# Study finds oysters can take heat and heavy metals, but not both

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Pollution is bad for the sea life and so is global warming, but aquatic organisms can be resilient. However, even organisms tough enough to survive one major onslaught may find that a double whammy is more than their molecular biology can take.

A new study has found that even relatively low levels of heavy metal pollution can interfere with the metabolic processes of oysters, and that the effects of the pollution become particularly notable when oyster metabolism is also affected by high seasonal temperatures. The combined effect is strong enough to lead to fatal weakness and disease, adding a fundamental explanation for documented oyster declines in the wild. The effect also reveals an additional impact that warming coastal waters may have on cold-blooded organisms.

Investigating the mechanisms by which the heavy metal cadmium and temperature can each affect metabolic processes in oysters, a new report by a team headed by University of North Carolina at Charlotte ecophysiologist Inna Sokolova finds that both cadmium and temperature independently decrease the efficiency of metabolic processes in the oysters' mitochondria – the place where stored food is turned into the energy living cells run on.

The study also finds that cadmium can cause an increase in the production of reactive oxygen species – dangerous metabolic by-products – while higher temperatures hamper the cellular processes that normally prevent the compounds from causing damage. The findings will appear in the December issue of the *Journal of Experimental Biology*.

“We are studying a combination of factors,” said Sokolova. “Essentially what we are trying to look at is how oysters that live in metal-polluted environments respond to an increase in temperature, including normal seasonal increases in the summer, and global climate change, which will add to the problems they are already having in warm periods.”

Coming from human sources as diverse as cadmium-nickel batteries, yellow paint and mining, heavy metals like cadmium are common pollutants in estuaries where oysters live, Sokolova notes, but their concentrations occur at only few parts per billion – quantities long assumed to be too low to threaten marine life.

“We have looked at oysters’ metabolism, and have found out that their respiration rate increases when they are exposed to cadmium at environmentally relevant levels, as the organism spends more energy on basal maintenance,” Sokolova said.

“Metabolism also increases when they are exposed to higher temperatures. At some point, when they are exposed to both cadmium and higher temperatures, their metabolism can not go up any more and they start dying because they have hit the maximum level.”

In its native habitat on the east coast of North America, the eastern oyster lives in estuaries where the temperature ranges fluctuate seasonally -- from 0 to 4 degrees centigrade in the winter to temperatures as high as 35 degrees centigrade in the summer. According to Sokolova, past studies have shown that oysters stop growing at about 28 degrees centigrade, a temperature that can persist under normal summer conditions for several months in a row.

Through a series of studies examining the impact of cadmium concentrations and high temperatures at the environmental, organismal, cellular and biochemical levels, Sokolova and her team have narrowed the problem down to the effects of the two factors on a complicated series of chemical reactions that occur in the oysters' mitochondria in the process of cellular metabolism.

The researchers found that cadmium affects mitochondrial function by reducing the efficiency of the metabolic cycle in producing adenosine triphosphate (ATP), the main molecule that cells use to transfer energy. The inefficiency is particularly pronounced as temperatures approach or exceed 30 degrees centigrade. The researchers suspected that the cadmium caused a malfunction in one of the stages of oxygen respiration resulting in the increased production of potentially cell-damaging compounds known as reactive oxygen species (ROS).

"We found that if you measure production of reactive oxygen species in the presence of cadmium, it is strongly increased," Sokolova said. "Normally, the amount of oxygen that slips towards producing reactive oxygen is something like five percent in mollusks. When cadmium is present, then it is 30 percent," she noted.

"In the presence of cadmium, mitochondria use nearly 30 percent of the oxygen that they consume to produce reactive oxygen species instead of using it for ATP synthesis."

The research found that the cadmium-induced increase in ROS production does not harm oyster cells when the organisms are living in temperature conditions of 20 degrees centigrade or lower, as other chemical processes in the mitochondria are able to neutralize ROS under those conditions. However, at 30 degrees centigrade the researchers found that the cleanup processes cannot cope with ROS and oxidative damage occurs.

The team detected the effect by examining the metabolic enzyme aconitase, which is susceptible to damage from ROS. In the presence of cadmium and at 30 degrees centigrade, significant quantities of the enzyme were disabled, indicating oxidative damage.

“The degree of inactivation of aconitase can be used as a marker of how bad the oxidative damage is. We don’t really see a lot of oxidative damage at 20 degrees, even when we see a larger amount of reactive oxidative species being produced in the presence of cadmium. This means that the anti-oxidant systems are still adequate. But at 30 degrees the same concentrations of cadmium cause extensive oxidative damage and we see it in the inactivation of aconitase.”

According to Sokolova, the combined effects of temperature and heavy metal contamination on metabolic chemistry spell trouble for oysters and probably other cold blooded organisms as well. Though the levels of the pollutants have been determined to be tolerable, and oysters have evolved to be able to handle warm water temperatures for a few months, the combination pushes them to a crisis point where any further change (such as seasonal temperature increases caused by global warming) can make their survival unlikely.

“Oysters are right at the boundary already,” she said. “Some earlier studies show that oysters stop growing when the temperature is above 28 degrees. These conditions are stressful for them and they spend all their energy just staying alive – they don’t have anything extra that they can invest in growth. This also means that they don’t have anything extra that they can invest in protection against toxins that may be in the water. An increase in seasonal temperatures would be an additional problem.”

The current environmental stresses on oysters may in fact be partially responsible for recent outbreaks of disease that have already decimated many eastern oyster beds.

“Metabolic dysfunction can certainly contribute to disease susceptibility,” Sokolova noted. “A host-parasite relationship is always a two-sided story, and the outcome is dependent on the invasiveness and abundance of the parasite and the host's ability to ward the parasite off.

“Most immune functions are energy-dependent and quite expensive in energetic terms, so when energy demands for basal metabolic maintenance increase during temperature stress, less is left over for other functions such as immunity. On top of this, if the parasite can better and faster proliferate in the warmth, the balance can be tipped towards disease.”

Source: University of North Carolina at Charlotte

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