

Anchialine Pools: Windows To Hawai'i's Underground Labyrinth – *Loko 'Ōpae 'Ula: 'Īpuka I Ke Kaiāola Malalo Honua*



Native species clockwise from upper left: 'ūlilī (wandering tatter); naupaka kahakāi (beach naupaka); milo (portia tree); ae'o (Hawaiian stilts) in flight; makaloa (sedge); maiapilo (Hawaiian caper); 'akulikuli (sea purslane); pinao 'ula (orangeblack Hawaiian damselfly); 'ōpae huna (glass shrimp); large red shrimp; pipiwai (limpet-like snail); 'ōpae 'ula (small red shrimp); and cyanobacteria (yellow-orange colored algae) close up on rock in the foreground; ruppia (seagrass); 'ōpae 'ula, pipiwai, and cyanobacteria on rocks in the background on the left and right.

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Anchialine Pools: Windows To Hawai'i's Underground Labyrinth

Loko 'Ōpae 'Ula: 'Īpuka I Ke Kaiaola Malalo Honua

At Kīholo in Kona, Hawaiian *ali'i* once bathed in the cool, deep waters of an anchialine pool known as Luahinewai. Its name means “old woman’s water” and provides a clue that in this pool may live a female *mo'ō* – a water spirit. Luahinewai may also conceal a secret cave where the *mo'ō* guards the bones of ancient chiefs.

Anchialine pools reveal an underground labyrinth that often connects the pools to the sea. According to some local traditions, these underground passageways enable the *mo'ō* to travel unseen by those of us who live on land. Other inhabitants of anchialine pools, such as the endemic *'ōpae 'ula* (red shrimp), make use of these subterranean waterways as well.

How Are Anchialine Pools Formed?

The islands of Hawai'i emerged from the sea, and the ground we now live on is made from two kinds of rock. The first, basalt, is the most common, made of hardened lava from volcanoes. The second, limestone, is created by coral reefs and other marine life.

Coral reefs are extensive structures made by a combination of coral polyp animals and a special kind of limu called coralline algae. As marine animals and plants die, their calcium carbonate skeletons, shells, and other parts remain. With the action of time and chemistry, they become limestone. As ice ages come and go, sea levels rise and fall, and solid limestone reefs formed long ago are left above sea level as dry land.

Are lava rock and limestone completely solid? *'A'ole!* Basaltic lava is often full of cracks, layers, and pores, and water can move, sometimes very slowly, throughout the entire, 3-dimensional form of an island. In limestone, small spaces can become larger as raindrops – made slightly acidic from absorbing carbon dioxide from the air – dissolve the rock, enlarging a network of tunnels, sometimes into huge underground caverns. Lava flows and limestone banks may be thousands or millions of years old, and water can move through both.

It seems so dry on the open lava fields along the sun-baked western side of Hawai'i Island, with Hualālai Volcano in the background. But if you could see down through the lava below your feet, you would see fresh water flowing downhill through the lava's underground network of cracks and pores, mixing with salt water pushed inland from the ocean's waves and tides. It is a brackish, watery world...all in the dark underground beneath your feet.

Near the shore, this underground water emerges on the surface. If land settles or sinks below sea level, for example, the underground water rises to fill the depressions. The water that fills such depressions in lava or limestone form an anchialine pool, a *loko 'ōpae 'ula* (*loko*: pool; *'ōpae 'ula*: red shrimp) or *wai 'ōpae* (*wai*: fresh water; *'ōpae*: shrimp).

Anchialine pools have no surface connection to the ocean; they are connected only through a network of underground cracks and crevices. Pools that are closer to the sea show strong tidal fluctuations, although somewhat dampened and delayed compared to nearby coastal waters. Salt content varies from almost fresh water to almost full strength ocean salinities, depending upon the tide, distance from shore, and rainfall. This rare and unique habitat is a window into Hawai'i's hidden water labyrinth and a fascinating world of aquatic plants and animals.

Scientists have agreed to use the term “pool” for the anchialine bodies of surface water, not “pond.” The first publication to describe this kind of habitat 40 years ago referred to them as “anchialine pools.”

Where Are Anchialine Pools Found?

Anchialine pools are found near tropical and subtropical coastlines around the world, from the Red Sea to the Caribbean, and on the islands of the Pacific and Indian oceans. Hawai'i is the only state in the United States with anchialine pools. The Island of Hawai'i has the greatest number of anchialine pools, including the famous Lua o Palahemo in Ka'ū near Ka Lae (South Point). Anchialine pools also have been found on Maui, Moloka'i, Kaho'olawe, and O'ahu.

Most of the state's anchialine pools are located in lava flows, including all the pools of Hawai'i Island, but also Maui's 'Āhihi-Kīna'u area and Wai'ānapanapa near Hāna. O'ahu's *loko 'ōpae 'ula*, largely found in the 'Ewa and Wai'anae districts, are the only known pools formed in weathered limestone in Hawai'i. A deep, brackish pool fills Kauhakō Crater on Moloka'i, the caldera of the shield volcano that forms the Kalaupapa Peninsula. Ironically, a large bomb crater, called Sailor Hat, is the site of Kaho'olawe's only anchialine pool. However, the pools at Kauhakō Crater and Sailor Hat no longer undergo tidal fluctuations or support populations of *'ōpae 'ula*. The underground connections may have sealed up, cutting off the tidal influence and preventing *'ōpae 'ula* from occupying the pools. The oldest main Hawaiian Islands, Kaua'i and Ni'ihau, presumably had anchialine pools in the distant past. Over time the pools have filled through sedimentation, and today there are no known pools there.

Pool Plants

Life growing in and around anchialine pools varies, depending upon substrate, rainfall, salinity of the pool, and other factors. Native trees are not common. There may be a few Polynesian introductions, such as *niu*, *milo*, or *noni*. Native shrubs and herbs can be found nearby, including the rare *maiapilo*, an endemic caper bush. Indigenous *naupaka kahakai* and *naio* are more common shrubs near the pools.

On the ground are native grasses and sedges, such as *'aki'aki* and *makaloa*, the sedge used to weave fine Hawaiian *mats*. Herbaceous plants, such as *'akulikuli*, *'ohelo kai*, *hinahina*, and *pōhuehue* might adorn a pool's edge. These plants are all salt-tolerant to some degree, and find a good home growing around the pools. However, many pools occur in areas where vegetation is sparse or lacking.

Loko 'ōpae 'ula are home to an interesting assortment of aquatic plants. Some pools may look as if yellow-orange paint had been spilled on the submerged rocks. However, the color is healthy, and comes from the blue-green alga, *Schizothrix*. This photosynthetic cyanobacterium, along with similar species, deposits a limestone crust along the pool's underground surfaces. Pool walls also can provide a stratified habitat for *limu*, or larger seaweeds. In upper, sunny water, green *Chaetomorpha* and *Valonia* may carpet rock walls down to 15-20 feet. Below this depth red algae, such as *Hildenbrandia*, dominate. The indigenous aquatic flowering plant, *Ruppia*, or seagrass, sometimes grows luxuriantly on pool bottoms.

Pool Invertebrates

As you approach an anchialine pool, the first small animals you might see would be insects. Adults of the endemic orangeblack damselfly, *pinao 'ula*, fly back and forth across the pool's surface. After mating, females dip their long tails into the water, laying eggs that hatch into the damselfly's young stage. These tiny, predatory nymphs cling patiently to underwater vegetation, waiting to ambush other pool creatures.

Stately snails move slower. One species, actually called the anchialine pool snail, may be found only in pools at Makalawena in Kona. The limpet-like snails, *hapawai* and *pipiwai*, inhabit *loko 'ōpae 'ula* and can tolerate a broad range of salinities. However, the most common snail is probably the seashore *pipipi*. There may be some endemic bivalve mollusks, the black purse shell, tucked into the pool's nooks and crannies.

Insects and mollusks are probably restricted to the observable, sunlit portions of anchialine systems, and so are called "epigeal" fauna. When we turn our attention to pool crustaceans, some of them are "hypogeal" creatures, those that are found in the sunlit areas, but which also travel into the dark, subterranean system of water-filled cracks. Some of these animals only rarely show themselves in the epigeal waters, and there certainly could be some species that might spend their entire lives underground, and therefore are not yet known to science.

The most obvious *loko 'ōpae 'ula* animals are those that give the pools their name – the famous *'ōpae 'ula*, or "red shrimp." There are a half-dozen or so different native species of anchialine shrimp that are reddish. However, the most common and well-known of them is the endemic *Halocaridina rubra*, the tiny red shrimp most properly called *'ōpae 'ula*.

H. rubra 'ōpae 'ula are only about half an inch long, although other red anchialine shrimp species range up to 1.2 inches long. They spend much time underground and occasionally emerge into sunlit pools, where there is a superabundance of algae and bacteria – their primary sources of food.

'ōpae 'ula reproduce in the dark, hypogeal areas, carrying their eggs loosely under their abdomens. When the eggs hatch, the larvae detach themselves, and larval development occurs in the underground passageways. When the larvae metamorphose (change) into juvenile shrimp, they swim into the sunlit portions of the pools.

'ōpae 'ula are important grazing animals that keep algae in check within the pool community. They, in turn, serve as food for pool predators. Other native anchialine pool shrimp include *Metabetaeus lohena*, *Palaemon debilis*, *Palaemonella burnsi*, *Procaris hawaiiiana*, and *Calliasmata pholidota*.

When disturbed or stressed, *'ōpae 'ula* contract microscopic color cells and turn pale. It may take minutes or hours for the bright red color to return to the recovering shrimp.

'ōpae 'ula may have been the inspiration for this *'ōlelo no'eau*:

Ho'okahi nō 'ōpae, 'ula ka pa'akai.

One shrimp can redden the salt.

Said of a poor fare of food due to a bad crop.

A single shrimp and some salt will do for the time being,
as long as the shrimp flavors and colors the salt.

Mary Kawena Pukui, *'Ōlelo No'eau Hawaiian Proverbs
& Poetical Sayings* Bishop Museum Press 1983



The anchialine pool swimming crab, *Pele ramseyi*, is a newly described Hawaiian genus and species from the 'Āhihi-Kīna'u Natural Area Reserve on Maui.

Pool Fish

Fish have been recorded from some anchialine pools. Where the pools have not been modified by people, most of the fish species are ones typically found in the nearby ocean, such as *āholehole* and *manini*. These fish cannot complete their life cycle within the pools, and they probably enter naturally only during periods of extreme tides and surf. A few species of *'o'opu* reside in some pools.

There is an extremely rare endemic anchialine pool *puhi*, or eel, *Gymnothorax hilonis*. One scientist reported seeing a foot-long specimen crossing lava between ponds spaced up to about 65 feet apart!

Pool Birds

Native birds would have been attracted to anchialine pools as an oasis in the middle of a dry landscape. The now-extinct flightless Hawaiian rail, *moho*, probably built nests among the plants and foraged for food nearby. Even today, migratory shorebirds, such as *‘ūlili* (wandering tattler), as well as native waterbirds, such as *ae’o* (Hawaiian stilt), search for food at pool edges.

Hawaiian Cultural Traditions

Over the ages and continuing today, Hawaiians have had different uses for *loko ‘ōpae ‘ula*. Fishers harvested *‘ōpae ‘ula*, took them out to sea in canoes, and used them to attract marine fish, such as *‘ōpelu* (mackerel scad). The *‘ōpae ‘ula* were mixed with dark dirt or mud, which likely appealed to the visual cues of *‘ōpelu*, but did not attract olfactory predators, such as sharks that relied on their sense of smell. Much of the *‘ōpelu* was salted, dried, and used to sustain families during the season of rough ocean waters – a life-sustaining practice for the people of these islands. The dried *‘ōpelu* was also traded for other items on land. Larger pools that

Ka’ū, i Palahemo – In Ka’ū, at Palahemo

Palahemo is a pool near Ka Lae in Ka’ū. Salt water is found under the fresh water, and any disturbance, like the dropping of a heavy stone, reverses the water, so that the salt water rises to the top. This place is famed in songs and chants.

Mary Kawena Pukui,
*‘Ōlelo No’eau Hawaiian
Proverbs & Poetical
Sayings* Bishop Museum
Press 1983

were closer to ocean salinity were modified and used as fishponds.

Pools that held almost pure fresh water were certainly sources of drinking water. As noted in the *mo’olelo* of Luahinewai in Kona, some pools were bathing areas. Lua o Palahemo in Ka’ū is an anchialine pool famed in songs and chants, and is thought to be the home of a *mo’o*, or water deity. During rainy periods, the pool was *kapu*, and bathing in it was forbidden.

In a *mo’olelo* about Wai’ānapanapa on Maui by Mary Kawena Pukui, a cruel chief, Ka’akea suspects his wife, Pōpō’alaea, of having a love affair with her younger brother. The wife hid in a cave, but the shadow

of the *kāhili* waved by her attendant betrayed their hiding place, and Ka’akea killed them both. On the night of Kū, the water in a pool is said to run red. What might have caused the water in the pool to turn red?

Wai ‘Ōpae – A Modern Hawaiian Perspective

By Hannah Kihalani Springer, Kama’āina o Ka’ūpūlehu

We can see them when the tide is higher and the sun is lower. They are shining bodies of water set back from the ocean, not far, but far enough to be separate, distinct. We see them even from a distance of 5 miles as the *kanaka* might walk or 3 miles as the *‘alalā* might fly. Our home, Kukui’ohiwai in Kona, sits at the 2,000-foot elevation on the northwest rift of Hualālai, and from here – even when the time of day or tide, or voggy atmosphere prevent us from seeing them – we know of the *wai ‘ōpae* and that their waters are rising and falling with the tide, shining in the sun, and glistening with the moon. Known to the world as anchialine pools, we know them as *wai ‘ōpae*, descriptive of two of their defining characteristics, *wai*: fresh water, and *‘ōpae*: shrimp, and in the case of anchialine pools, red shrimp.

In the *wai ‘ōpae*, we know again the waters that spilled from *nā lanī* – the heavens – in the form of *ua* or wafted in the form of *noe* in the uplands. The water that has not evaporated or transpired, percolates through the substrate in a course that leads to the sea, and on the way, passes through the *wai ‘ōpae*. Where our ancestors lived along the shoreline of Hualālai, they gathered at the *wai ‘ōpae*. The shoreline of our homeland is nowhere punctuated by a stream, and the only *‘auwai* that we know are the ones that link our *loko i’a* with the sea, and so these *wai ‘ōpae* were *nā wai ola* – the waters of life – for them.

According to the circumstances and configuration of the pools and the protocols of the people, certain pools met domestic needs and certain pools met occupational needs. Groves of *niu* and *hala* were planted near the *wai ‘ōpae*, and as they rose above the generally flat shorescape, they indicated to travelers by foot or by canoe, the presence of water. The pools were tended for those purposes that met the needs of the people. Leaves of *niu* and *hala* were removed, and today the sediment dredged up by the *po’e kahiko* may still be seen at pools that have not been repurposed.

Repurposing has been aggressive. While our ancestors valued the pools as family water sources and as habitat for the *‘ōpae ‘ula* used as chum for *‘ōpelu* and *akule* fishing, and to water their plantings of *niu* and *hala*, *malihini* have not always recognized the value of the pools. *Wai ‘ōpae* were covered to create an airport runway and holiday hotels. A rural legend tells us that with no regard to their salinity, which does not allow the pools to host mosquitoes, they have been stocked with mosquito fish as a measure against the spread of dengue fever. At high-end resort and residential clusters the pools have become decorative water features and stocked with bigger more charismatic species, such as *‘ōmilu*.

But repurposing is about human will, and the aggression is being redirected towards education and restoring the *wai ‘ōpae*. School and community groups are conducting cleanups, removing alien plants, and dredging sediment by hand. Some developers are removing sediment and encouraging visitors and residents to know the charisma of the *‘ōpae ‘ula*.



Modern Threats To Anchialine Pools

Human impact on anchialine pools has increased and diversified since traditional times:

- The alien, invasive Tahitian prawn (*Macrobrachium lar*), has spread aggressively into many pools. Invasive predators prey upon or outcompete native animals, such as the 'ōpae 'ula.
- Both native and alien, invasive fish are stocked intentionally in pools for use as bait by fishers, disrupting predator balance in pools.
- New neighborhoods and shopping areas need fresh water, depleting the underground aquifers that supply anchialine pools.
- Invasive plants, such as *koa haole* (*Leucaena leucocephala*), *kiawe* (*Prosopis pallida*), and Indian fleabane (*Pluchea* sp.) have taken over terrestrial margins of pools, outcompeting native plants. These fast-growing aliens produce large amounts of leaf litter. Excessive plant debris falls into pools, causing them to age faster than would happen naturally.
- Fertilizers draining from landscaped grounds and golf courses cause a change from the natural chemical balance in pools.
- Many anchialine pools have been destroyed by land development.
- 'Ōpae 'ula, and other pool inhabitants, are removed and sold in the aquarium trade. When 'ōpae disappear permanently from a pool, the balance among aquatic plants is upset.
- Picnickers who bathe in anchialine pools may use harsh, non-biodegradable soaps, shampoos, and lotions, and leave behind paper and plastic litter, as well as human and dog wastes.
- Hikers walk through pools at low tide.

What Can You Do To Protect Anchialine Pools?

Because of its remote geographic location, Hawai'i may have the highest variety of unique plants and animals of any anchialine pool area in the world. A number of Hawaiian anchialine pool species are candidates for endangered species status. Anchialine pools may be one of the most heavily impacted environments in Hawai'i and need to be treasured. They offer one of the most important keyhole views into an underground marine habitat that exists beneath us, all around the world. They connect us to our islands' cultural history, and they represent a living library of natural history information.

What an extraordinarily mysterious, largely unknown ecosystem! For example, how can it be that the hypogeal shrimp, *Callinectes pholidota*, found only in a few anchialine pools in Hawai'i, is also found only in the Sinai Peninsula in the Red Sea and Tuvalu's Funafuti Atoll in the South Pacific? How does *Callinectes* get around? Does the web of lava and limestone cracks continue in the plumbing

systems of atolls and submerged seamounts around the globe, providing "stepping stones" for *Callinectes*? There may be many more discoveries awaiting the diligent student of anchialine pools. Unique creatures emerge from the earth from time to time, new to science, waiting to be described!

Here are some suggestions on how you can *mālama* Hawai'i's loko 'ōpae 'ula:

- After learning about anchialine pools from this poster, continue to update your understanding by searching for current information about the anchialine environment in libraries and online.
- Educate others; most people have never heard of anchialine pools.
- If you visit one of these loko 'ōpae 'ula, do not release fish into it, and leave your dog at home.
- Treat the pool with respect. Pick up any litter you see, leaving it cleaner than you found it.
- Observe anchialine pools from above. Do not get in!
- Ask your representatives in government to pass legislation and provide sufficient funding to protect anchialine pools and their native living things.
- Support the effort to erect fences to keep alien, invasive goats from trespassing in the pool environment.
- Volunteer with an environmental restoration project near you.

Fascinating Facts

- L. B. Holthuis wrote the original scientific paper defining anchialine pools in 1973, <http://science.naturalis.nl/research/publications/zoologische-verhandelingen>
- "Anchialine" comes from the Greek language, meaning "near the sea."
- Anchialine pools range in size from about 15 acres (six football fields) to smaller in area than a bathtub or suburban, backyard swimming pool.
- Most anchialine pools are shallow, averaging less than a few feet deep.
- There is evidence that adult 'ōpae 'ula migrate into the hypogeal recesses during low tide, but return to the pool at high tide. Some shrimp may migrate according to the day-night cycle.
- Biologists have been trying to collect the illusive anchialine pool swimming crab, for over 50 years! The crab was recently collected and described as a new genus and species to science – *Pele ramseyi* – named after Matthew Ramsey, who collected it on Maui.



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This poster can be found at the Conservation Council for Hawai'i website: www.conservehi.org. For copies, contact CCH at (808) 593-0255 or info@conservehi.org.