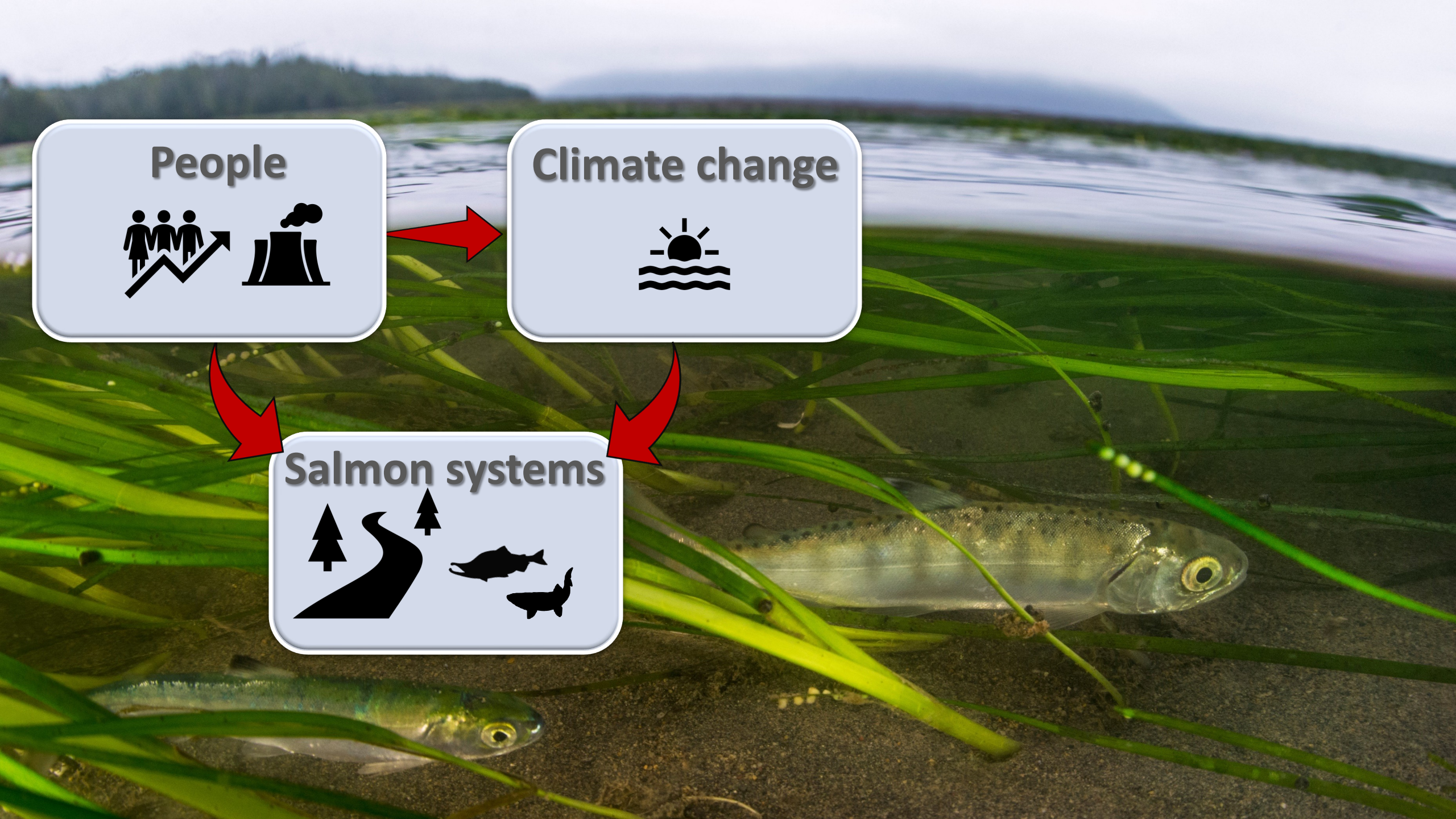
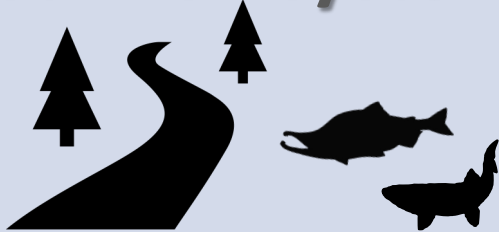
People

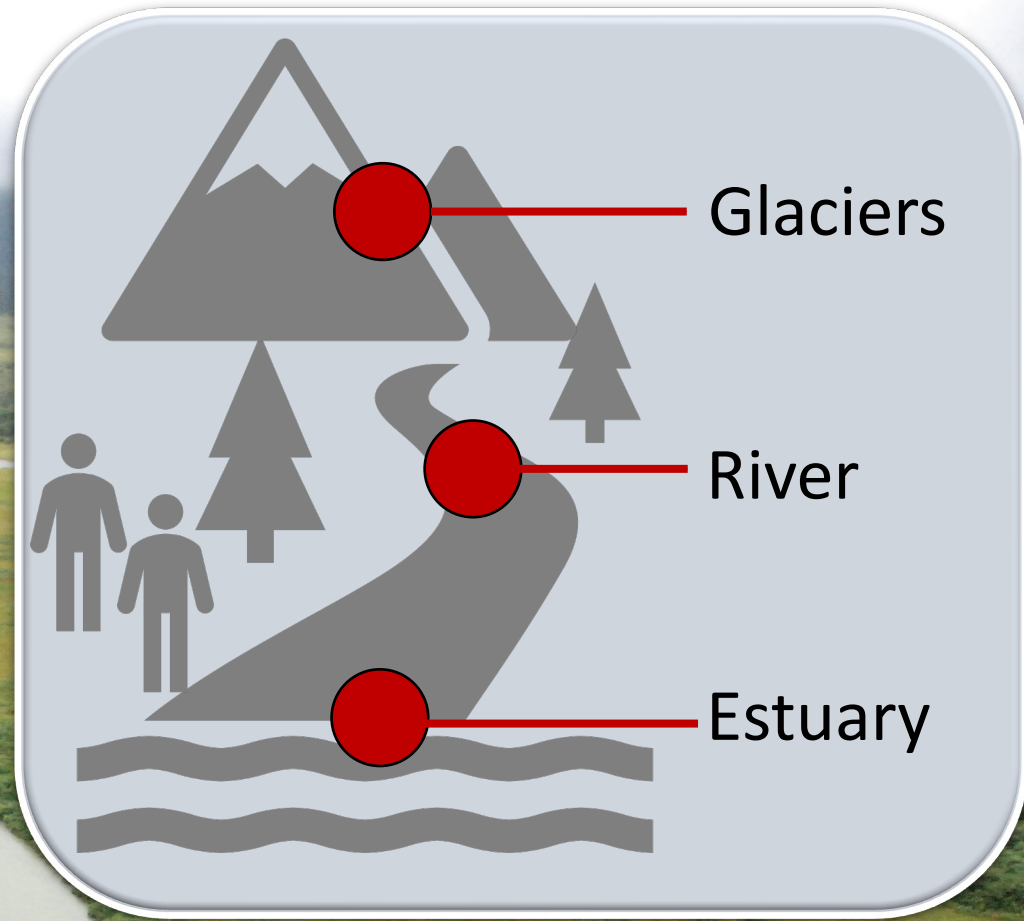
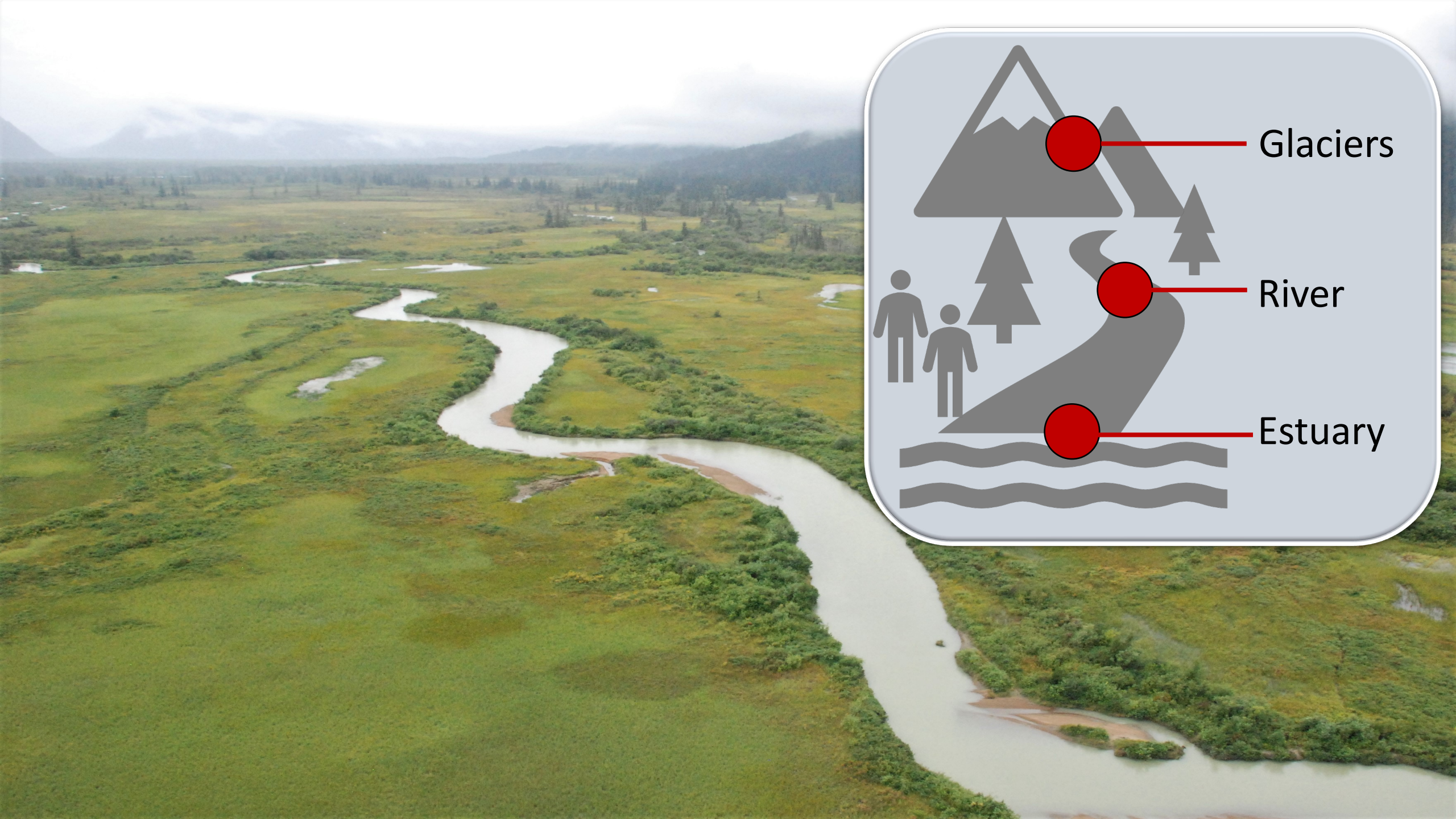


Climate change



Salmon systems





Glaciers

River

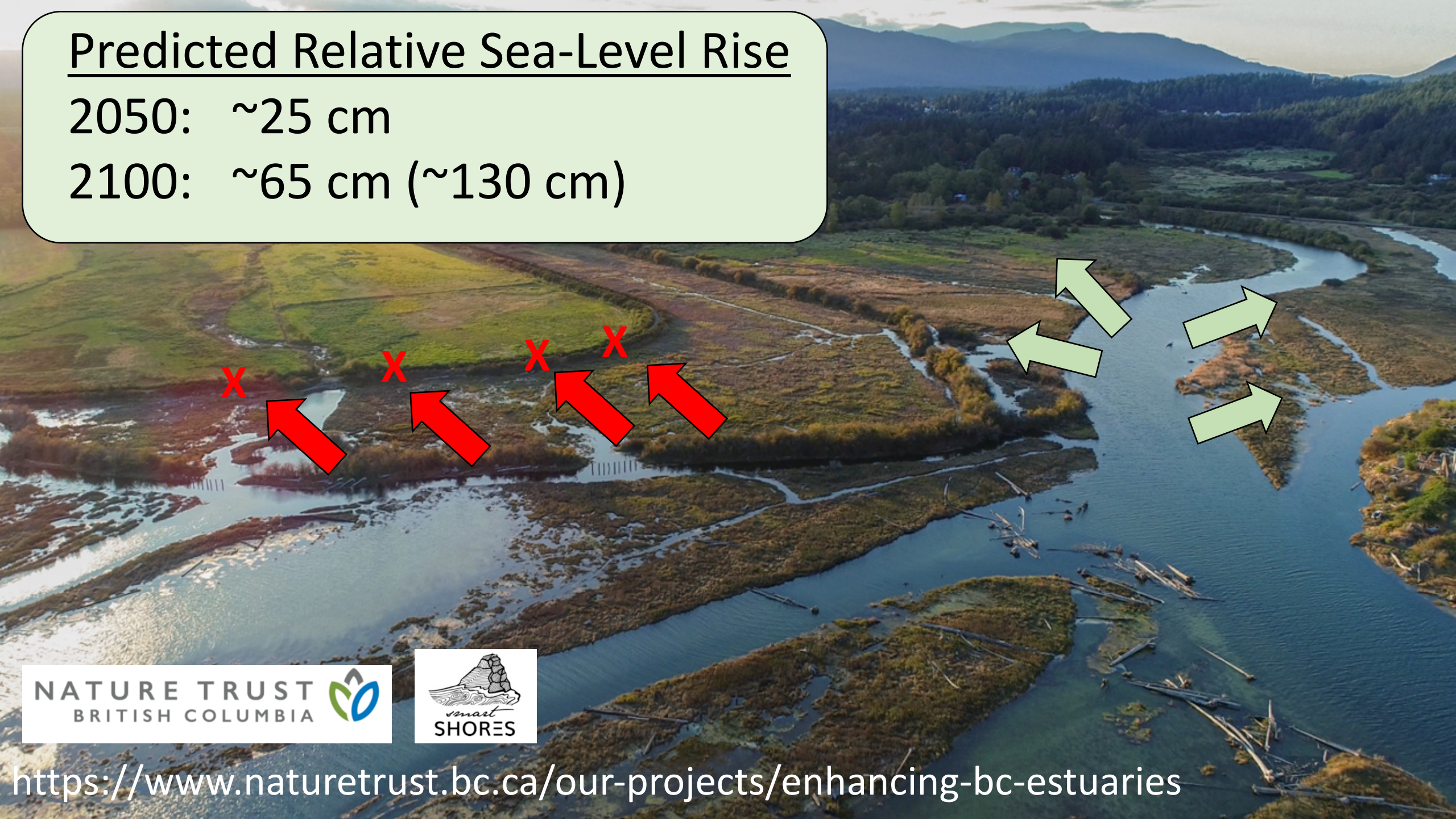
Estuary



Predicted Relative Sea-Level Rise

2050: ~25 cm

2100: ~65 cm (~130 cm)

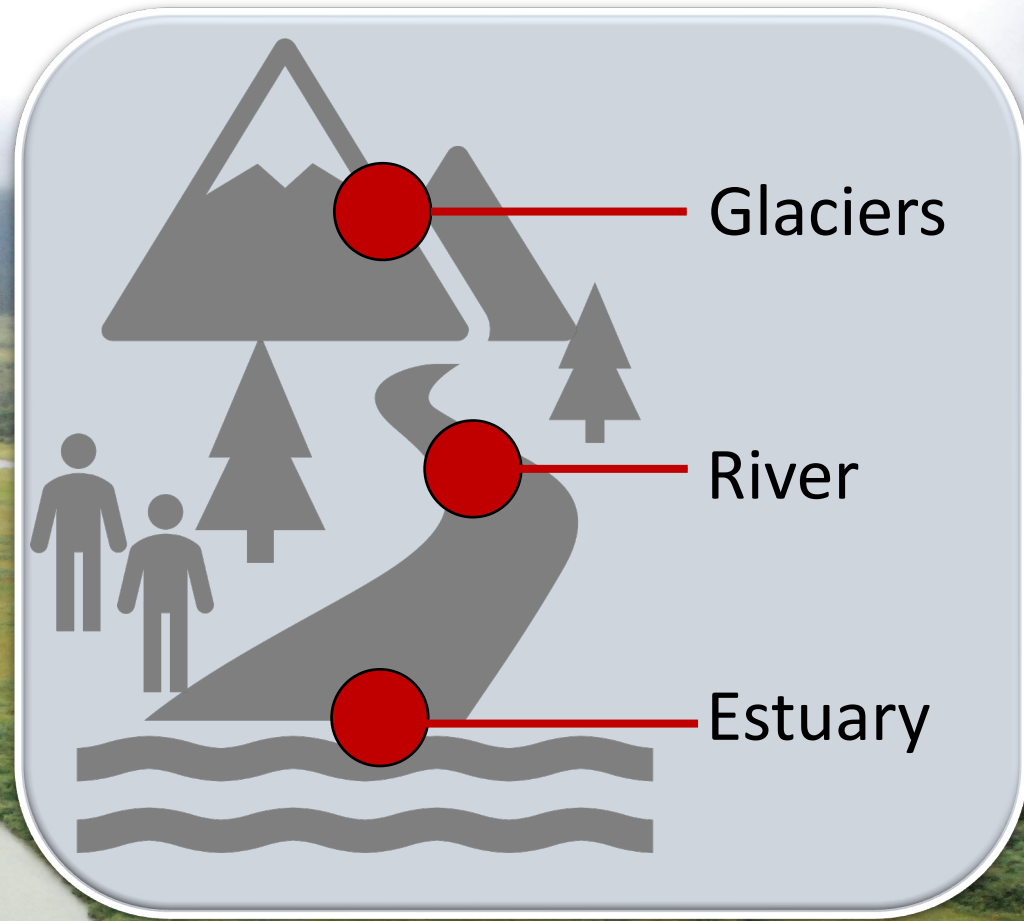
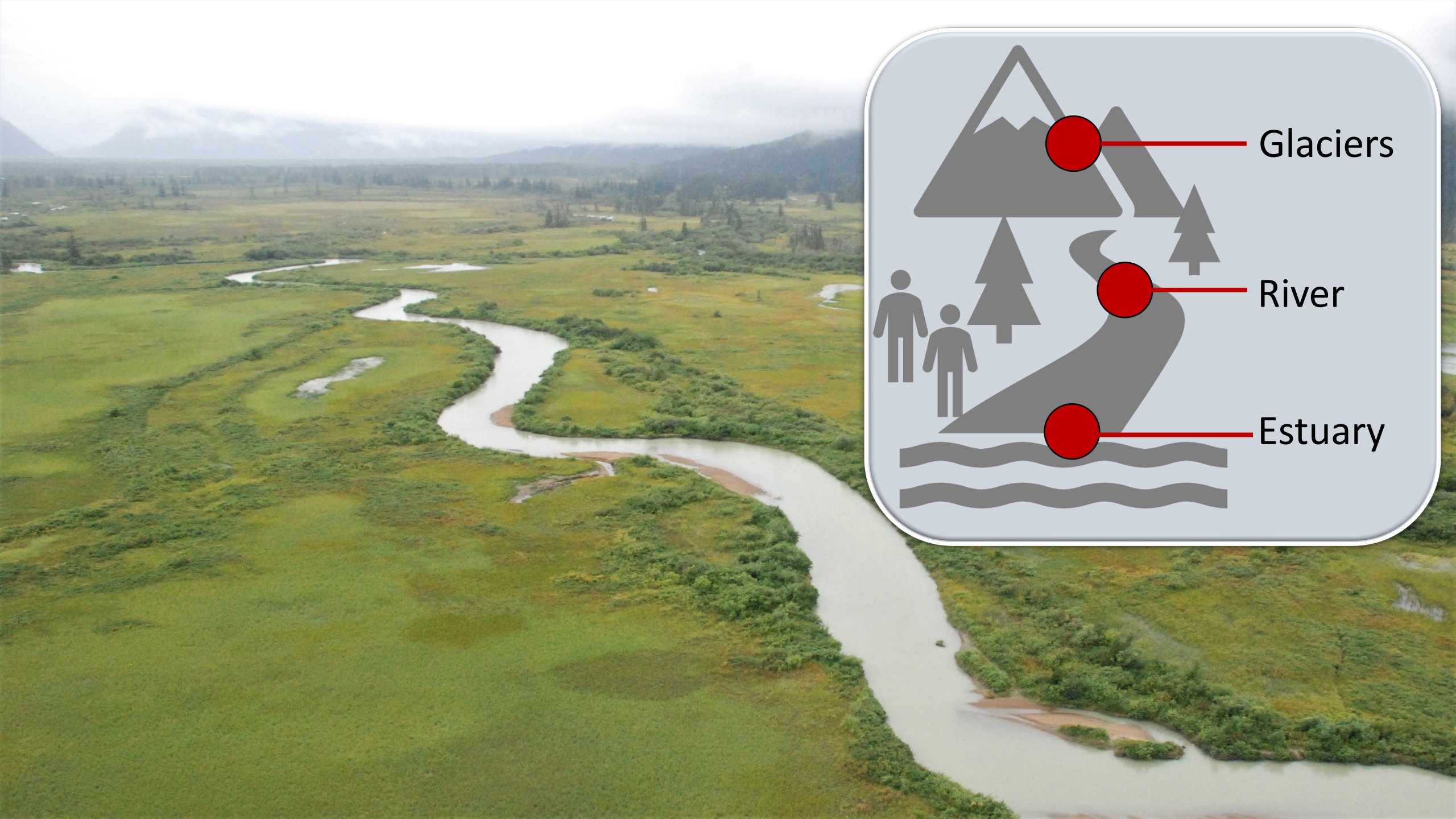




Estuary resilience



<https://www.naturetrust.bc.ca/our-projects/enhancing-bc-estuaries>



Glaciers

River



Estuary

Multiple stressors

An aerial satellite view of a forest landscape in interior British Columbia. The image shows a complex pattern of dark green forest and brownish, cleared areas, illustrating the impact of logging over 30+ years. The cleared areas are irregular in shape and scattered throughout the forest, with some showing signs of regrowth. The overall appearance is one of a fragmented and stressed forest ecosystem.



Logging in interior BC over 30+ years. Derived from Google Earth Engine by Joanne Hammond

Logging



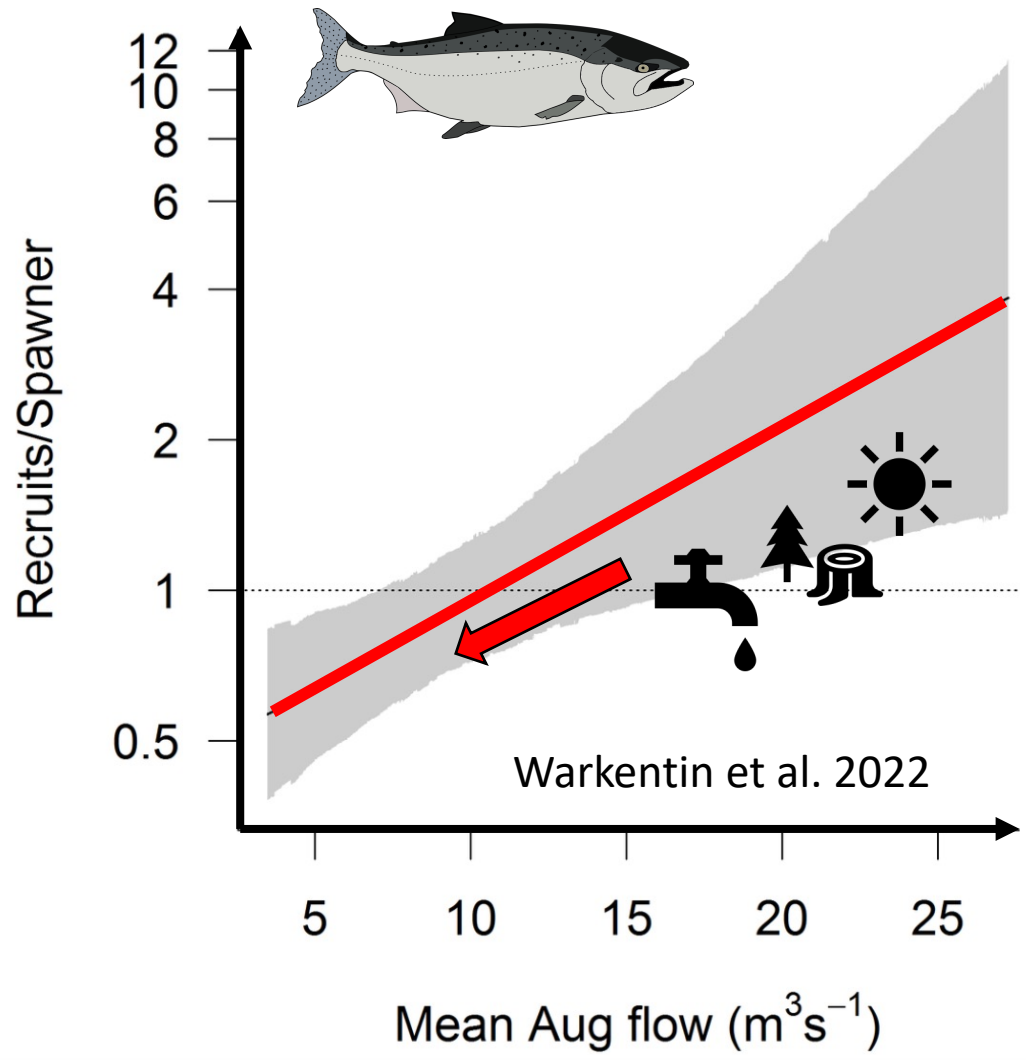
~2 - 6°C

Wondzell et al 2019; etc.



~ 25%

Gronsdal et al. 2019; etc.



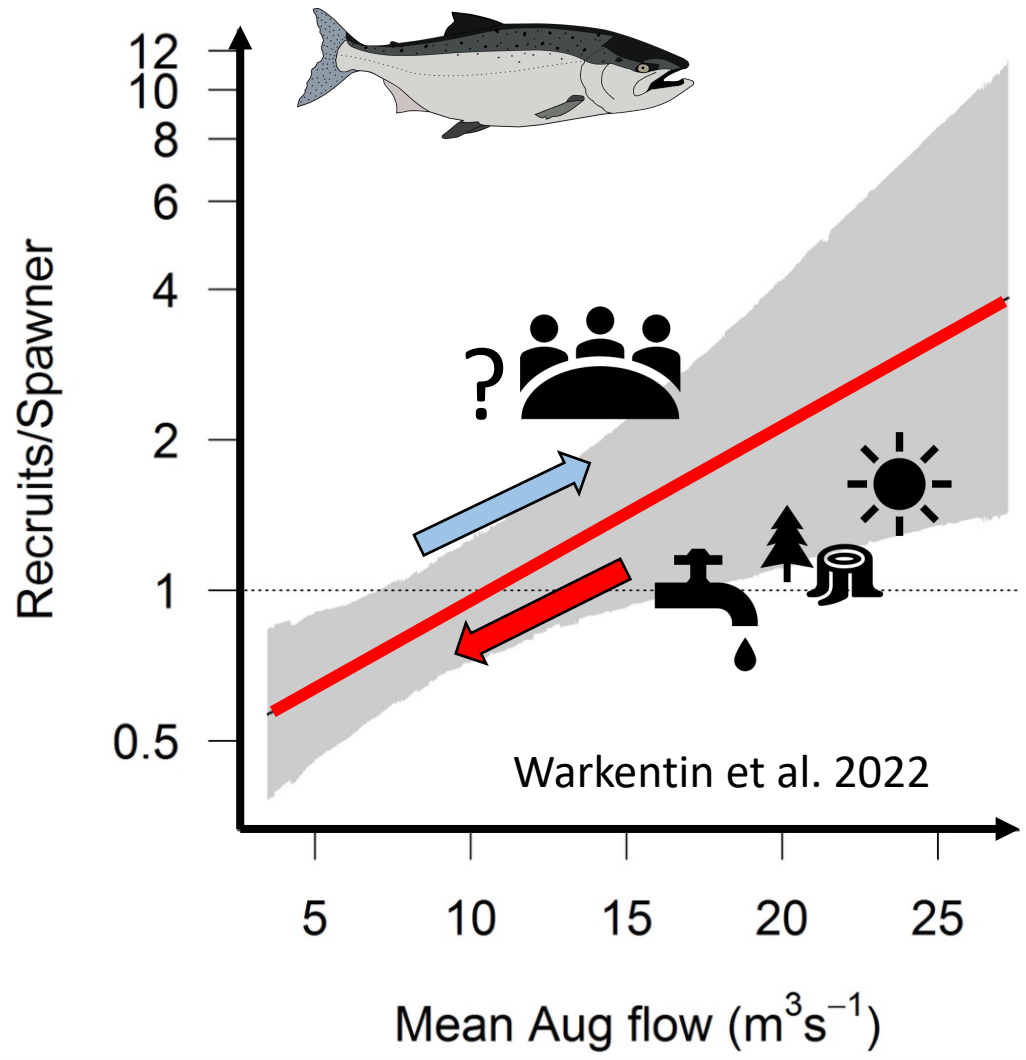
DOI: 10.1002/2688-8319.12124

RESEARCH ARTICLE



Low summer river flows associated with low productivity of Chinook salmon in a watershed with shifting hydrology

Luke Warkentin¹ | Charles K. Parken² | Richard Bailey^{2,3} | Jonathan W. Moore¹



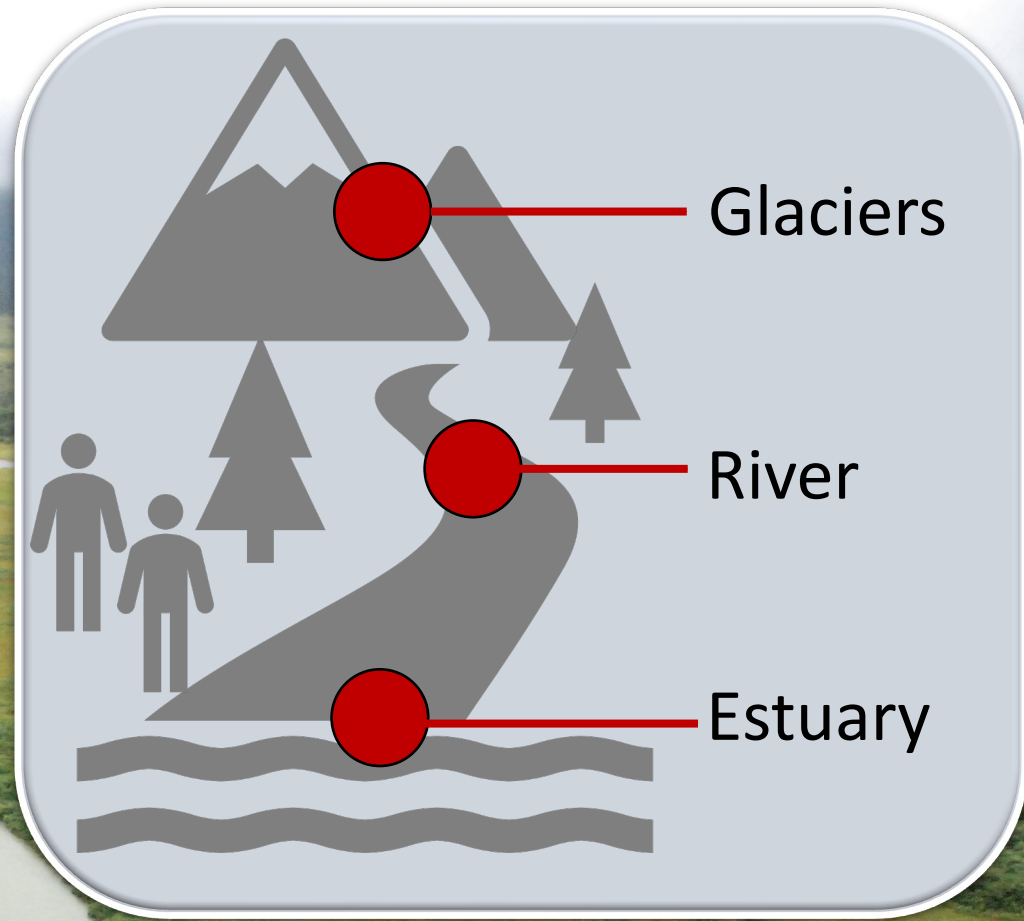
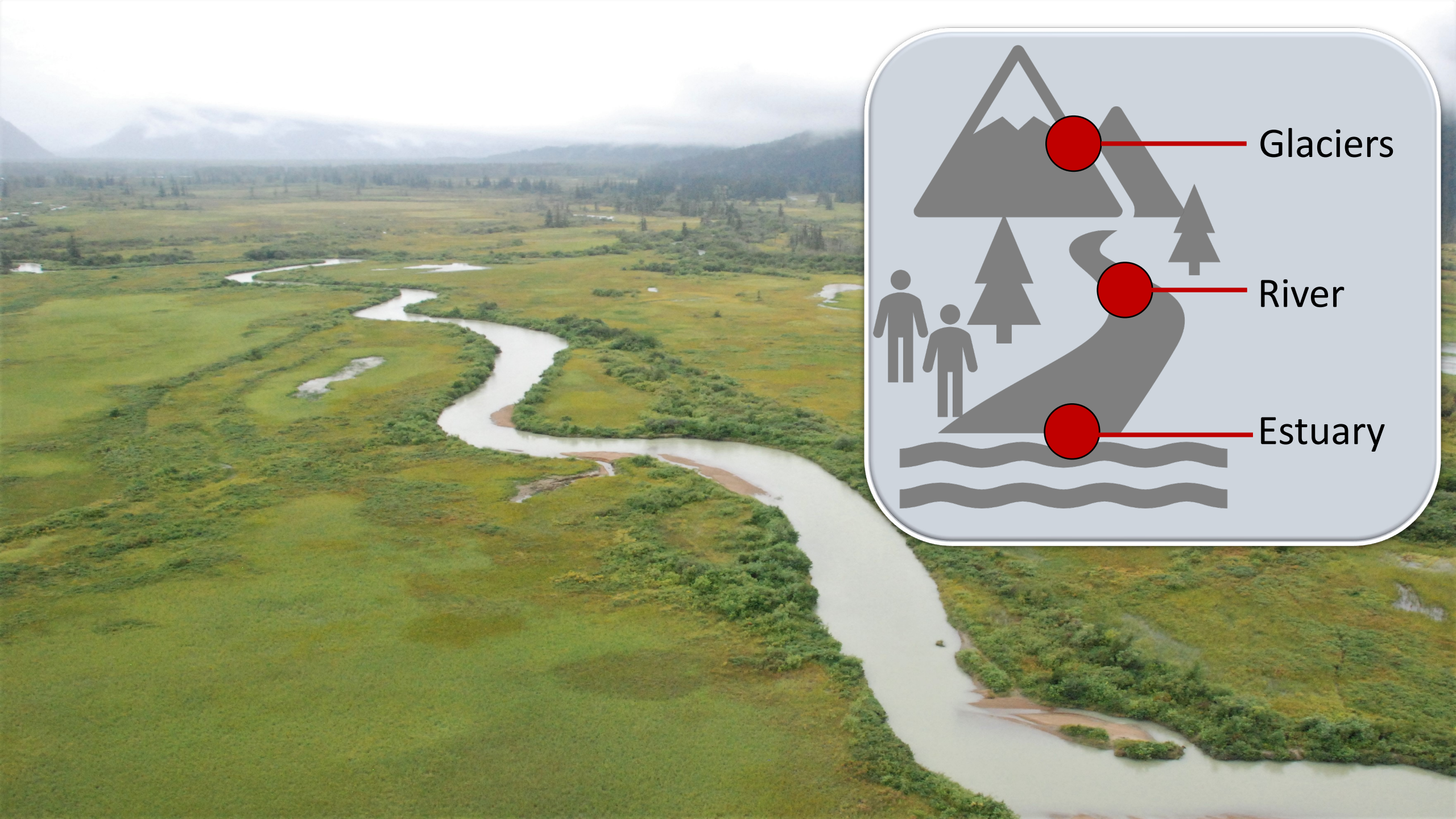
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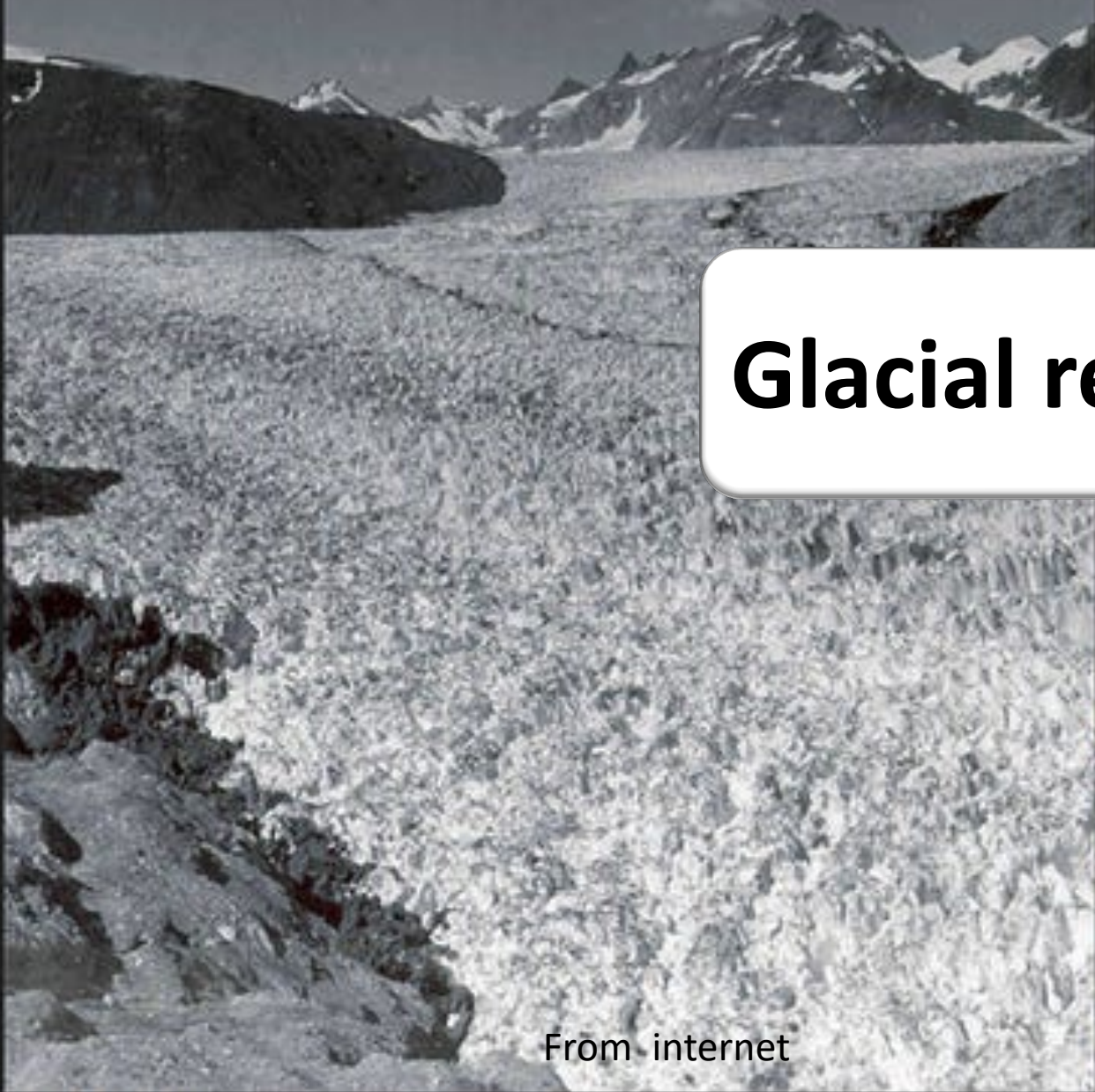


Glaciers

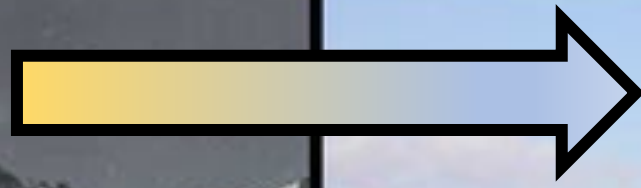
River

Estuary

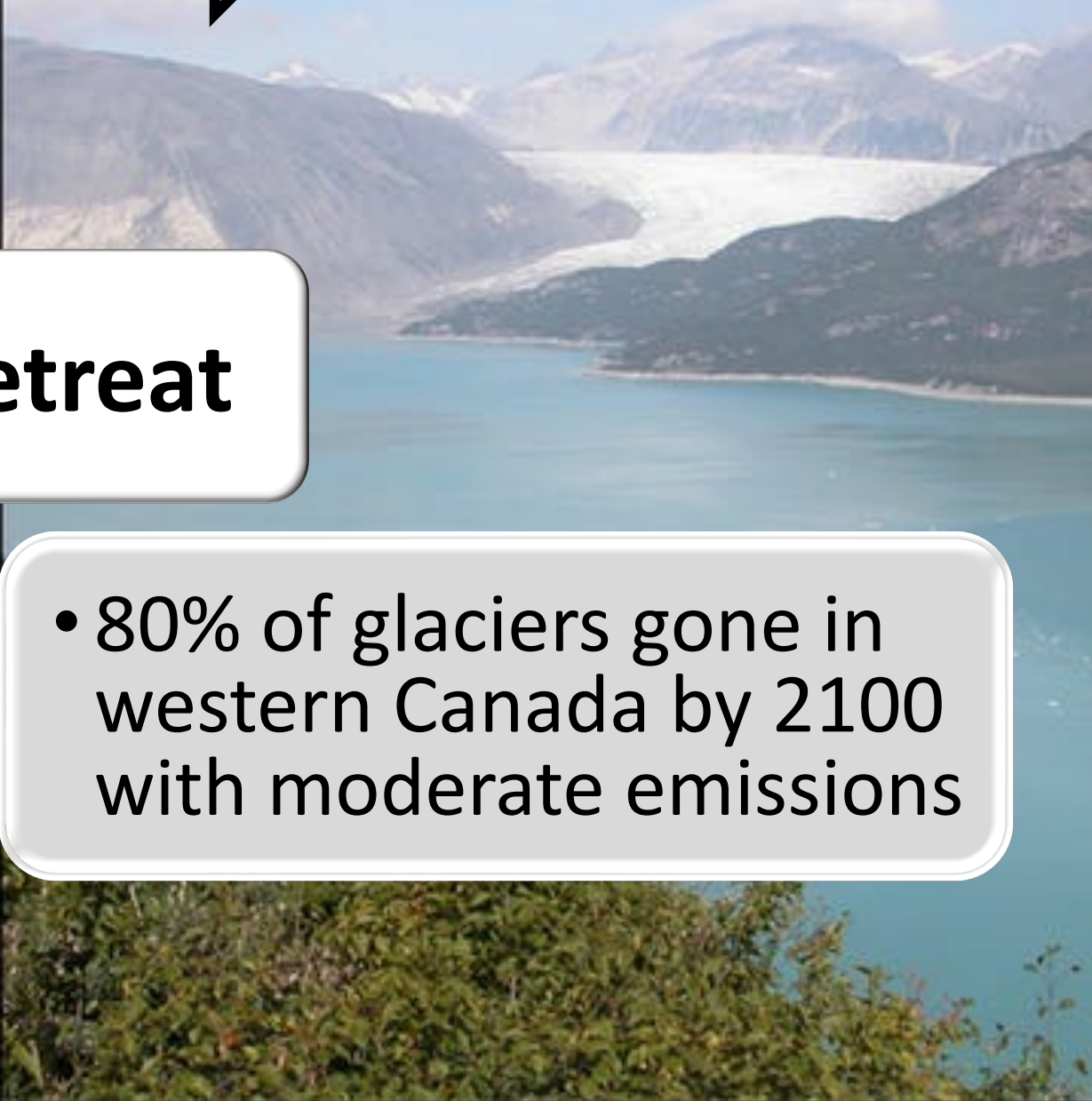
1941



From internet



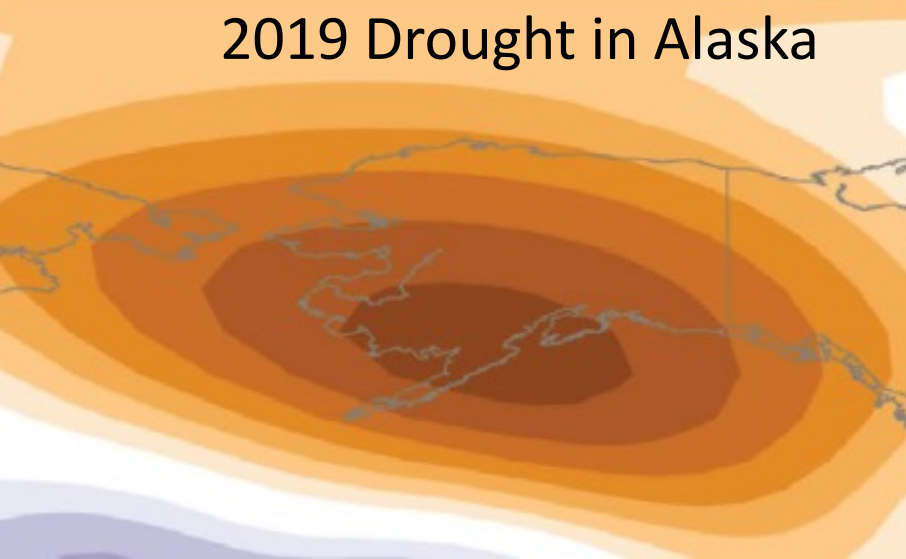
2004



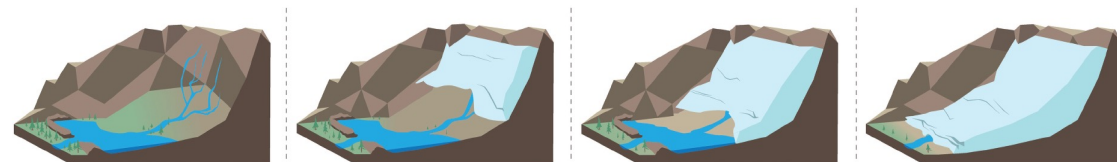
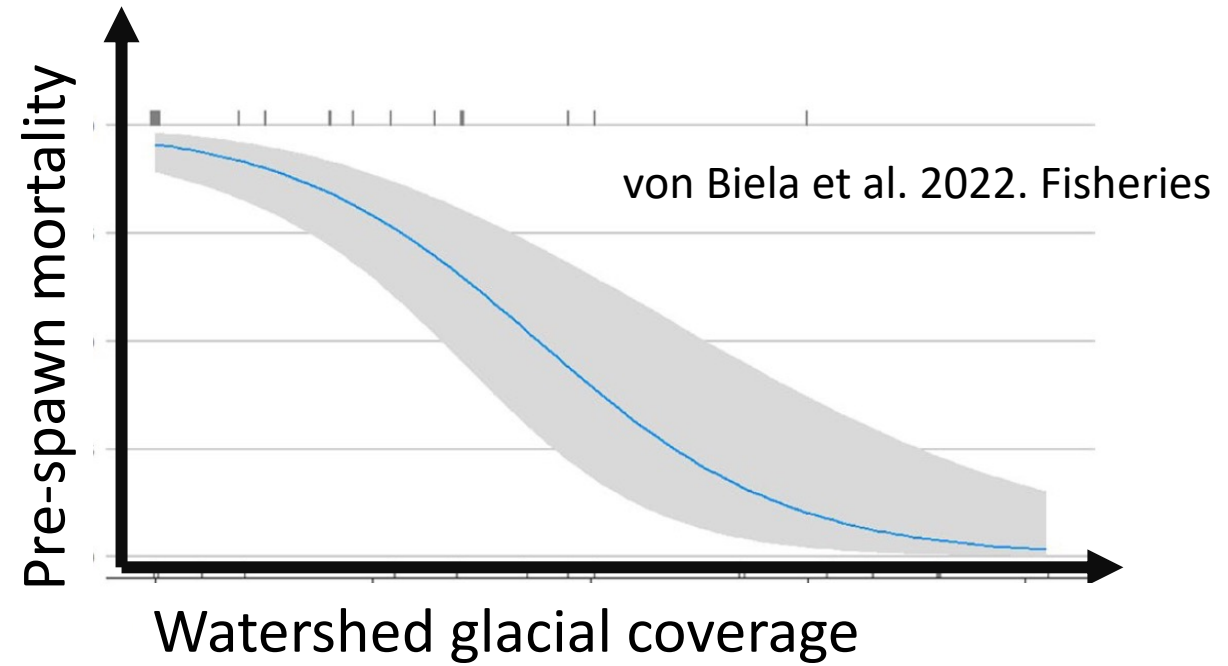
Glacial retreat

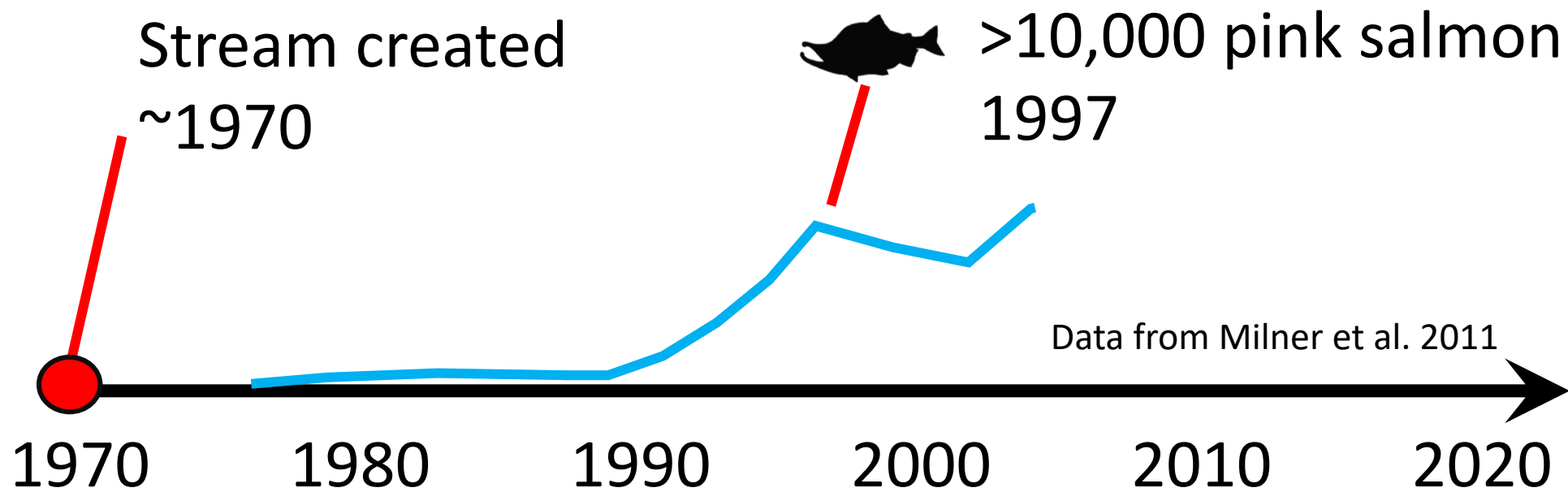
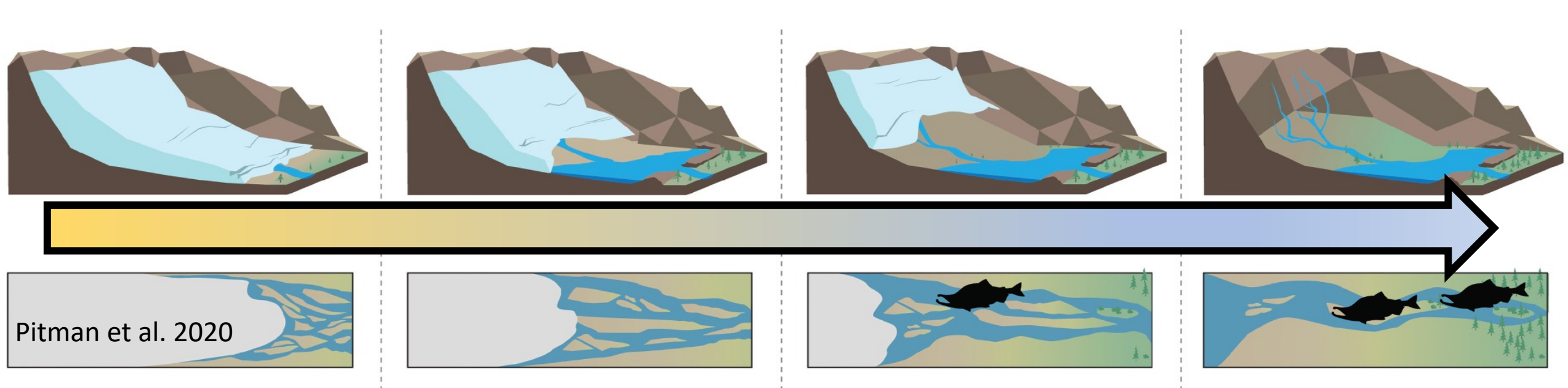
- 80% of glaciers gone in western Canada by 2100 with moderate emissions

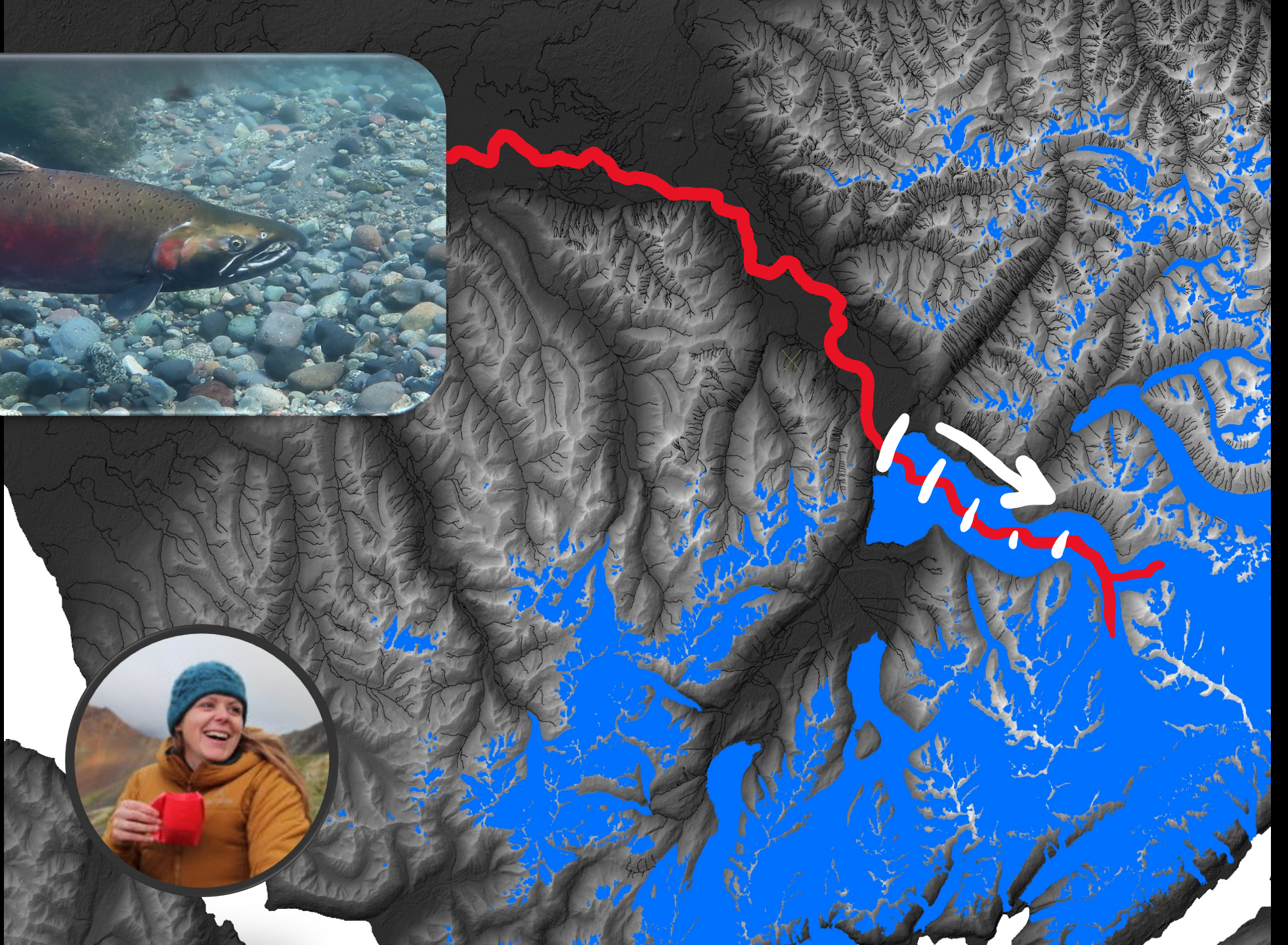
2019 Drought in Alaska



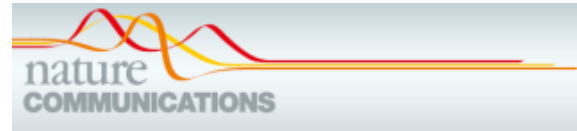
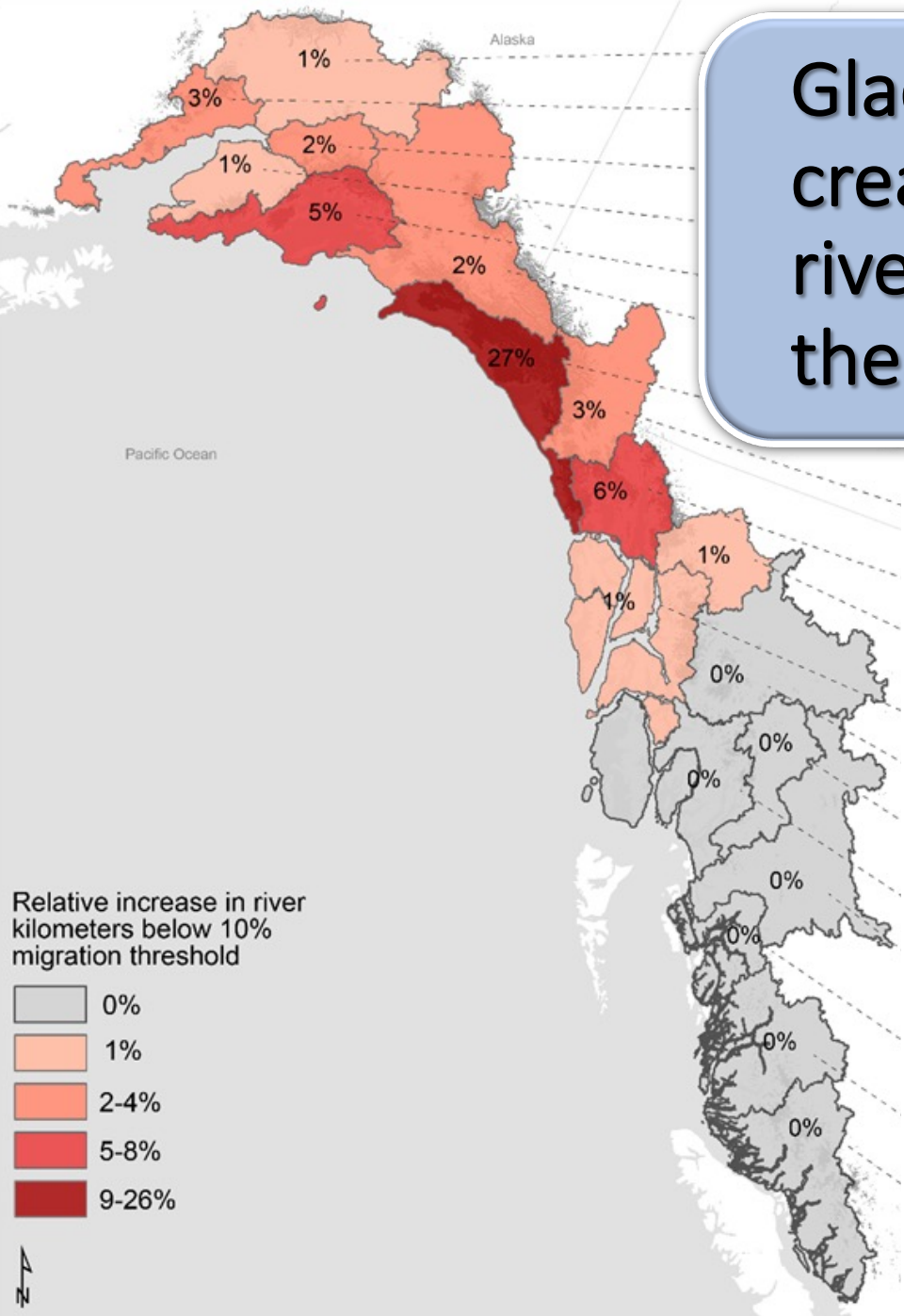
Glaciers provide cool summer water to salmon streams







Glacier retreat will create >6000 km of new rivers for salmon over the next 100 years



ARTICLE

<https://doi.org/10.1038/s41467-021-26897-2> OPEN

Check for updates

Glacier retreat creating new Pacific salmon habitat in western North America

Kara J. Pitman¹, Jonathan W. Moore¹, Matthias Huss^{2,3,4}, Matthew R. Sloat⁵, Diane C. Whited⁶, Tim J. Beechie⁷, Rich Brenner⁸, Eran W. Hood⁹, Alexander M. Milner^{10,11}, George R. Pess¹², Gordan H. Reeves¹³ & Daniel E. Schindler¹⁴



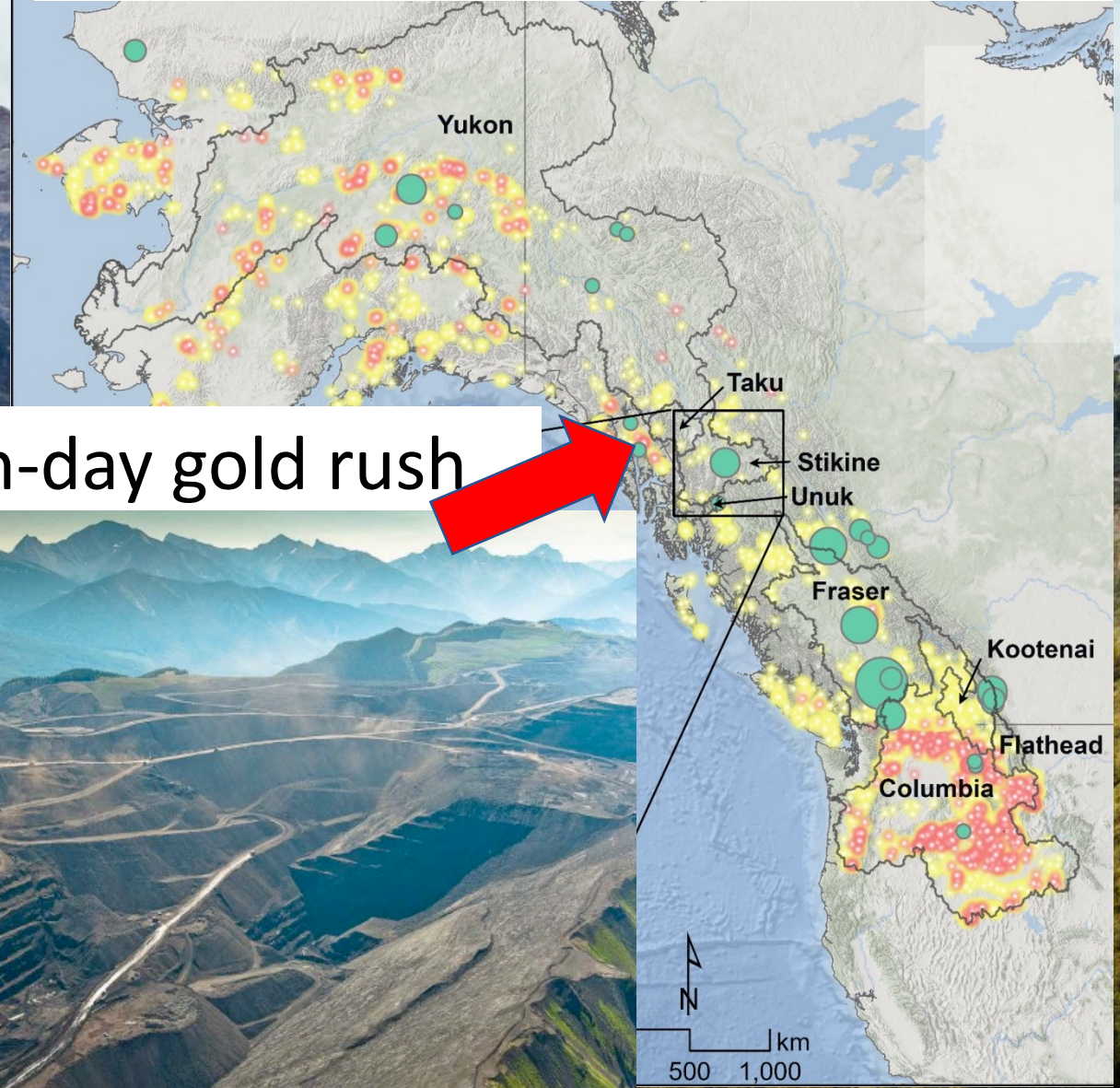
Glacier retreat— frontiers for salmon & mining

“In eight years of glacial retreat, at the rate it has been going, there could be an ore body sticking right out of the ground that nobody’s even seen before”

<https://www.mining.com/web/a-revival-takes-shape-in-bcs-golden-triangle/>



Mines across the salmon coast



Modern-day gold rush

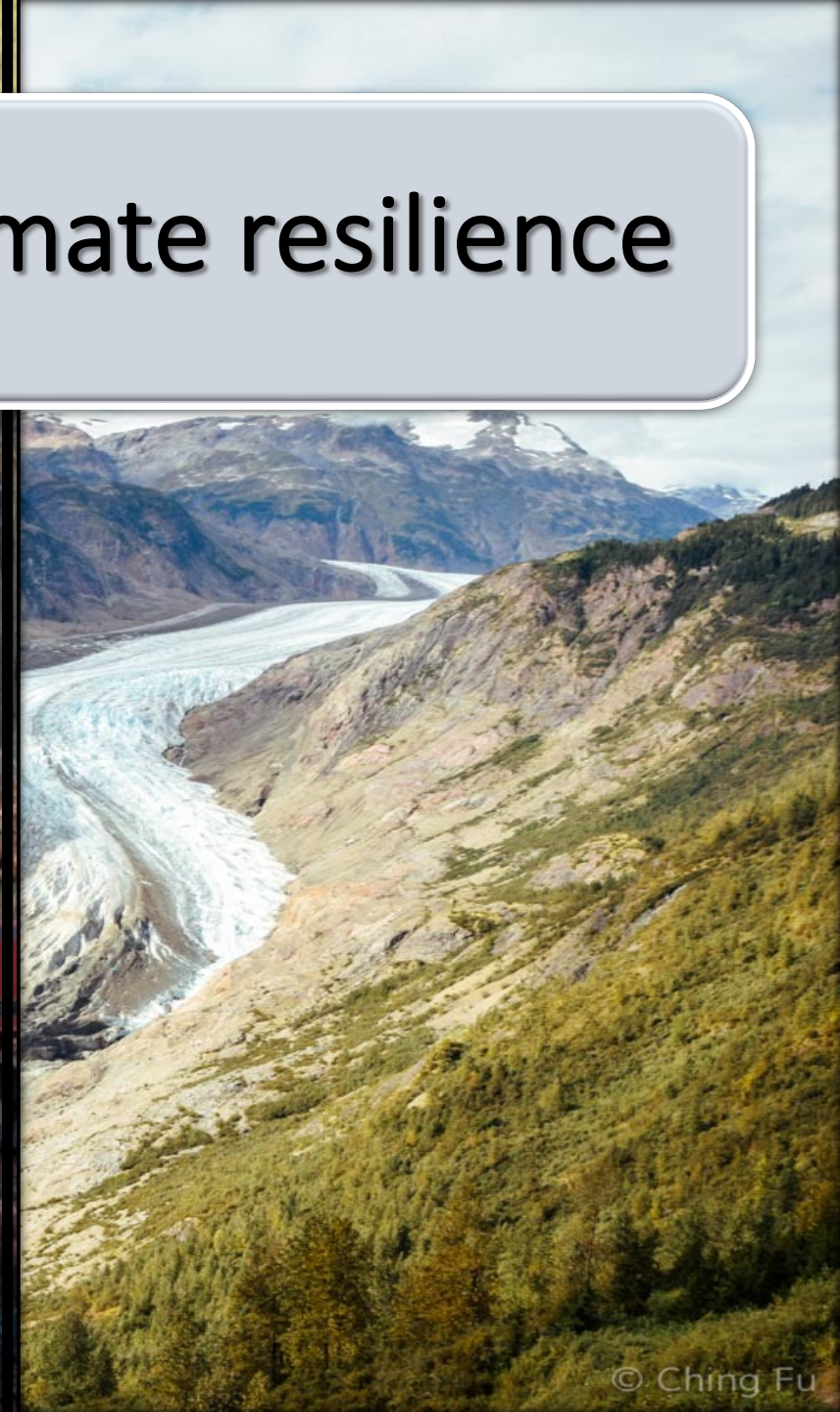
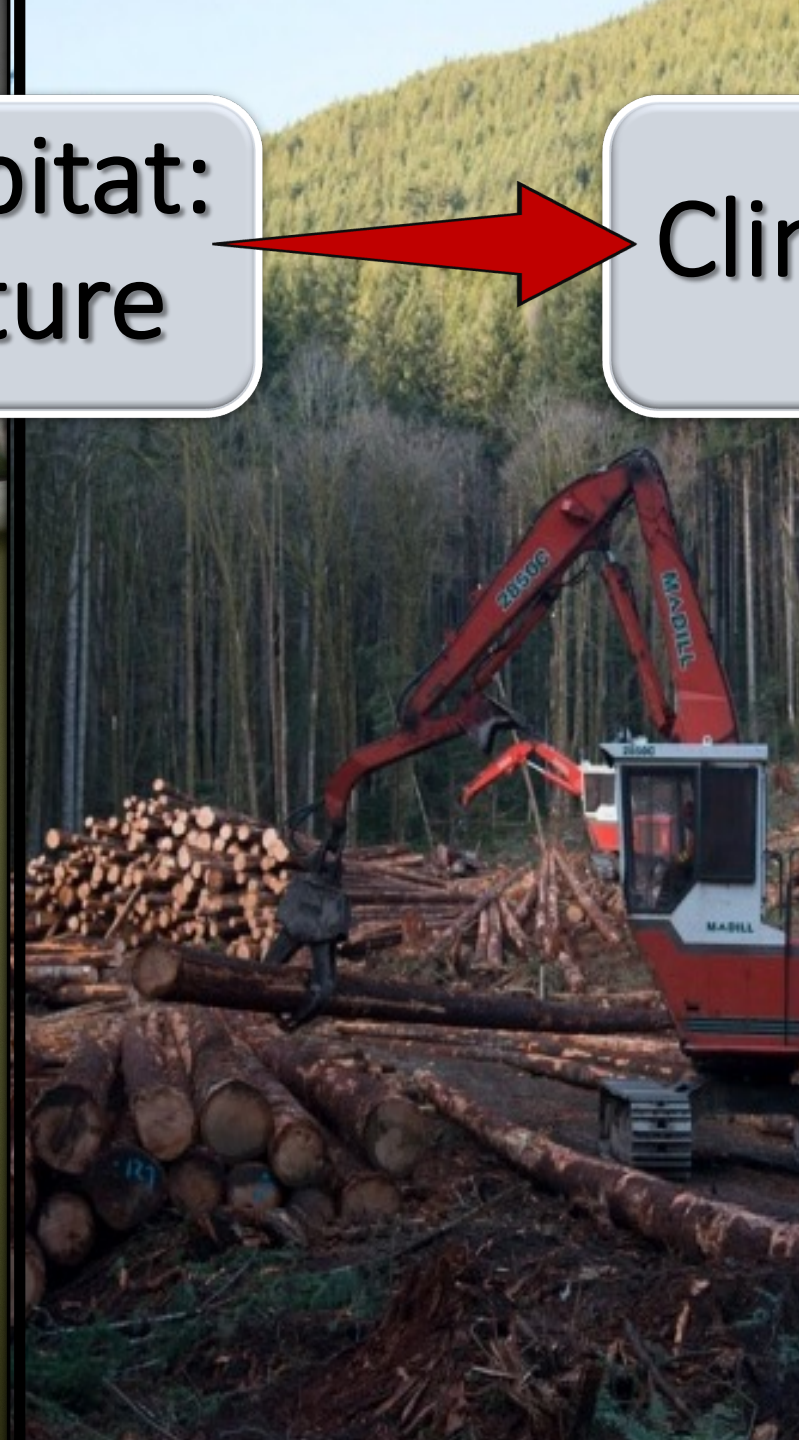
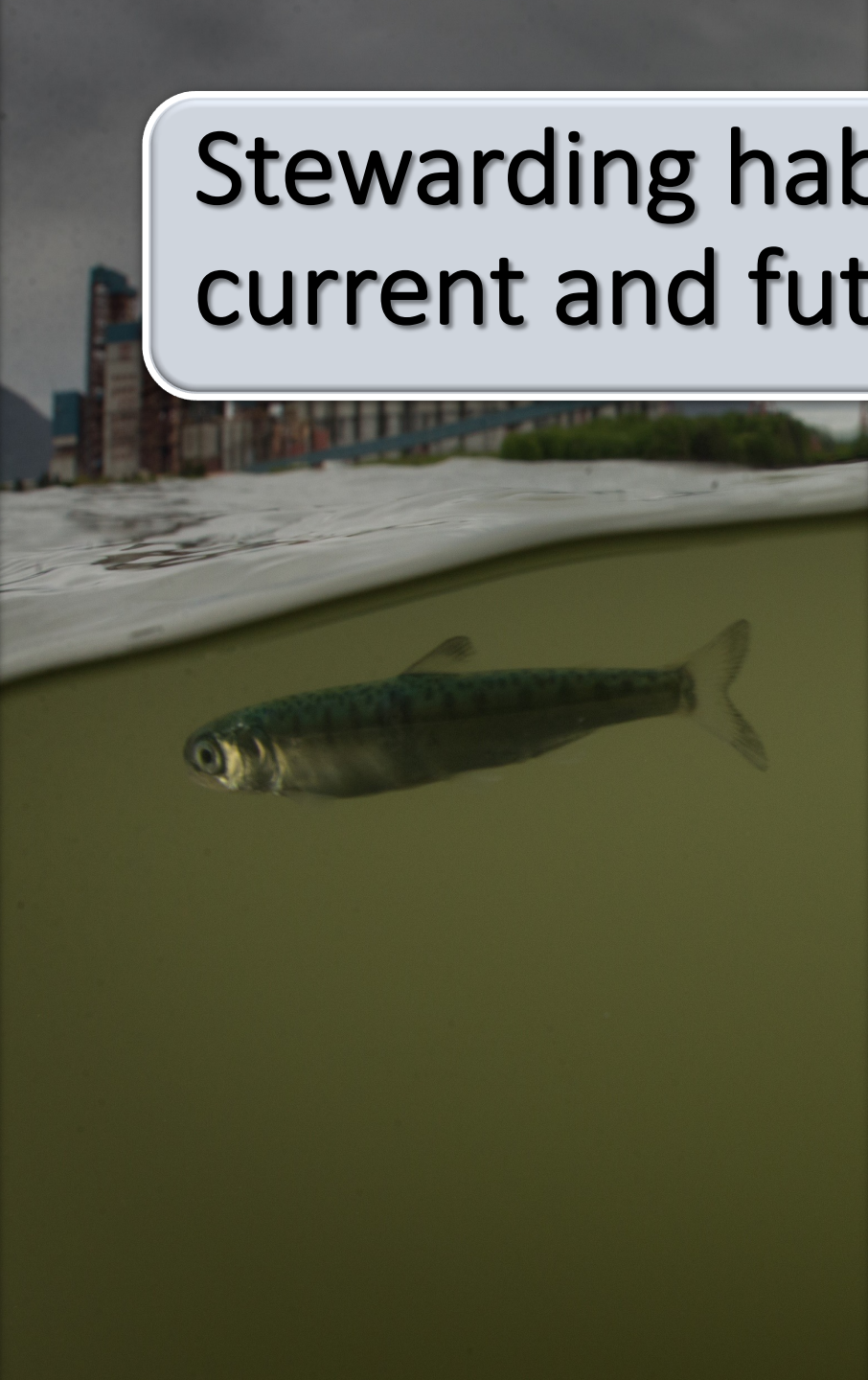


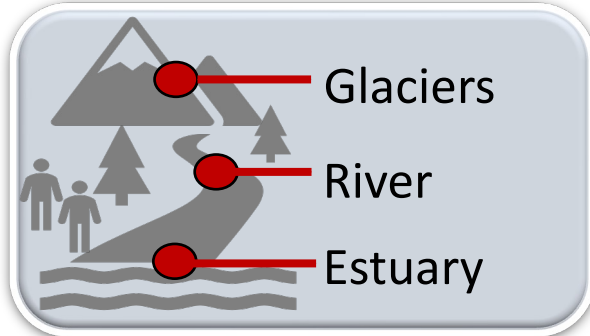
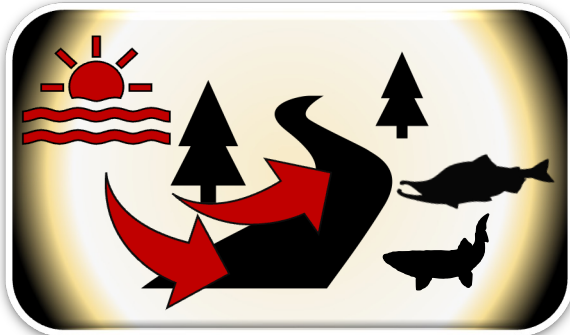
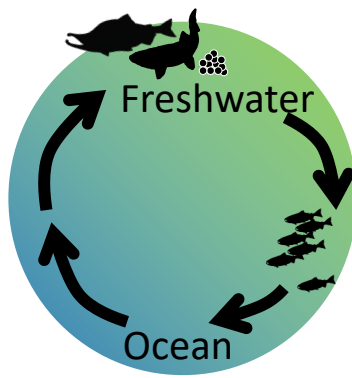
Sexton et al. 2020. Science.
Sergeant et al. 2022. Science Advances.

Stewarding habitat:
current and future



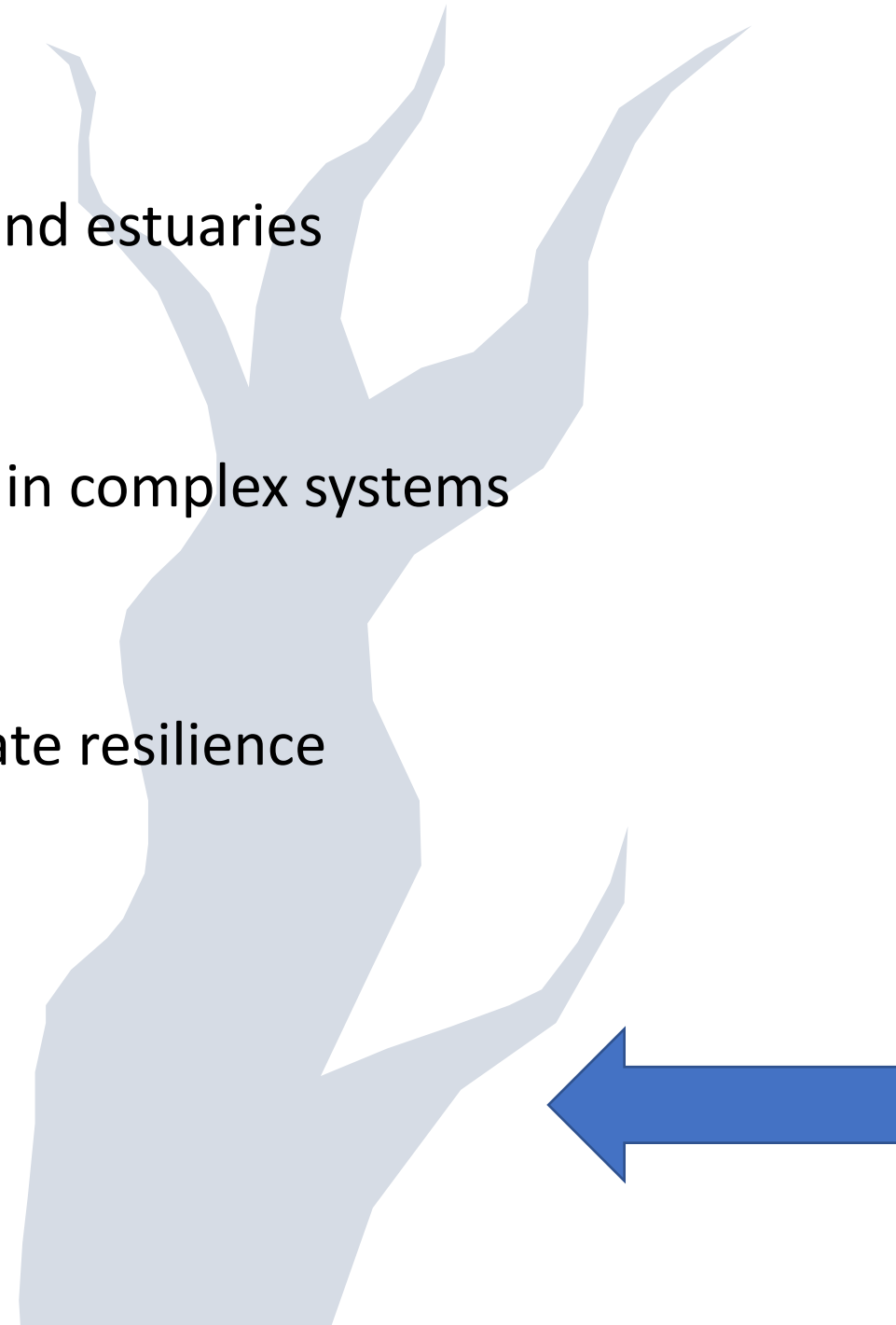
Climate resilience



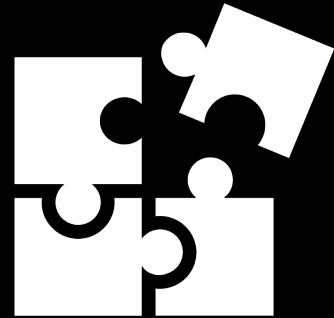
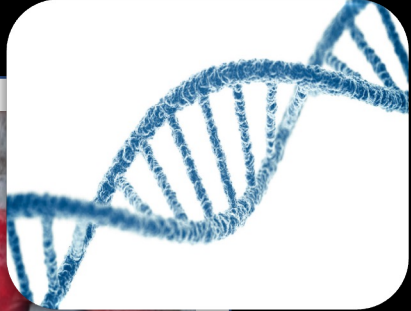


FLOW

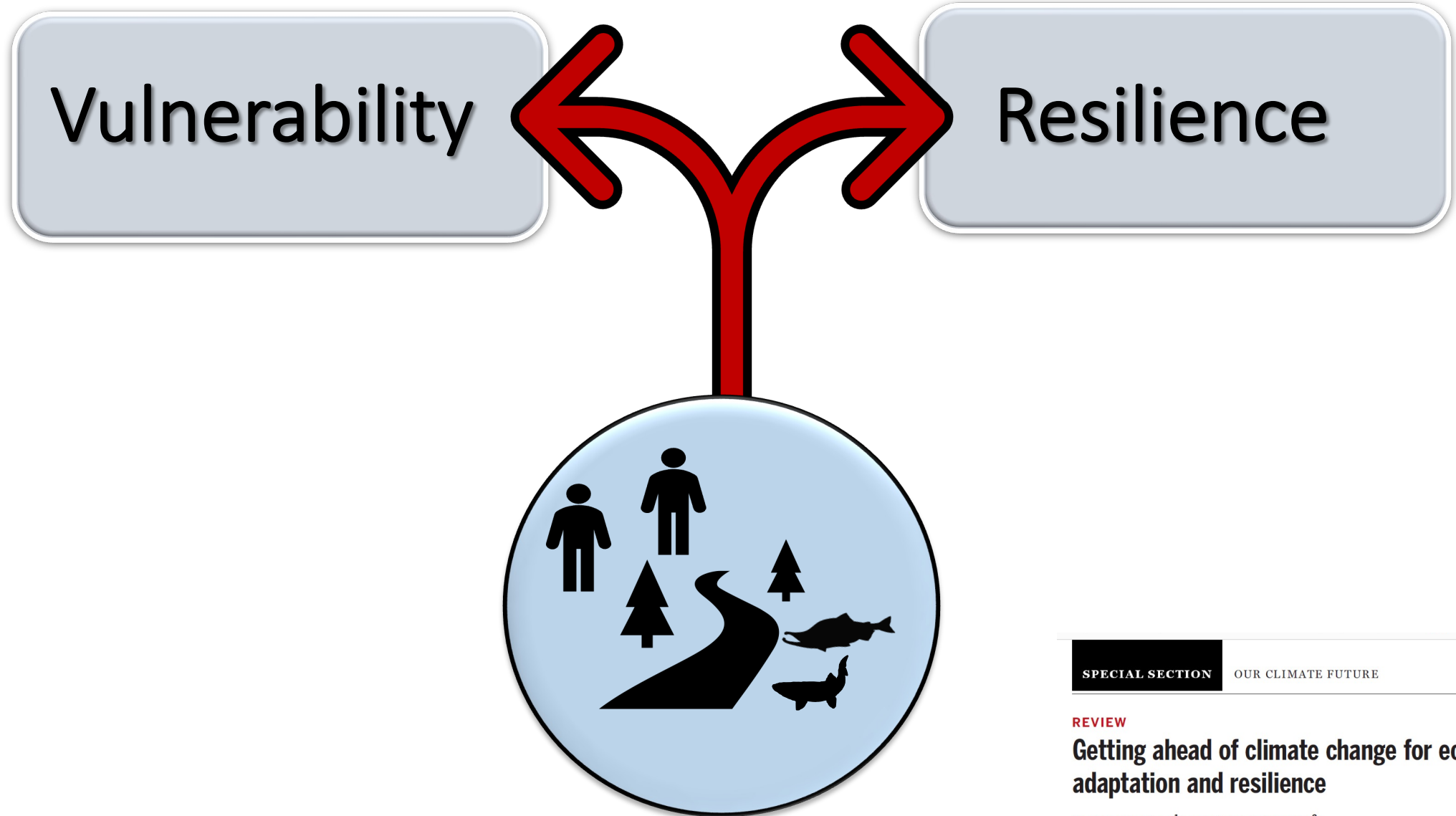
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Amazing biodiversity of salmon systems



Crossroads



SPECIAL SECTION OUR CLIMATE FUTURE


REVIEW

Getting ahead of climate change for ecological adaptation and resilience

Jonathan W. Moore^{1*} and Daniel E. Schindler^{2*}



Need for collaborative & forward-looking science, action

Jonathan Moore
jwmoore@sfu.ca
www.jonwmoore.org
[@jon_w_moore](https://twitter.com/jon_w_moore) 



Many many
collaborators!

 Wilburforce
Foundation

 MakeWay

 sitka
foundation

 Canada

GORDON AND BETTY
MOORE
FOUNDATION

 NSERC
CRSNG

LIBER  ERO
And more

Imagery:

Tavish Cambell

Danny Scurfield

Fernando Lessa

Freshwater Illustrated

Joanne Hammond





16:9. 20 min + 10 questions

- Back to the Future: Advances in understanding the value of fresh and brackish water habitats, their future with climate change, and the efficacy of habitat restoration