Study proposes new explanation for California anchovy booms and busts

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A Northern Anchovy larva (25 mm long) collected during biological surveys and preserved in formalin. Credit: Credit: Rasmus Swalethorp

New research from Scripps and NOAA scientists has discovered ecological correlations that could help explain the booms and busts of

California's anchovy population. If the correlations hold up to further research, they could one day help inform management of California's anchovy fishery and improve conservation.

The Northern Anchovy (Engraulis mordax) is a crucial food source for much of California's most conspicuous marine life—including droves of sea lions, pods of dolphins, lucrative tuna fisheries, and throngs of whales. But one of the hallmarks of the anchovy population off California is the cycle of booms and busts that can last for more than a decade. These ups and downs reverberate through the entire marine ecosystem, with busts at times contributing to starving sea lion pups or leading brown pelicans to abandon their chicks.

Exactly what drives these booms and busts has remained elusive despite decades of scientific study, notably by the CalCOFI research program which is cooperatively run by UC San Diego's Scripps Institution of Oceanography, the National Oceanic and Atmospheric Administration (NOAA), and the California Department of Fish and Wildlife. The program surveys marine ecosystems up and down the California coast and is one of the largest and longest ocean monitoring programs in the world.

The study, published in *Nature Communications*, points to the marine ecosystem surrounding newly hatched anchovies known as larvae. The researchers analyzed 45 years' worth of anchovy larvae collected during CalCOFI surveys and found that the length of the food chain supporting the larvae strongly correlates with anchovy population booms and busts.

Specifically, shorter food chains preceded booms, and longer ones preceded busts. Shorter larval food chains have fewer steps of one animal eating another between the photosynthetic phytoplankton harvesting the sun's energy at the base of the food chain and the larvae, which eat mostly zooplankton.

Rasmus Swalethorp, the study's lead author and an associate project scientist at Scripps, said one of the likely explanations for this correlation is that shorter food chains are more efficient and result in more energy from the base of the food chain reaching the anchovy larvae. Swalethorp said this is because each time organisms from different parts of the food chain consume each other, there is a loss of energy that is known to occur.

"It's analogous to the energy loss that occurs when electricity goes from the power plant to our homes—the longer the distance, the more energy gets lost along the way," said Swalethorp. "That's how it is going from one level of a food chain to the next—the more steps, the less energy gets to the anchovy larvae. The larvae could be eating the exact same foods, but when the food chain elongates, it may mean food is less plentiful or that the same foods don't contain as much energy."

As a result, a shorter food chain can likely support more individual anchovy larvae.

Swalethorp began the research behind this paper in 2014, hoping to use the strength of CalCOFI's sampling program to better understand the mechanisms underpinning the rises and falls of this crucial player in the California Current Ecosystem.

"The ocean is a very big place, and our ability to sample it in a way that's representative is very limited," said Swalethorp. "CalCOFI is the most comprehensive ocean ecosystem survey on the planet, and it's the best shot we have at getting at these bigger ecological mechanisms."

Specifically, the researchers wanted to test the idea that a key determinant of how many Northern Anchovy survive the dangers of larval life in a given year is the structure of the food chain in which larvae participate. To do this, the researchers used stable nitrogen isotope analysis to determine the food chain length for 207 roughly three-week-old anchovy larvae collected by the CalCOFI program between 1960 and 2005.

In 2020, the team published a paper detailing this method of estimating food chain length in chemically preserved fish, which rests on the basic idea that when one organism eats another, the consumed creature leaves a chemical signature in the tissues of its consumer. In this case, the analysis doesn't reveal the precise identity of who was eating whom but could be used to infer how many links were in the food chain between the phytoplankton and the anchovy larvae.

The analysis revealed that shorter larval food chains tended to precede periods of booming anchovy populations by a year or two, and longer larval food chains were associated with depressed anchovy numbers in the following one to two years. Additionally, the changes in food chain length persisted throughout most of the boom and bust phases.

As for how and why food chain length might increase or decrease from year to year, Swalethorp offered some potential explanations.

"Young anchovy larvae are very susceptible to starvation, and their survival really depends on the efficiency by which energy reaches them," said Swalethorp. "If the food chain is short and efficient, that likely helps more larvae survive, which can help drive a boom cycle in the next year or two."

Because the current study can't identify the individual species in the longer and shorter food chains it found, Swalethorp said the study can't explain why longer food chains correlate to anchovy busts and vice versa. Regardless of why this correlation exists, Swalethorp said a larval food chain index—a yearly measurement of larval food chain length using stable nitrogen isotopes—could potentially be a useful tool for estimating anchovy population trends in the near future, but that more research is needed to explore its potential.

Swalethorp also noted that while larval food chain length appears to have been an important driver during the studied period, other important drivers exist, and their relative importance likely varies over space and time.

In the future, Swalethorp said extending the study's time series to the present would be fascinating because the current analysis does not cover the years following 2015, when anchovy populations once again boomed off California. He also said the team is beginning to probe the complex questions of who exactly is eating whom when the food chains elongate, as well as what is triggering these changes at the base of the food chain.

Beyond this, the true test of this correlation's explanatory power will be when the researchers attempt to apply it to other regions and other species of fish, such as the Peruvian anchoveta (Engraulis ringens)—the single largest fishery in the world.

More information: Michael Landry et al, Anchovy boom and bust linked to trophic shifts in larval diet, *Nature Communications* (2023). DOI: 10.1038/s41467-023-42966-0

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