Mysteries on Moloka'i: Odd Invertebrates

As we descended into Kauhakō crater in Kalaupapa National Historical Park on Tuesday morning, November 1st, an unusual smell of rotten eggs wafted up from the lake in the crater's inner pit. We descended further and the smell intensified. At the lake's edge, the normally bright green water was a dark, foreboding blue-green. The normally abundant shrimp (*Palaemon debilis*) and aquatic insects were nowhere to be seen. "What", we asked ourselves, "had happened to the lake since our last visit?

Palaemon debilis, a normally common species in Lake Kauhakō. Photograph: Yuko Stender

Lake Kauhakō at the bottom of Kauhakō Crater on the Kalaupapa peninsula, is one of the most unique lakes entrusted to the National Park Service.

With a depth estimated at 832 feet, Lake Kauhakō has the greatest ratio of depth to surface area of any lake in the world.

The lake has brackish water at the surface, with salty, anaerobic (no oxygen) water at depths greater than 6 feet. However, there is no evidence to suggest that Lake Kauhakō has an open connection to the sea, even though it sits at sea level and is in close proximity to the Pacific Ocean.

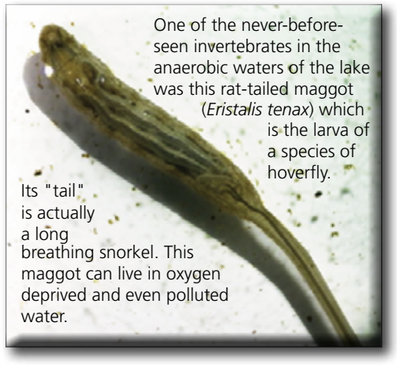
The plants and animals in Lake Kauhakō are normally restricted to the shallow, oxygen-rich surface layer. Nutrients in this upper layer support a dense and highly productive phytoplankton community, which in turn sustains invertebrates such as the native *palaemonid* shrimp. Below this layer, special bacteria survive by extracting energy from sulfate in the water. As a by-product, the bacteria produce a gas called hydrogen sulfide (H_2S), which smells of rotten eggs.

When we visited the lake in August 2011 for regular water quality testing, all appeared normal. However, after the November visit and the sulfurous smell, we began asking other community members if they had noticed the odor. Based on their reports, it appears that sometime after our August survey and before September 27, 2011 the lake began emitting hydrogen sulfide gas into the atmosphere, possibly the result of an "overturning" event in the lake.

Typically, an overturning event is caused by strong winds generating a convection current that starts on the surface and cycles through a water body like a conveyer belt. At Lake Kauhakō, however, the surface winds are not strong enough to create this current and cause upwelling of the deeper water. Rather, the deep, hydrogen-sulfide rich water may have come to the surface by one of two means: 1) a landslide which disrupted the boundary layer between the surface and deeper water layers, or 2) prolonged drought which resulted in evaporation of the brackish, oxygen-rich surface layer. Whatever the cause, the lake began to undergo a series of dramatic transformations on a daily basis, sometimes shifting water color several times within a day (see next page).

Our water quality monitoring efforts captured the dramatic changes that occurred in the surface waters of the lake as a result of this overturning event (see graph at bottom). After overturning, the surface water was saltier, more acidic, and most noticeably, lacking in oxygen (often >100% saturated, now only 2-3% oxygen).

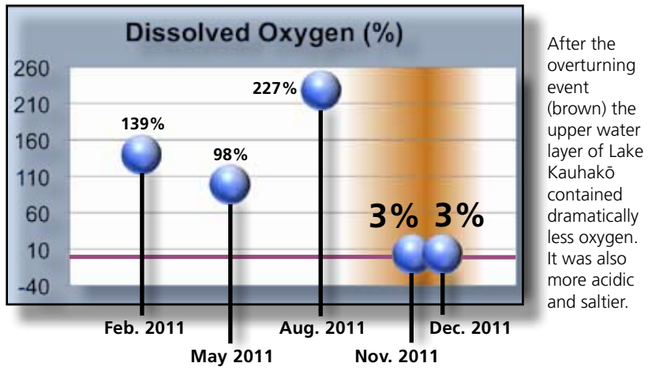
No wonder the shrimp couldn't survive! Phytoplankton in the lake also disappeared, and the water became extremely clear. Interestingly, two new-to-this-lake invertebrates were found, so it was not completely devoid of life.



One of the never-before-seen invertebrates in the anaerobic waters of the lake was this rat-tailed maggot (*Eristalis tenax*) which is the larva of a species of hoverfly.

Its "tail" is actually a long breathing snorkel. This maggot can live in oxygen deprived and even polluted water.

Although scientists had long suspected an event like this could occur in Lake Kauhakō, such an event had never been physically recorded at Kalaupapa. However, similar overturning events have occurred in stratified (layered) lakes in Africa, with devastating consequences. Lake Nyos in Cameroon partially overturned in August 1986, belching large quantities of carbon dioxide (CO_2) into the air and suffocating 1,700 nearby villagers. The H_2S gas emitted by Lake Kauhakō is extremely poisonous in high concentrations (>300 parts/million). CO_2 (which is odorless) may also have been emitted from the lake. Fortunately, the effects of this event appear limited to the lake itself, since no dead animals such as deer or birds have been found in the crater.



After the overturning event (brown) the upper water layer of Lake Kauhakō contained dramatically less oxygen. It was also more acidic and saltier.

As we continued to monitor the changes in the lake, we began to wonder if and when it would recover. On December 12, the lake water was clear, no shrimp were observed, and a hydrogen sulfide smell was still detectable in the air.

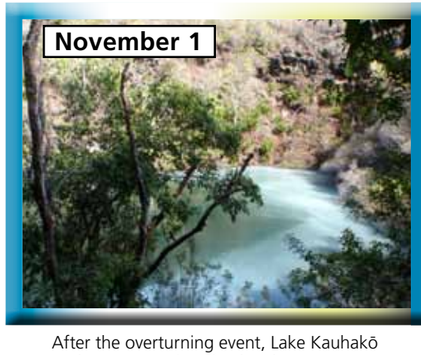
Heavy rains fell on Kalaupapa over the next 48 hours, causing a rapid and dramatic change in the lake. When we returned on December 14, we immediately noticed the lake was a bright green color, no smell was detected, and most incredibly, two *palaemonid* shrimp were spotted swimming along the rocky shore. It appeared the rain built a new oxygen-rich surface layer on the lake, trapping the anaerobic waters below. Phytoplankton had already begun to bloom, turning the water a murky, bright green (nearly normal color). The shrimp, which can survive for long periods under adverse conditions, had also begun to recover.

The recovery, however, was short-lived. The lake was back to a dark, blue-green color on December 16 with no signs of life. We will continue to monitor the lake, but there is now hope that the lake can renew itself in a short time span given the right conditions such as an abundance of rain. The mystery continues to unfold as we enter 2012.

...and a Lake that Changes Color

–E. Brown, NPS-KALA
Marine Ecologist
–K. Tice, NPS
Biological Technician

September 27: This is the first known photo after the overturning event.



After the overturning event, Lake Kauhakō underwent a series of color changes. November 1: the surface of the lake had a milky white layer, most likely caused by a bloom of sulfide oxidizing bacteria.

December 8 and 12: in the absence of phytoplankton, the lake was clear with a deep blue-green color.

December 14: after heavy rainfall, the lake had turned bright green as a result of a phytoplankton bloom.