Researchers Probe Deaths of Central Valley Chinook, with Possible Ties to Ocean Changes

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Deficiency in Vitamin B1 linked to higher juvenile mortality in California fish hatcheries.

Offspring of endangered female winter-run Sacramento River Chinook salmon that had been injected with thiamine on their return to the Livingston Stone National Fish Hatchery. Biologists brought them to UC Davis as embryos and then examined them to tell if the fish that received supplemental thiamine injections produced healthier offspring. Photo by Heather Bell/UC Davis.

Scientists from several fish and wildlife agencies have launched a rapid research and response effort for deficiency of thiamine, or Vitamin B1. This deficiency was recently found to be increasing juvenile mortality among Chinook salmon in California's Central Valley.

The magnitude of its effect is not clear. However, it could be a risk to Chinook stocks, including endangered winter-run Chinook salmon and the fishery for fall-run Chinook salmon.

Experts at the California Department of Fish and Wildlife's Fish Health Laboratory and UC Davis Aquatic Animal Health Laboratory first wondered whether an emerging virus was causing young salmon in fish hatcheries to swim in corkscrew patterns and die at unusually high rates last winter. When they could not pinpoint a cause for the high losses at hatcheries and in rivers, they shared their results with the U.S. Fish and Wildlife Service's California-Nevada Fish Health Center.

Investigators there noticed that a bath of thiamine immediately revived the ailing juveniles.

They now suspect the problem is linked to a deficiency of thiamine in the returning adult salmon that fed off the coast of central California in 2018 and 2019. This was a time of booming anchovy populations and scarcity of other typical salmon prey. Anchovies produce an enzyme called thiaminase that breaks down thiamine, which typically supports nerve, muscle, and heart function.

Scientists hypothesize that female Chinook salmon preying heavily on anchovy in the ocean returned to Central Valley rivers and streams with low thiamine concentrations in their eggs. The concentrations were so low it caused Thiamine Deficiency Complex, or TDC, in their offspring.

Impacts in Rivers Unclear

Biologists have observed TDC in multiple Central Valley Chinook salmon hatcheries, where they have proven methods for treating the condition. However, they know little about effects on naturally spawned juvenile salmon in rivers, where similar treatment is not possible.

Now scientists from NOAA Fisheries, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, U.S. Geological Survey and academic partners from UC Davis and SUNY Brockport are researching the cause and impacts of TDC on California salmon.

The research includes a major marine focus. Scientists from the NOAA Fisheries Southwest Fisheries Science Center are getting help from fishermen to sample salmon and document what they are eating offshore. Scientists at University of California Davis and the U.S. Fish and Wildlife's Livingston Stone National Fish Hatchery are also collaborating. They are investigating the effectiveness of thiamine injections in pre-spawning adult female winter-run Chinook salmon to mitigate TDC impacts on juvenile salmon behavior, performance, and survival.

Surveys off the West Coast in 2019 found the highest abundances of northern anchovy off central and southern California since systematic surveys began in 1983. The 2019 annual report of the California Cooperative Oceanic Fisheries Investigations called the conditions a "novel anchovy regime." Fishermen reported catching salmon with stomachs full of anchovy, but not other typical prey items such as krill, squid, juvenile rockfish, or sardines.

"We are trying to understand how the unusual ocean conditions off the West Coast in recent years affect the salmon that spend much of their lives in these waters," said research scientist Nathan Mantua of the Southwest Fisheries Science Center.

First Time Documented in California

Large populations of anchovy and some other marine forage fish have been found to cause deficiencies of thiamine among predators that consume them in other parts of the world, including the Great Lakes and Baltic Sea. Research in Alaska indicated thiamine deficiency may have reduced productivity of western Alaska's Chinook salmon in the mid-2010s.

This is the first time TDC has been documented in California salmon.

"We had never seen TDC issues at the Coleman National Fish Hatchery prior to this year, but the Service has some experience dealing with it at some of our other hatcheries back east," said Bob Clarke, deputy assistant regional director for Fish and Aquatic Conservation with the U.S. Fish and Wildlife Service. "Once our staff began to suspect TDC, we were able to move very quickly to a diagnosis and treatment for these hatchery fish."

Researchers and fisheries managers are concerned about potential impacts on endangered winter-run Chinook salmon, which spawn in the Sacramento River below Shasta Dam. Recent drought years took a toll on the species. Winter-run Chinook rely on cool water released from Lake Shasta to keep their incubating eggs and embryos alive.

At Livingston Stone National Fish Hatchery, U.S. Fish and Wildlife Service biologists have injected some returning female winter-run Chinook salmon with thiamine. That will help determine whether such supplementation reduces the likelihood of TDC in their offspring.

“This is similar to women taking prenatal vitamins when they are pregnant to make sure their babies get the important vitamins they need,” said Rachel Johnson, a research fishery biologist at the Southwest Fisheries Science Center and a leader of the research. “We are giving female salmon a nutritional boost to help produce healthy young fish.”

Staff at the U.S. Fish and Wildlife Service's Livingston Stone National Fish Hatchery prepare egg samples from endangered winter-run Chinook salmon for further study at UC Davis. Photo: Travis Webster/U.S. Fish and Wildlife Service

Less Visible Effects

Researchers are also concerned, however, about lingering, “sub-lethal” effects of TDC. Treating young fish in hatcheries may correct visible effects such as swimming in circles. While low levels of thiamine may not directly kill the juvenile fish, it may make them weak to fighting off diseases or escaping predators as they migrate into the ocean and back.

“That is a very real risk, but it is also very difficult to measure,” Johnson said. “The outcome is the same whether there is initial reproductive failure or whether juveniles die later due to their poor physical condition—fewer fish in the ocean for marine mammals to eat or for us to catch.”

Scientists will track the eventual fate of juvenile fish that had shown signs of TDC, including whether they were treated. That will help understand the magnitude of any sub-lethal risk to juvenile fish, and what might be done to reduce it.

“Thiamine Deficiency Complex is one example of how events in one ecosystem can have repercussions in others. We need to observe and better understand ongoing changes in ocean and freshwater ecosystems, and be ready for surprises,” said Steve Lindley, director of the Southwest Fisheries Science Center’s Santa Cruz Laboratory.

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