

9. K. Shirai, N. Yoshizawa, Y. Takebayashi, M. Murakami, *PLoS One* **14**, e0221561 (2019).
10. T. Sawano, Y. Nishikawa, A. Ozaki, C. Leppold, M. Tsubokura, *J. Rad. Res.* **59**, 381 (2018).
11. M. Tsubokura *et al.*, *PLoS One* **13**, e0203594 (2018).

10.1126/science.aaz3408

## Salmon in clear and present danger

During the summer of 2019, record heat events caused thousands of adult Pacific salmon to die of heat stress while migrating to their spawning grounds throughout Alaska (1). These die-offs come as many rivers in western North America have started transitioning to a regime of lower summer flows and higher temperatures during the salmon migration and spawning season (2). This transition, driven by warmer air temperatures and reduced snow and ice, will increase in severity and pervasiveness during the next few decades (3). Marine heat waves are also increasing in frequency (4), causing poor marine survival of many salmon populations (5). The threat of climate change is here and demands action now.

Curtailing the rise of global air temperatures by reducing carbon emissions is vital for salmon conservation. Aside from emission reductions, we urge federal governments to prioritize climate change resilience in fisheries and environmental policy. This means protecting evolutionarily unique populations of salmon as well as diverse landscapes that naturally vary in hydrology (6, 7). It also means that the remaining hotspots of salmon productivity



Record heat has caused salmon to die from heat stress, putting populations at risk.

must be safeguarded against degradation.

One such region is the watersheds of Bristol Bay, Alaska, where the controversial Pebble Mine has been proposed (8). Bristol Bay supports the most abundant sockeye salmon populations in the world, with a wild salmon fishery that provides 12,000 jobs and generates \$1.5 billion annually (9) while providing food security for rural Alaskans. However, the U.S. Environmental Protection Agency recently overturned its previous conclusion that the mine would cause irreparable harm to this ecosystem (10); barring congressional intervention, the final permitting decision is expected from the U.S. Army Corps of Engineers in early 2020.

Habitat destruction has driven the collapse of wild salmon fisheries from California to Washington, where 93% of wild salmon abundance has been lost (11). Intact habitat confers resilience to environmental change; the Pebble Mine would erode resilience when it is needed most. The warming caused by global carbon emissions will continue to kill salmon (12) and will kill the jobs and food security that salmon provide if our governments do not give them a fighting chance.

Nicolas J. Muñoz<sup>1\*</sup>, John D. Reynolds<sup>1</sup>, Jonathan W. Moore<sup>1</sup>, Bryan D. Neff<sup>2</sup>

<sup>1</sup>Earth to Ocean Research Group, Simon Fraser University, Burnaby, BC, Canada. <sup>2</sup>Department of Biology, Western University, London, ON, Canada. \*Corresponding author. Email: nmunoz445@gmail.com

### REFERENCES AND NOTES

1. M. C. Martin, "Warm waters across Alaska cause salmon die-offs" *Juneau Empire* (2019); [www.juneauempire.com/news/warm-waters-across-alaska-cause-salmon-die-offs/](http://www.juneauempire.com/news/warm-waters-across-alaska-cause-salmon-die-offs/).
2. P. W. Mote, A. F. Hamlet, M. P. Clark, D. P. Lettenmaier, *Bull. Amer. Meteor. Soc.* **86**, 39 (2005).
3. S. U. Islam, S. J. Déry, A. T. Werner, *J. Hydrometeorol.* **18**, 473 (2017).
4. T. L. Frölicher, C. Laufkötter, *Nat. Commun.* **9**, 650 (2018).
5. S. T. Lindley *et al.*, "What caused the Sacramento River fall Chinook stock collapse?" (Tech. Memo NMFS-SWFSC-447, National Oceanic and Atmospheric Administration, 2009).
6. K. I. Ashley, in *Salmon 2100: The Future of Wild Pacific Salmon*, R. T. Lackey, D. H. Lach, S. L. Duncan, Eds. (AFS, 2006), chap. 4.
7. D. E. Schindler *et al.*, *Fisheries* **33**, 502 (2008).
8. U.S. Army Corps of Engineers (USACE), "Pebble Project EIS" (USACE, 2019); [www.pebbleprojecteis.com/](http://www.pebbleprojecteis.com/).
9. G. Knapp, M. Guettabi, S. Goldsmith, "The economic importance of the Bristol Bay salmon industry" (Institute of Social and Economic Research, 2013; <https://iseralaska.org/publications/?id=1410>).
10. S. Bronstein, C. Devine, D. Griffin, A. Hackett, "EPA dropped salmon protection after Trump met with Alaska governor" *CNN* (2019); [www.cnn.com/2019/08/09/us/epa-alaska-pebble-mine-salmon-invs/index.html](http://www.cnn.com/2019/08/09/us/epa-alaska-pebble-mine-salmon-invs/index.html).
11. T. Gresh, J. Lichatowich, P. Schoonmaker, *Fisheries* **25**, 15 (2000).
12. N. J. Muñoz, A. P. Farrell, J. W. Heath, B. D. Neff, *Nat. Clim. Change* **5**, 163 (2015).

10.1126/science.aaz3914