PRESS RELEASE

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Hot spots of salmon production shift across Western Alaska's largest rivers and stabilize the region's critical fisheries

Chemical signatures imprinted on tiny stones that form inside the ears of fish show that Alaska's most productive salmon populations, and the fisheries they support, depend on the entire watershed and the diversity of populations and habitats represented at the ecosystem scale.

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Chinook salmon born in the Yukon and Kuskokwim rivers, and sockeye and Chinook salmon of the Nushagak River and their network of streams, rivers, and lakes in western Alaska use the whole basin for spawning. As juveniles they use these habitat networks for the best places to find prey, shelter and safety from predators. From birth until the fish migrate to the ocean a year later is a critical period for young salmon to eat and grow.

By analyzing each fish's ear stone — called an otolith — scientists have found that different parts of these large watersheds are hot spots for salmon production and growth, and these favorable locations change year to year depending on how climate conditions interact with local landscape features like topography to affect the value of habitats.

A new study, led by the University of Washington, appeared May 24, 2019 in Science. This study quantified how Chinook and sockeye salmon production shifts across the Nushagak River basin (Figure 1).

The research team, with funding from the AYK-SSI, has developed and applied this analytical framework to quantify how Chinook salmon production shifts across the Yukon and Kuskokwim rivers as well. In all three of these vast rivers systems, the production of salmon is patchy across the landscape. Some habitats are more productive than others for any given year (see Figure 2-5).

"We found that the areas where fish are born and grow flicker on and off each year in terms of productivity," said lead author Sean Brennan, a postdoctoral researcher at the UW School of Aquatic and Fishery Sciences. "Habitat conditions aren't static, and optimal places shift around. If you want to stabilize fish production over the years, the only strategy is to keep all of the options on the table."

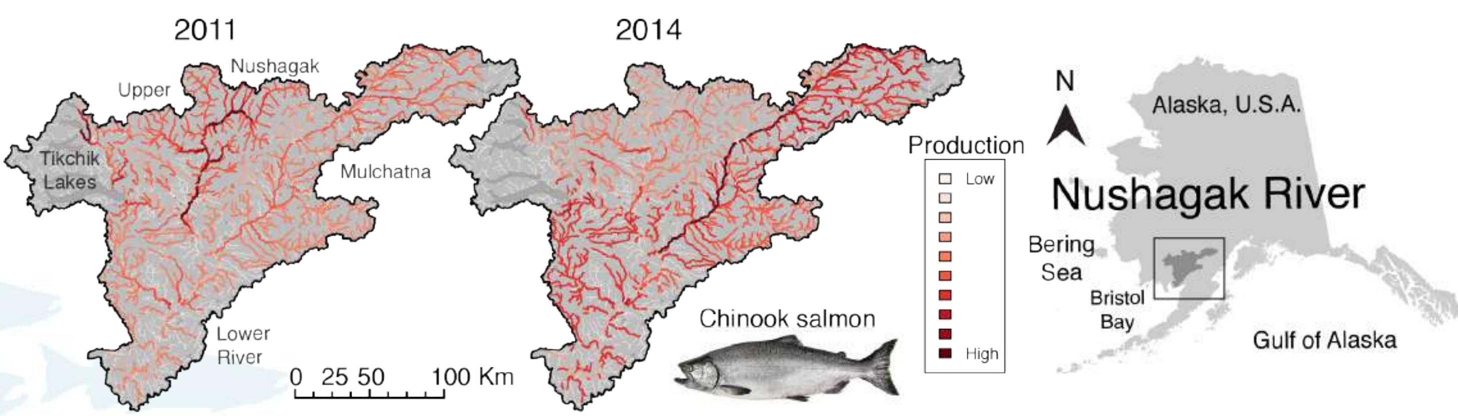


Figure 1: Hot spots of Chinook salmon production shift across the Nushagak River basin year to year. The Nushagak's portfolio of habitats, life histories, and locally adapted populations makes the fisheries of this region more reliable [redrawn from Brennan et al., *Science* 364, 783-786, (2019)]

The Yukon, Kuskokwim, and Nushagak river watersheds are the largest river basins in western Alaska. Together, these basins support the production of approximately 80 percent of the wild Chinook salmon globally.

The new *Science* study on the Nushagak, plus the ongoing studies in the Yukon and Kuskokwim, show that key salmon habitat shifts year to year, and how productive one area is for a short period might not represent its overall value to the fish population or larger ecosystem.

"The overall system is more than just the sum of its parts, and small pieces of habitat can be disproportionately important," said senior author Daniel Schindler, a professor at the UW School of Aquatic and Fishery Sciences. "The arrows point to the need to protect or restore at the entire basin scale if we want rivers to continue to function as they should in nature." The ecosystem is relatively stable because different stocks originating from areas of the watershed compensate for each other's booms and busts. This also has important implications for the fisheries of these river basins because it leads to more stable harvests year-to-year (Figure 2).

The research team has reconstructed the likely geographic locations of nearly 3,650 adult salmon (~250 fish per species per river per year) from their birth in a Yukon, Kuskokwim, or Nushagak stream until they migrated to the ocean. These annual production estimates span from 2010-2018 in the Yukon, 2017-2018 in the Kuskokwim, and 2011-2015 in the Nushagak. By looking at each fish's otolith — which accumulates layers as the animal grows — researchers can tell where the fish lived by matching the chemical signatures imprinted on each "growth ring" of the otolith with the chemical signatures of the water in which they swam.

These chemical signatures come from isotopes of the trace element strontium, found in bedrock. Strontium's isotopic makeup varies geographically from one tributary to another, particularly in the Yukon and Kuskokwim basins, making it easy to tell where and when a fish spent time.

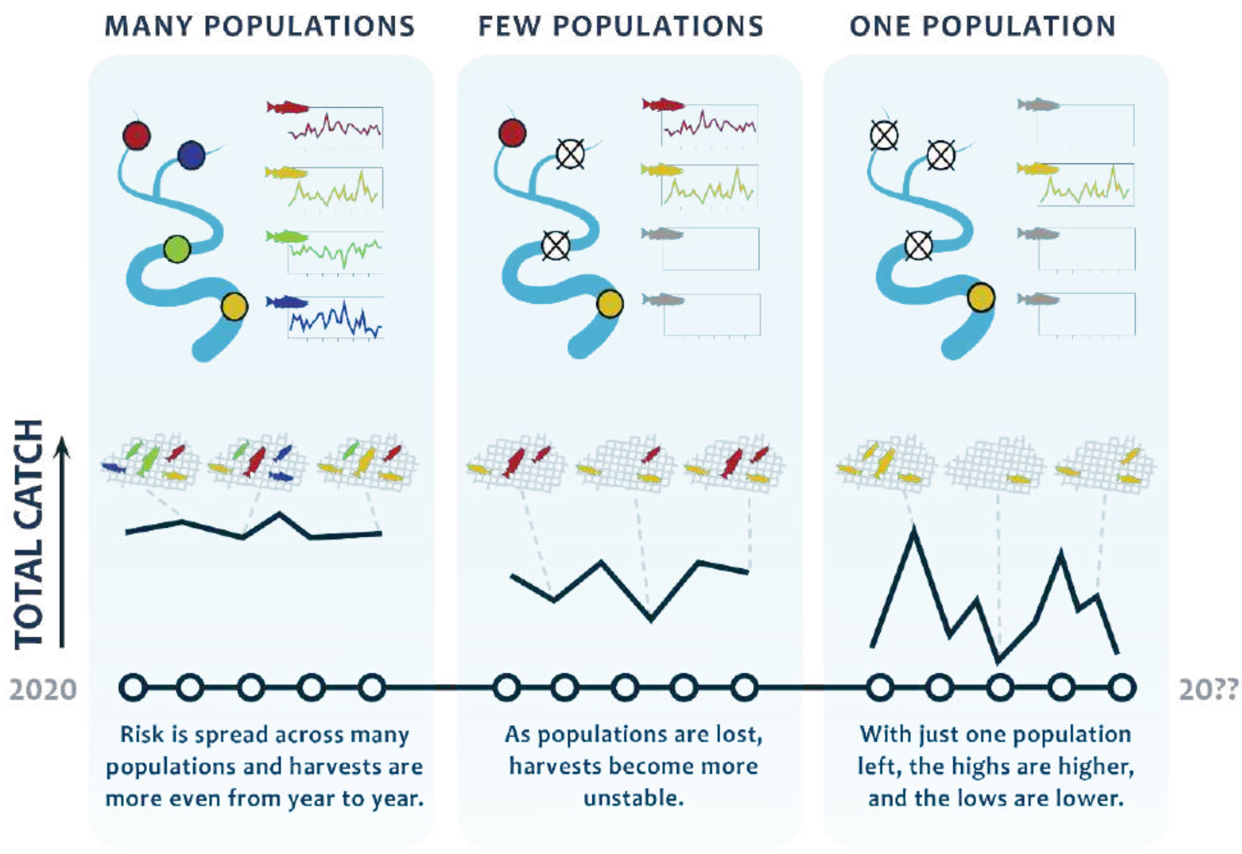
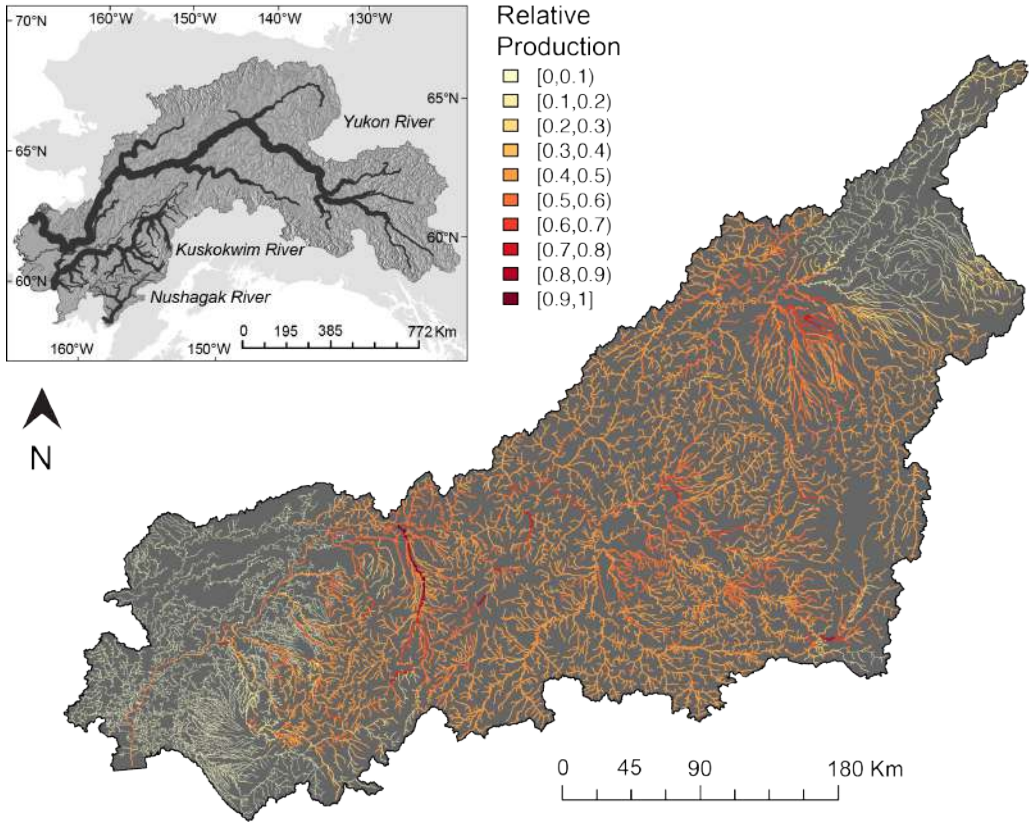


Figure 2: Illustration of how population diversity contributes to harvest stability. When diversity is high, individual populations doing very well can compensate for those that are doing badly, leading to a more stable average harvest over time. When diversity is low, all your eggs are in one basket and so harvest is more unpredictable from year to year



<u>Figure 3:</u> Results showing the spatial pattern of production of Chinook salmon across the Kuskokwim River from the 2017 return. The production is not spread evenly across the basin

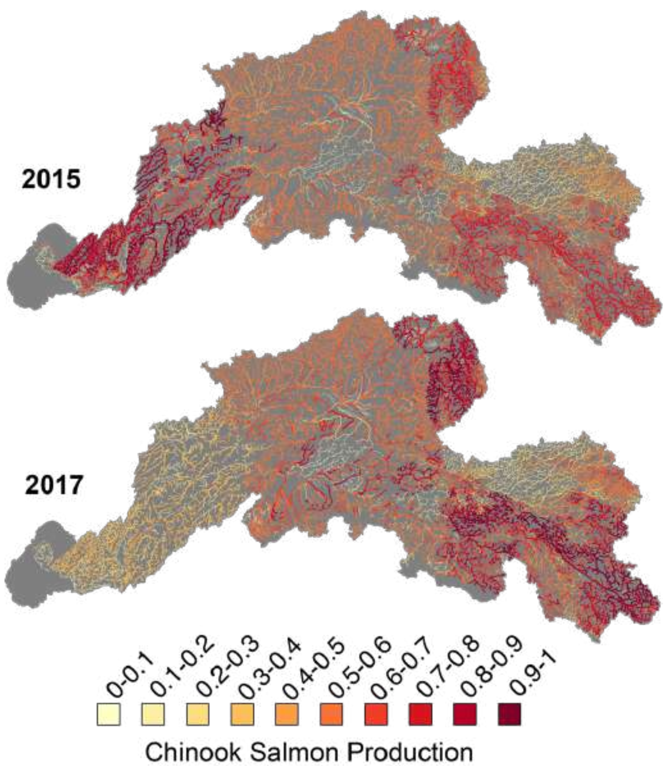


Figure 4: Shifts in the spatial pattern of Chinook salmon production among return years in the Yukon River basin. These estimates are based on the run composition up to the peak of each run.

"The otolith is this natural archive that basically provides a transcript of how a fish moved downstream through the river network," Schindler said. "Essentially, we're sampling the entire watershed and letting the fish tell us where the habitat conditions were most productive in that year."

In the Yukon River, the team has integrated both genetic and isotopic analyses to delineate the birth place of Chinook salmon (Figure 4 and 5). Combining these two natural tags provided much more fine scale and detailed information about the birth place of individual salmon than using any one of these two tags alone.

Results from the Kuskokwim River (Figure 3) and the Yukon River (Figure 4) support the results reported in the May 24 study in *Science* on the Nushagak River salmon ecosystem. Entire riverscapes are involved in producing Chinook salmon. When the biocomplexity of free-flowing rivers, and the processes that maintain it through time, remain intact – the critical fisheries of the region are more reliable. In the Nushagak, the researchers noticed significant shifts in production patterns when comparing where fish lived year to year (Figure 1). The ongoing projects in the Yukon and Kuskokwim are quantifying how these shifts play out in these other large river basins.

Similar types of shifts have been documented in a number of land- and water-based animal populations, but these studies on the Yukon, Kuskokwim, and Nushagak are the first to show the phenomenon at a watershed-wide scale, the authors said.

"The big thing we show is these types of dynamics are critical for stabilizing biological production through time. When you have a range of habitat available, the total production from the system tends to be more stable, reliable and resilient to environmental change," Brennan said.

The Yukon and Kuskokwim studies have been funded by the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYKSSI). The Nushagak study was funded by Bristol Bay Regional Seafood Development Association, the Bristol Bay Science Research Institute and the AYKSSI.

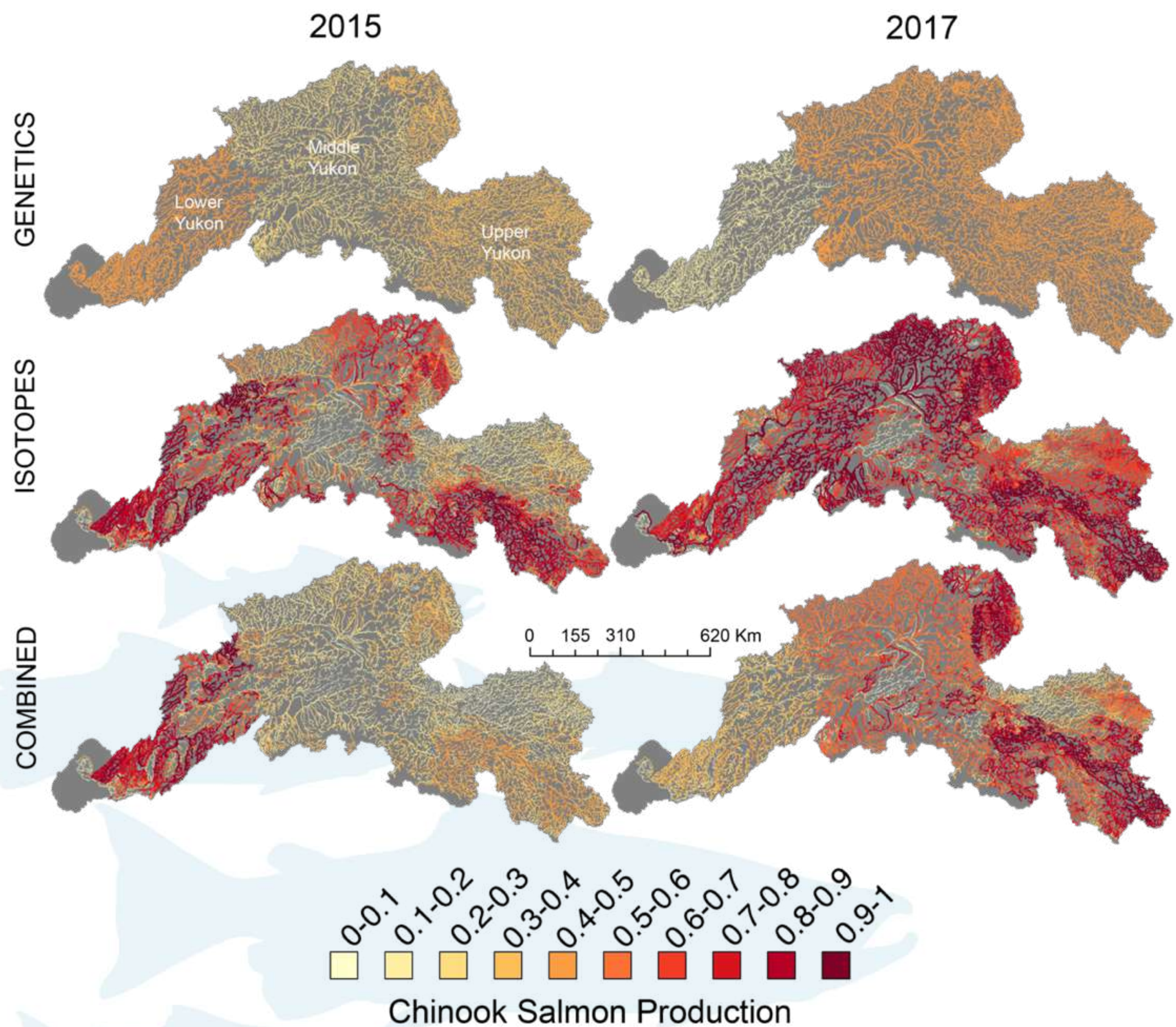


Figure 5: Yukon River results showing the power of integrating isotopes and genetics to quantify the spatial patterns of production of Chinook salmon across the Yukon River for the 2015 and 2017 return years. The 2015 return reflects fish sampled over the course of the entire run, whereas in 2017, the map shows the pattern from fish sampled up to the peak of the run. The different rows correspond to quantifying the spatial pattern of production using different methods (only genetics, only isotopes, and combining genetics and isotopes). The genetics-only maps depict the proportion of production for each year, whereas the isotope-only and combined maps are scaled by the maximum relative production value.

This research was made possible with support from AYK-SSI

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