UC SANTA BARBARA

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An Opaleye-opening Result

Whether it's warm outside or cold, people generally eat about the same amount. But a fish's appetite can vary enormously with the temperature. As coldblooded animals, their metabolism is governed by external conditions: It's slow going for a cold fish, but high temperatures kick them into high gear.

To better understand how temperature affects our finned friends, researchers at UC Santa Barbara studied opaleye fish under a variety of temperatures and diets. They found that both diet and temperature influenced fish physiology and metabolism, but the effects were specific to each trait. The results, published in the Journal of Experimental Biology, further chip away at the assumption that an animal's biological processes all respond the same way to different temperatures.

Opaleye were an ideal model to study this interaction. The omnivorous fish are a common sight in kelp forests and reefs from Point Conception to southern Baja California. In 2006, UCSB researchers found that wild opaleye eat more algae in the warmer, southern part of their range than in the colder north. And other omnivorous fish show a similar trend.

"We hypothesized they were doing this because it benefitted them," said lead author Emily Hardison, a doctoral student in the Department of Ecology, Evolution, and Marine Biology.

To test this, the team observed the fish under four different temperature and diet combinations. Half the fish were fed exclusively brine shrimp, while the other half

were free to eat a mixture of brine shrimp and *Ulva* algae, a species that opaleye consume in the wild. The researchers then divided each of these groups, with half in water at 12° Celsius and the other half at 20° C. These temperatures correspond to the seasonal extremes wild fish experience in Santa Barbara.

The team recorded the fish's growth over time and their sprint speed under the various treatments. They also measured the animals' baseline metabolic rates, as well as the maximum metabolic rate the fish achieved when they were active. To do this, the scientists used a method called aquatic respirometry, where they logged the rate of oxygen consumption for each fish after exercise and during rest. The difference between the maximum and the baseline rates is the animal's aerobic scope, which Hardison described as the fish's energetic capacity to thrive in its environment: swim, eat, digest, find a mate and so forth.

The researchers also conducted tests to establish the fish's thermal tolerance limits, including measuring the thermal tolerance of the animal's heart. Previous findings suggest that the heart may be the first organ to fail due to heat stress in fishes.



Hardison with her rod, reel and tiny hook fishing for opaleye in the Santa Barbara harbor. Juveniles are abundant in harbors throughout their range.

Photo Credit: SAMANTHA CSIK

“We found that diet could influence the temperature response that the fish had, but it wasn’t consistent across all these important measurements that we made,” Hardison said. Fish that ate a mixed diet had a higher baseline metabolism, which the researchers expected given that plant matter requires more energy to digest. Meanwhile, the fish’s sprint speed was completely unaffected by diet or temperature.

Diet also had no effect on the animals’ growth rates; however, temperature made an enormous difference. “At 20 degrees, the fish ate so much, and they grew so much. Whereas at 12 they barely ate, and they did not grow,” said co-author Erika Eliason, an assistant professor of ecological and evolutionary physiology.

“All these different rates don’t scale in the exact same way,” she continued. “Growth does not scale in the same way as heart rate, which doesn’t scale in the same way as metabolism. They’re all influenced by temperature in different ways.”

Scientists used to assume that all of an animal’s processes were optimized to the same temperature range. It certainly made modeling easier. “But biology’s complex,” said Hardison, “and so we think that the optimal range for different biological rates is going to be different.” While this is not the first paper to chip away at this assumption, it is the first to investigate how an animal’s diet may influence the optimal temperature for different processes.

Additionally, the more herbivorous diet didn’t seem to confer any benefits. For instance, omnivorous fish couldn’t achieve heart rates as high as their more carnivorous counterparts. This suggests that the mixed diet may have reduced their hearts’ capacity.

“That was a big surprise,” Hardison said. Since wild opaleye are more herbivorous in the warmer parts of their range, the researchers had thought this diet might help the fish’s hearts. “On the contrary, there were only costs to eating more algae. There were no benefits to the traits that we measured.

“That suggested it’s a more complex story than what we originally thought,” Hardison continued, “and that there could be other ecological reasons why these fish are changing their diet with temperature.”

Indeed, this is still an open question. The team plans to look into the digestive costs of an herbivorous diet, which might shed some light on the opaleye’s preferences.

The group is also investigating how a fish’s diet can influence its response to marine heatwaves. In order to respond to these events, animals need the energy and nutrients to remodel their physiology. As a result, the researchers suspect that diet may influence how quickly animals can acclimate to new conditions. “The intersection between nutrition and temperature is really understudied,” Hardison said.

Understanding the nexus of diet and environmental conditions is crucial in the face of climate change. Global warming is not only raising water temperatures, it’s also changing the nutritional landscape. Climate change can alter food quality and quantity, Eliason explained. So even for animals that don’t shift their diet in

response to temperature, what’s available to them might change.

And temperature is just one condition in flux. Climate change is affecting acidity, salinity and even dissolved oxygen content in the ocean. How these interact with animals’ diets and physiology is still under study.

Krista Kraskura and Jacey Van Wert (both in the Eliason lab) also contributed to this study, as did former UC Davis student Tina Nguyen, who spent eight weeks in the lab as part of the UC LEADS program. The work was funded by Eliason’s Hellman Faculty Fellowship.

About UC Santa Barbara

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