Diver with an Acoustic Wave and Current (AWAC) profiler on the bottom of Hanauma Bay.

Do Internal Tides Influence Coral Distribution in Hanauma Bay?

by Katie Smith, UH Sea Grant graduate trainee

Just as waves form on the surface of the ocean—that is, the interface between the water and the air above it—waves also form on the interface between the ocean's cold, dense bottom water and the surface water above it, which is less dense due to being warmed by the sun. These underwater or "internal" waves can break on underwater slopes leading up to a shoreline, transporting the cold water from depth to shallower regions of the slope; this is similar to waves breaking on a beach and washing water up the beach slope. When deep water is transported by internal waves to shallower depths, it can affect the ecology of the organisms with which it comes in contact, since it is different from the ambient surface water that these organisms otherwise experience.

Coral reefs in particular can be influenced by the up-slope transport of deep water due to internal waves. Coral bleaching, when corals lose the symbiotic algae that not only give them color but also give them the ability to gain energy from the sun through photosynthesis, is one of the main dangers coral reefs face today. The cold temperatures of water carried by internal waves may reduce coral bleaching, because prolonged exposure to higher than normal temperatures is one of the main stressors that lead to bleaching. Additionally, the water from depth can have nutrient concentrations higher than ambient surface waters, due to the fact that algae use up most of the nutrients in the surface layer where light is available for photosynthesis, while in the deeper regions of the ocean without light for photosynthesis, far more nutrients are left available. The deep water can thus act essentially as a fertilizer to enhance coral growth. Corals influenced by physical features such as internal waves may react differently to the shifting conditions of climate change, ocean acidification, and other anthropogenic impacts. Therefore, understanding these interactions can help us assess the ability of different sectors of the coral community to survive in the changing environment.

Strong internal tides, which are internal waves that occur at tidal frequencies, are generated off the coast of Makapuʻu Point on the southeastern tip of Oʻahu. The internal tides propagate westward and enter nearby Hanauma Bay, a nature preserve and marine life conservation district with a vibrant coral reef community. But are the internal tides transporting cool water from depth over the coral reefs and influencing the health and growth of the coral community? That is one of the questions my research attempts to answer.

For this University of Hawai‘i Sea Grant project led by professor Mark Merrifield of the University of Hawai‘i at Mānoa, we in Dr. Merrifield’s lab placed several sensors on the bottom of Hanauma Bay from late February to mid June 2009 that measured the velocity of the water currents above the sensor as well as the bottom temperature. The temperature readings showed that beginning in May, not only did the temperature in the bay start to increase significantly due to the warming summer months, but there was also an increase in the daily temperature variability: about twice a day, the water temperature would drop significantly, then warm again. This variability is explained by internal tides entering the bay, because internal tides occur approximately twice daily, much like high tides at the beach. Internal tides are expected to be stronger in the summer because the water stratification, i.e., the layering of different water densities, is enhanced in the summer; increased warming of the surface water by the summer sun lowers the density of the surface water compared to the deep water even more than in the cooler winter.

By multiplying the measured temperature with the velocity of the water current, we can see not only the temperature but also what direction the water of that temperature is being transported and how fast it is moving. The sensor placed on the southwest side of the mouth of the bay showed a significant transport of cool water into the bay during the summer months, whereas the sensor on the northeast side of the mouth of the bay showed a significant transport of cool water out of the bay during the summer months. This indicates that during the summer, internal tides carry cool bottom water into Hanauma Bay on the southwest side, which then circulates and exits the bay on the northeast side.

Nutrient concentrations were not measured alongside the temperature and current, but the cold water associated with internal tides is reliably more nutrient-rich than surface water because it comes from depth. Thus it is a fair assumption to make that cold water entering the shallow Hanauma Bay with internal tides carries with it significant nutrients. As it happens, the population of live coral in Hanauma Bay is larger on the southwest side of the bay than the northeast side. This is consistent with a pattern of cool, nutrient-rich waters entering on the southwest side of the bay before being washed around and exiting on the northeast side, as is indicated by the data.

Further measurements are needed in the bay to confirm these findings. Temperature measured over the depth of the water column as well as currents would give us a picture of the vertical structure of the heat transport and internal tidal flows. Nutrient measurements could confirm the assumed link between cold-water pulses and nutrient-rich water.

Coral reefs are not only one of the most biologically diverse ecosystems in the world, they are also economically important, creating hundreds of billions of dollars worth of food, jobs, tourism, and coastal protection globally. Understanding how coral reefs are affected by their physical environment is important in helping us to predict their responses to environmental changes and allowing management to protect them accordingly.

Aerial view of Hanauma Bay with locations of sensors used for this study.