Marine heat waves found to trigger shift in hatch dates and early growth of Pacific cod

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Marine heat waves appear to trigger earlier reproduction, high mortality in early life stages and fewer surviving juvenile Pacific cod in the Gulf of Alaska, a new study from Oregon State University shows.

These changes in the hatch cycle and early growth patterns persisted in years following the marine heat waves, which could have implications for the future of Gulf of Alaska Pacific cod, an economically and culturally significant species, said Jessica Miller of OSU's Coastal Oregon Marine Experiment Station at Hatfield Marine Science Center in Newport and the study's senior author.

"We found that the fish were hatching two to three weeks earlier. To see that dramatic of a shift in hatch dates of a species due to a one- or two-year event is pretty remarkable," Miller said. "That those changes continue to persist suggests that marine heat waves might be having long-lasting impacts that also influence the likely trajectory of the species under climate change."

An otilith, or ear stone, from a Pacific cod. Credit: Jessica Miller, Oregon State University

The findings, which were just published in the journal *Elementa: Science of the Anthropocene*, could also have implications for future management of the fishery.

Pacific cod, perhaps best known as the key ingredient in fish and chips, is the second largest commercial groundfish fishery off the coast of Alaska. The 2022 commercial harvest totaled 403 million pounds and was valued at $225 million, according to NOAA Fisheries. The Gulf of Alaska stock is one of four Pacific cod stocks. It has a long history in Alaskan culture and is important to Indigenous communities in the region.

From 2014 to 2016 and in 2019, marine heat waves, which are periods of unusually high ocean temperatures, led to a steep decline in the abundance of adult Gulf of Alaska Pacific cod. As a result, the fishery was closed in 2020, and a federal disaster was declared in 2022.

Collecting juvenile Pacific cod. Credit: Ben Laurel, NOAA Alaska Fisheries Science Center

To better understand how these heat waves impacted the Gulf of Alaska population of Pacific cod, the researchers studied otoliths, or ear stones, from young Pacific cod. The tiny bony structures begin to grow during the embryonic stage of development and chronicle a fish's life in a manner similar to rings on trees.

Most fish die at the larval stage. The events of the first year of the animal's life impact their survival and ability to reproduce. Understanding how marine heat waves impact the fish's early growth

cycle provides critical information to researchers and to fisheries managers, Miller said.

"The stones are a common tool in fish ecology. They are a time capsule that can be very useful for tracking what the fish ate and how fast they grew across time," said Miller, a professor in the Department of Fisheries, Wildlife, and Conservation Sciences in OSU's College of Agricultural Sciences.

The researchers found that Pacific cod were hatching earlier during and after the 2014-2016 marine heat wave began, and those earlier hatches continued even when ocean temperatures cooled in 2017 and 2018.

Collecting juvenile Pacific cod. Credit: Ben Laurel, NOAA Alaska Fisheries Science Center

"Fish responded to temperature differently during and after the marine heat waves," said Zoe Almeida, who worked on the research as a post-doctoral scholar at Oregon State and is now at Cornell University. "Warmer temperatures only partially explained the earlier hatch dates in 2017 and 2018, and faster growth was not always associated with warmer temperatures as we often assume."

Overall, fewer juveniles survived the first year of life during marine heat waves.

"These are some complex, unexpected consequences we're seeing and will continue to see in the future as the climate changes," Miller said. "It's not just straightforward changes in growth, with the young fish growing faster because the ocean is warmer, as predicted by several models. The shifts in hatch timing influenced their body size as much, if not more, than the moderately faster growth, which can affect Pacific cod's ability to survive past the first year. There can be future impacts to reproduction timelines as well."

The findings suggest that fisheries managers may want to continue to monitor marine heat wave events and take a more conservative approach during subsequent years, when fish stocks are likely to be reduced, Miller said. Monitoring programs in the future may also have to be redesigned, in terms of their timing or types of nets used, to account for changes in spawn timing and body size.

The researchers are also working on three other projects to further

explore the impact of marine heat waves on Pacific cod, including characteristics of fish who survived the first year after a marine heat wave and cascading effects of growth pattern changes as the fish get older.

Additional co-authors are Hillary Thalmann of Oregon State and Benjamin Laurel of the National Oceanic and Atmospheric Administration's Alaska Fisheries Science Center.

More information: L. Zoe Almeida et al, Warmer, earlier, faster: Cumulative effects of Gulf of Alaska heatwaves on the early life history of Pacific cod, *Elem Sci Anth* (2024). DOI: 10.1525/elementa.2023.00050

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