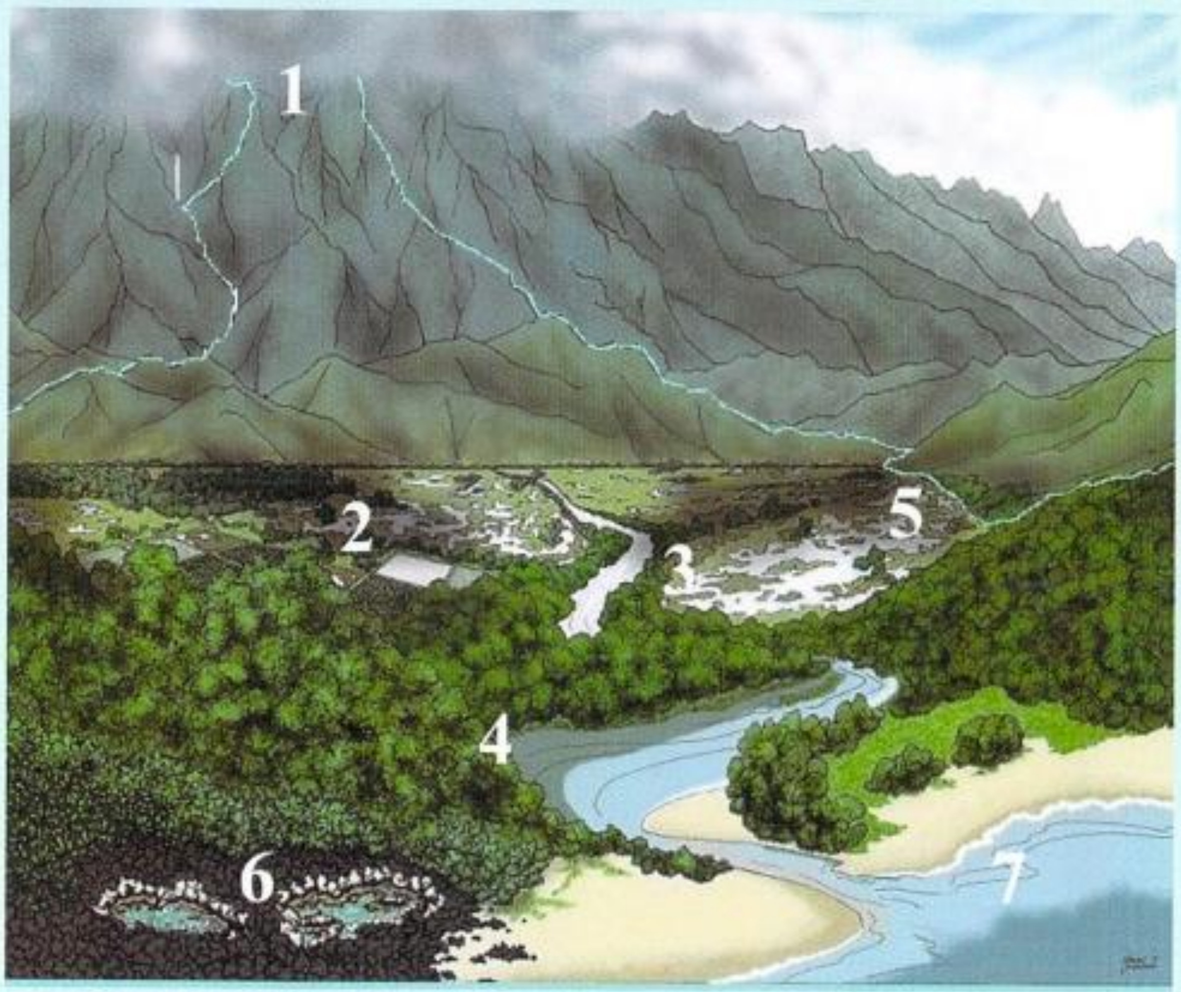
Hawaiian Fresh Waters

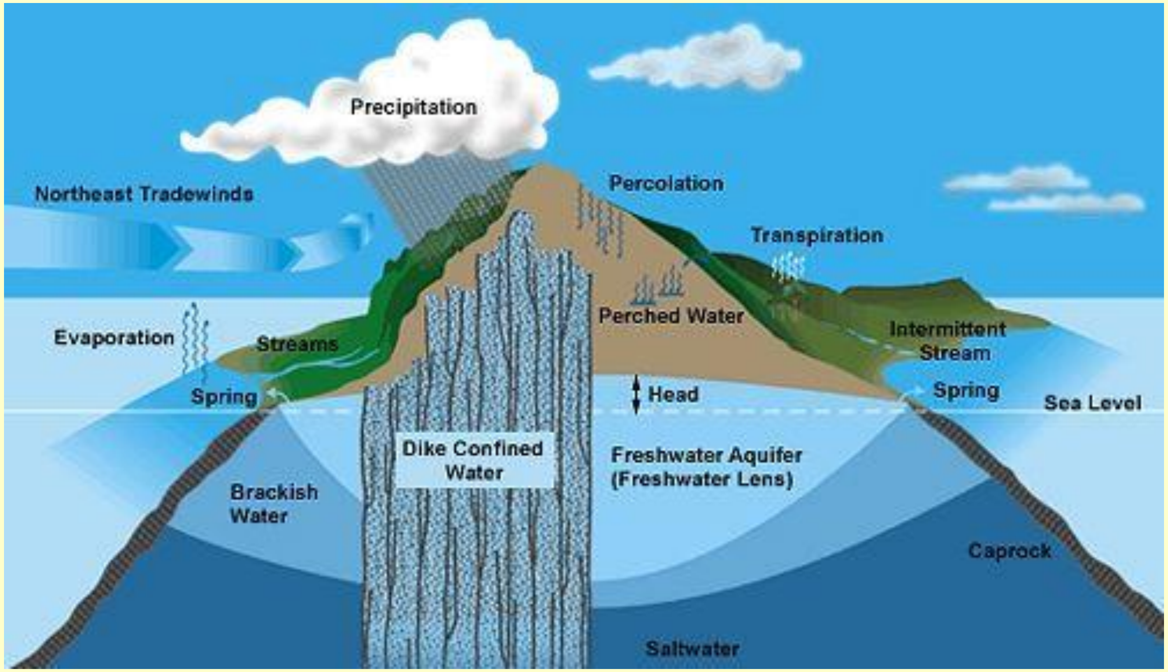


1. Montane bog 2. Aquacultural 3. Riverine 4. Estuarine
5. Palustrine Marsh 6. Anchialine pool 7. Marine

The Water Cycle

Influenced by physiographic and geological conditions:

- Precipitation patterns (leeward / windward)
- Physiography (steepness)
- Geological formations (soil / lava / sediments)



The Water Cycle - Precipitation

Rainfall is spatially variable because of the islands' topography and the persistent northeasterly tradewinds

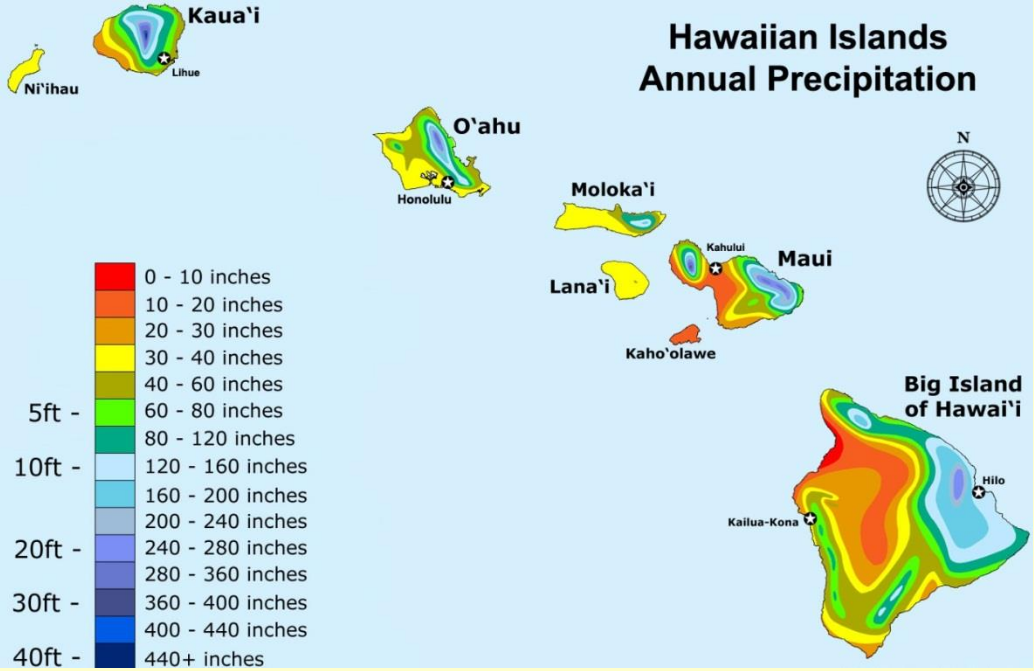
In dry areas, annual rainfall is less than 10 inches; in wet areas, annual rainfall is greater than 400 inches

In general, southwestern, leeward sides of islands are driest and northeastern, windward sides are wettest

Fog drip, cloud vapor intercepted by vegetation and subsequently drips to the ground, occurs between 2,000 and 6,000 ft

The Water Cycle - Precipitation

Only five islands (Kaua'i, O'ahu, Moloka'i, Maui, Hawai'i) are high enough to capture the rain clouds riding the NE trade winds, and for the resulting orographic (mountain-generated) rainfall to generate streams



The Water Cycle - Surface

Amount of recharge available to enter aquifers is the volume of rainfall, fog drip and irrigation water not lost to runoff or evapotranspiration or stored in the soil

Amount of soil (and vegetation) also influences run-off and water seepage into the substrate

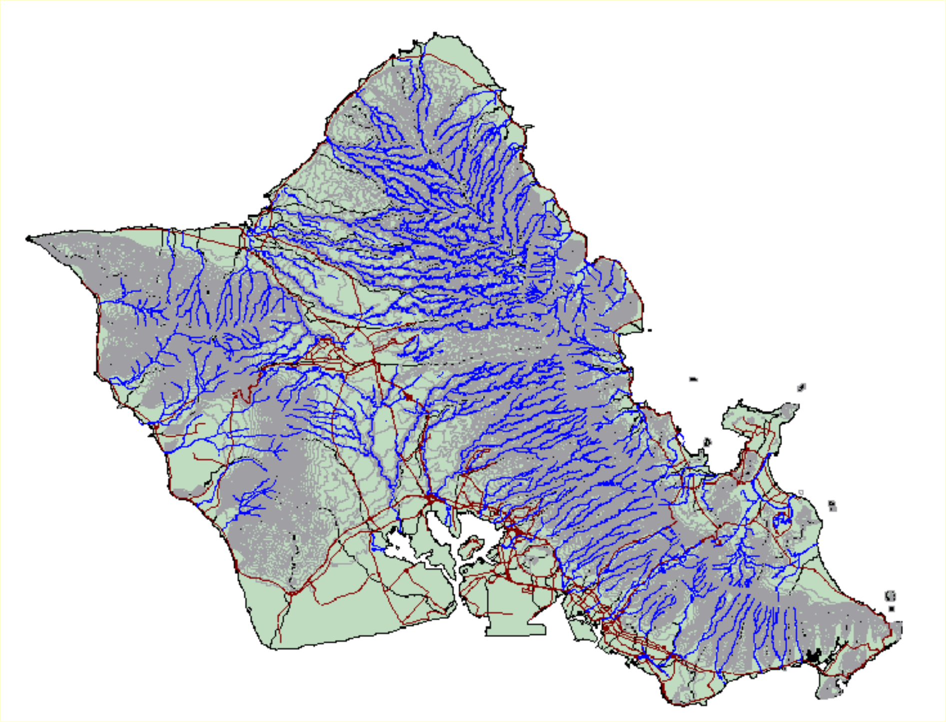
Permeability of volcanic rocks depends on mode of emplacement, amount of weathering and thickness

Three main types of volcanic rocks (lava flows, intrusive dikes, pyroclastic deposits) formed by different processes and have different permeabilities

Surface – Vegetated Soil

An estimated 376 small torrential mountain streams are located on the windward sides of these islands

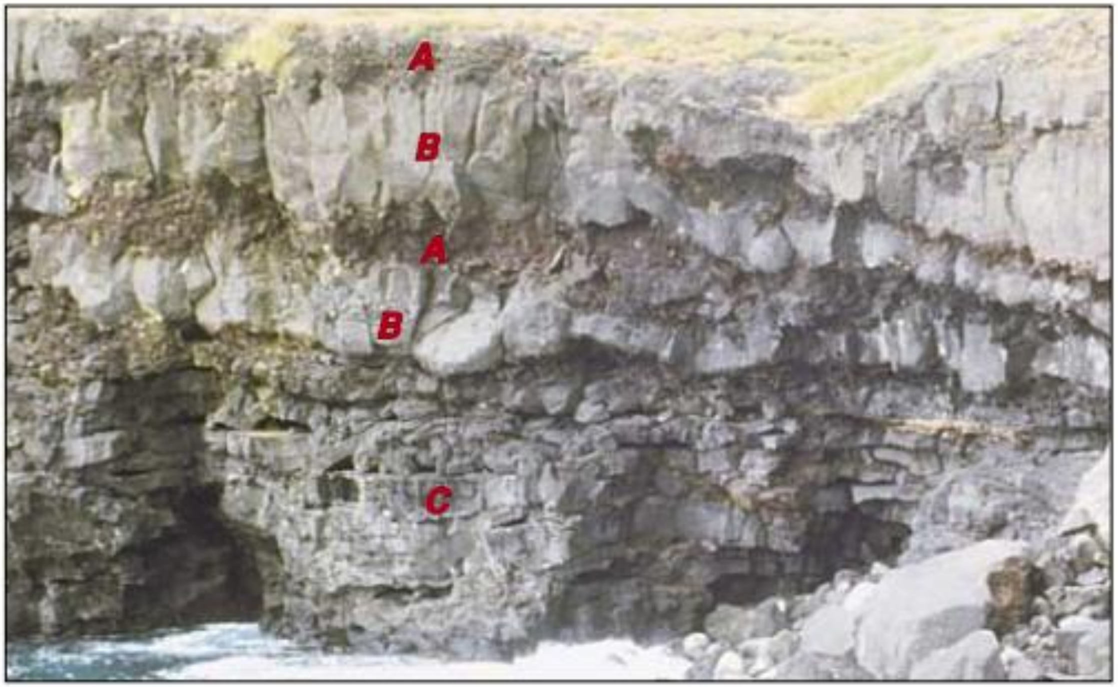
Watersheds delineated by the topography



Surface – Lava Flows

Lava flows are mainly:

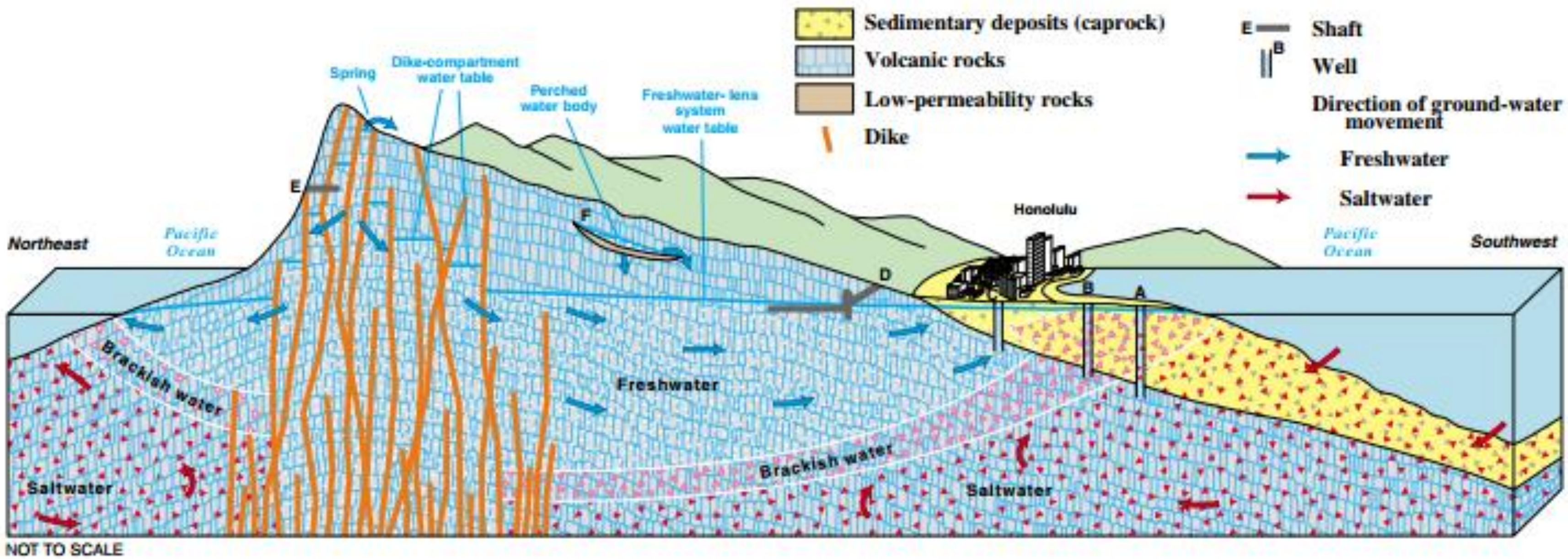
- aa: coarse rubble surface and interior of massive rock
- pahoehoe: smooth and undulating surface



*A typical sequence of lava flows contains aa clinker zones (**A**) of relatively high permeability that occur above and below the massive central cores of aa flows (**B**), and many thin pahoehoe flows (**C**). The sequence shown is about 50 feet thick. (photo by Scot K. Izuka, USGS).*

Water seeps through aa layers and travels along the lava flows

The Water Cycle - Subterraneous



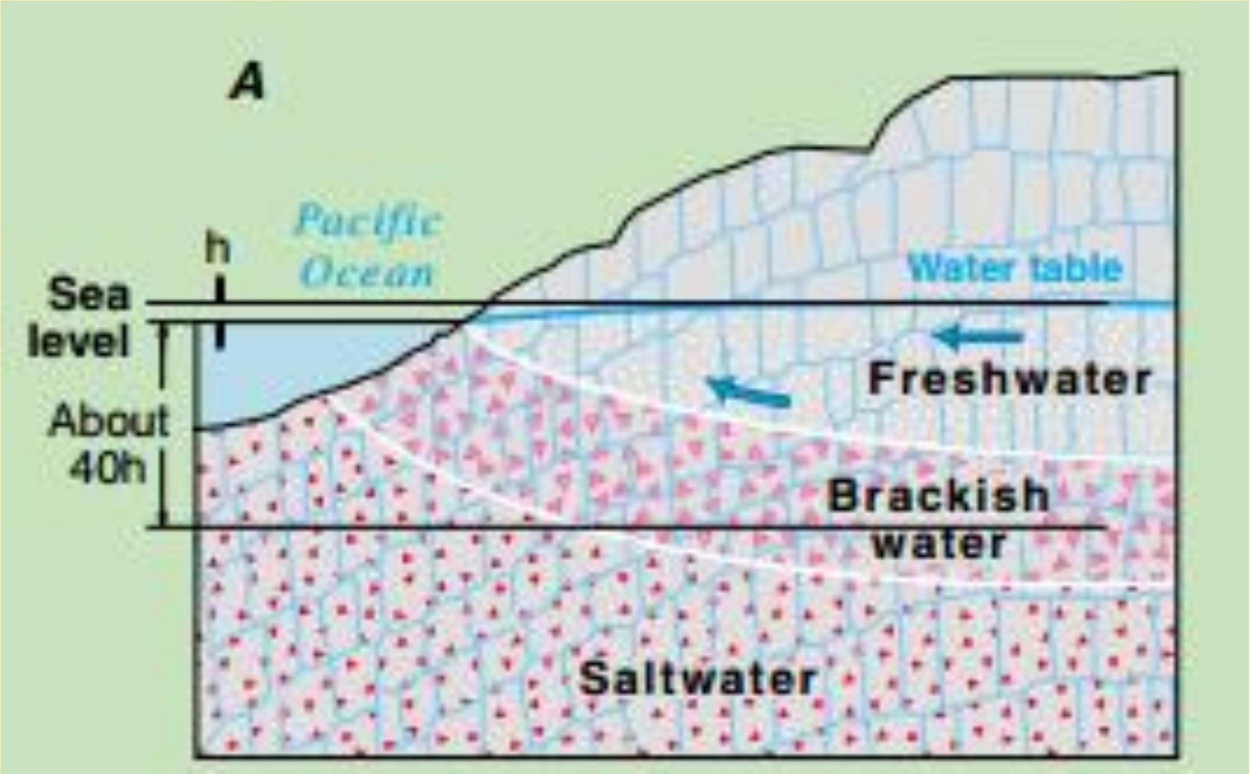
Fresh ground water generally moves from topographically high areas towards the ocean. Fresh ground-water flow is generally downward in the inland areas, upward in the coastal areas, and horizontal in between. A saltwater circulation system exists beneath the freshwater lens. Saltwater flows landward in the deeper parts of the aquifer, rises, then mixes with fresher water and discharges to the ocean.

A freshwater-lens system underlies much of southern Oahu. Well **A** *produces saltwater from below the transition zone, well* **B** *produces brackish water from the transition zone, and well* **C** *produces freshwater.*

Horizontal shaft **D** *(sometimes called a Maui shaft) produces large volumes of freshwater by skimming water from near the top of the freshwater lens. Shaft* **E** *(sometimes called a Lanai shaft) is dug horizontally into one or more of the dike-bounded compartments. Location* **F** *indicates a perched water body containing minor amounts of water.*

The Water Cycle - Lenses

On oceanic islands, such as Hawai'i, freshwater water lenses float on top of saltwater. Both bodies of water are separated by separated transition zone of brackish water

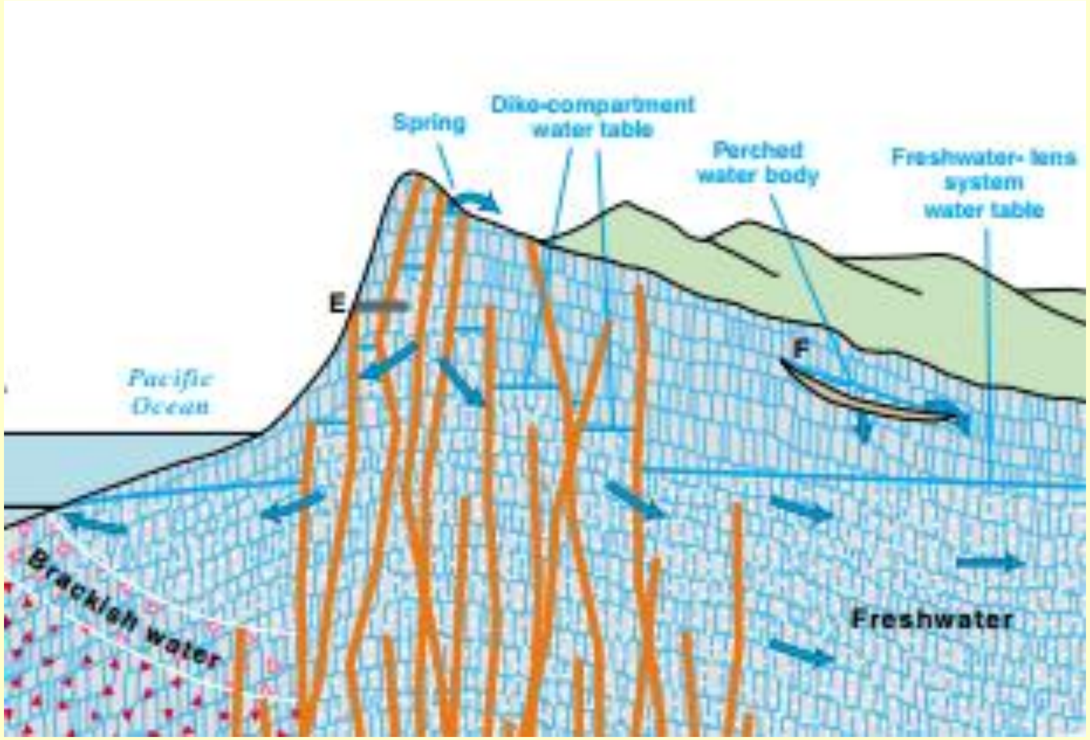


Subterraneous Structures – Dikes

Dike-impounded systems found in rift zones and calderas, where low-permeability dikes intruded other rocks

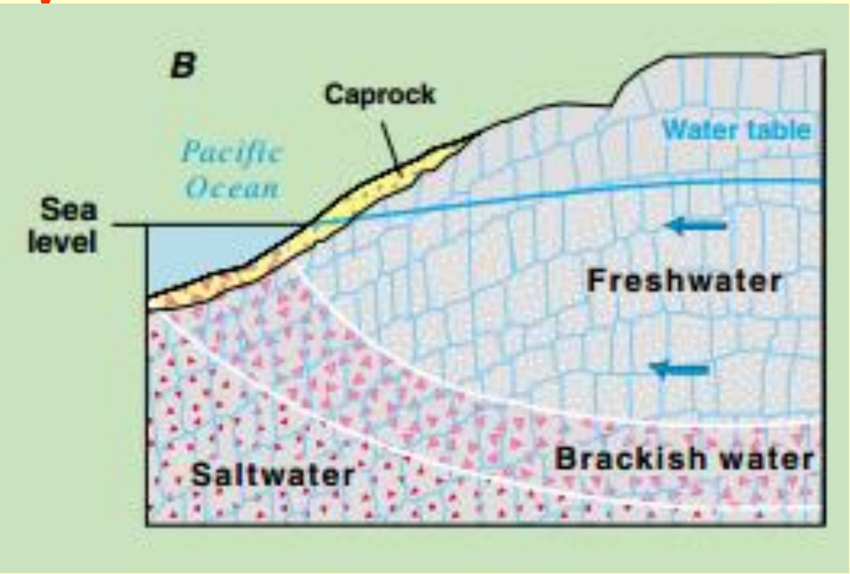
Near-vertical dikes compartmentalize areas of permeable volcanic rocks

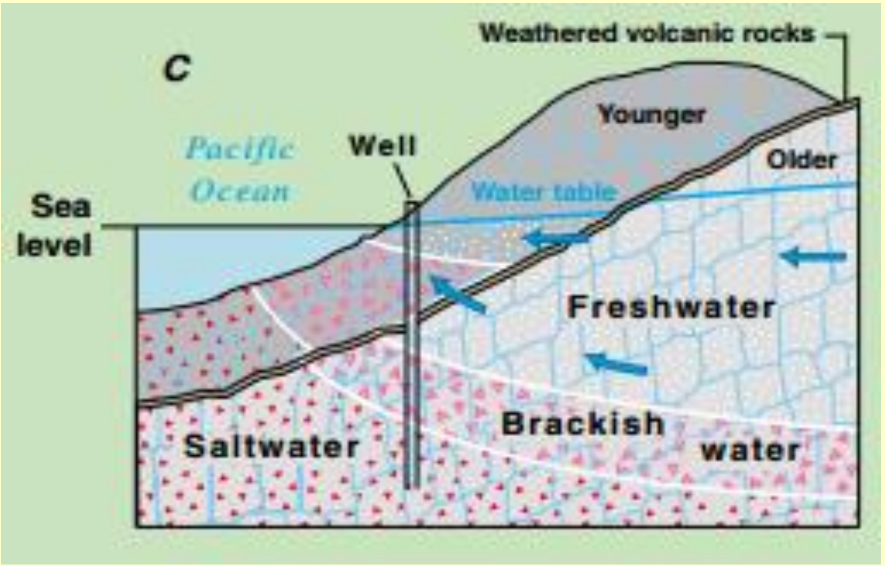
Dikes impound water to heights as much as 3,300 feet above sea level on Maui and the Big Island, and 1,600 feet on O'ahu

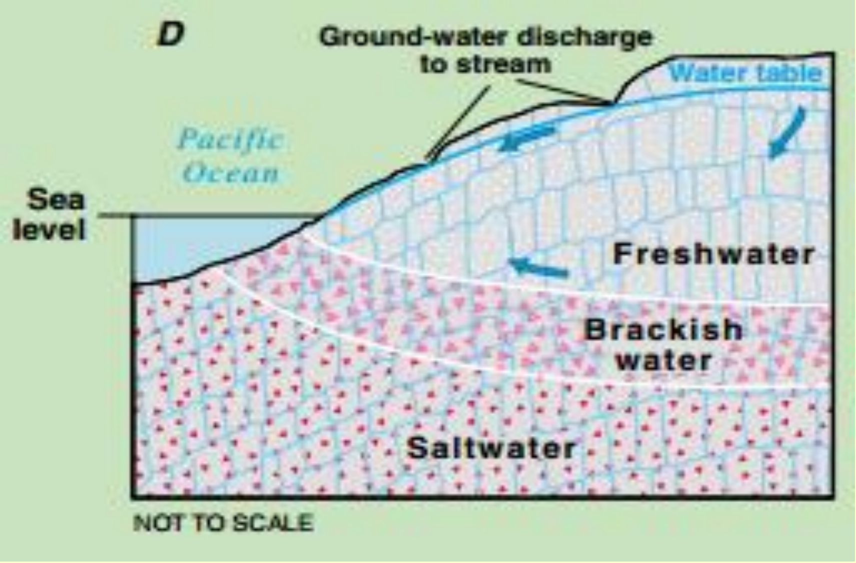


The Water Cycle - Lenses

The thickness of the freshwater lens is influenced by the local geological formations: (B) caprock, (C) weathered rocks, and (D) springs







Hawaiian Streams

1. Small compared to larger streams on US mainland. Only 28 or 7.4% of the streams are 10 miles or longer.

2. Numerous waterfalls characterize Hawaiian streams. This feature gives the stream a steep profile.

3. Stream flow tracks annual rainfall. Localized heavy rainfall from passing storms cause frequent flooding.

4. Flow spikes, lasting 2 – 3 days, contribute to the flash floods characteristic of Hawaiian streams.

Native Species

Isolation of Hawai'i has resulted in impoverished freshwater fauna

For instance:

There are only about 550 species of marine fishes, as compared to about 2,000 fish species in the Philippines

Hawaiian streams have only five native species of fishes (4 endemic, 1 indigenous: native but found elsewhere), 2 crustaceans (endemic) and 3 mollusks (all endemic)

Native Fish Species

Two closely related families:

Gobiidae and Eleotridae,

collectively referred to as 'o'opu in the Hawaiian.

River Gobies (Awaous guamensis)
`o`opu nakea

Island Sleepers
(Eleotris sandwicensis)
'o'opu-akupa

(Stenogobius hawaiiensis) `o`opu naniha
(Lentipes concolor) `o`opu alamo`o
(Sicyopterus stimpsoni) `o`opu nopili

Native Crustacean Species

Represented by two species.

The mountain shrimp, opae kuahiwi, inhabits higher sections of streams with cooler, clear, fast-flowing water

The prawn, 'opae oeha'a, is most common in the lowest stream section in warmer, murkier, slow-flowing water

(Atyoida bisulcata)
'Öpae kala'ole,'Öpae kuahiwi

(*Macrobrachium grandimanus)*
ʻ ōpae oehaʻa

Native Mollusks

Three endemic species of river opihi (limpets) but the most common is the larger hihiwai (*Neritina granosa*), most common in lower to mid stream sections

Nerite Snail
hīhīwai
(*Neritina granosa*)

The other two species are found at the mouth of rivers.

Pseudisidora producta

Erinna newcombi

Goby Life History

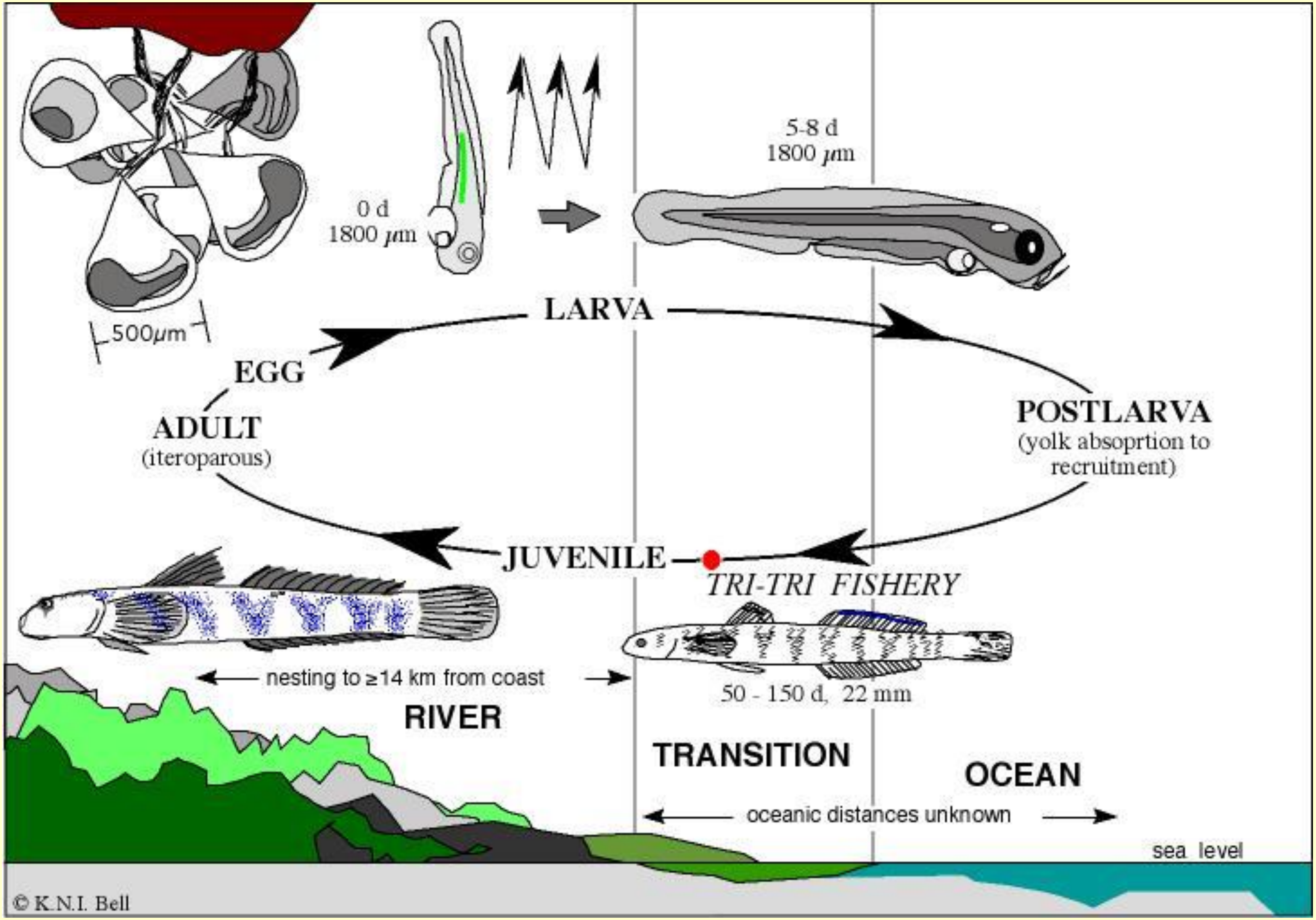
Most native Hawaiian stream animals share a unique life cycle pattern, called amphidromy

Gobies lay eggs in streams, and upon hatching, the larvae swept out to sea

After living in ocean plankton community (3 – 6 months), the postlarvae return to the adult habitat by migrating upstream, often climbing numerous waterfalls

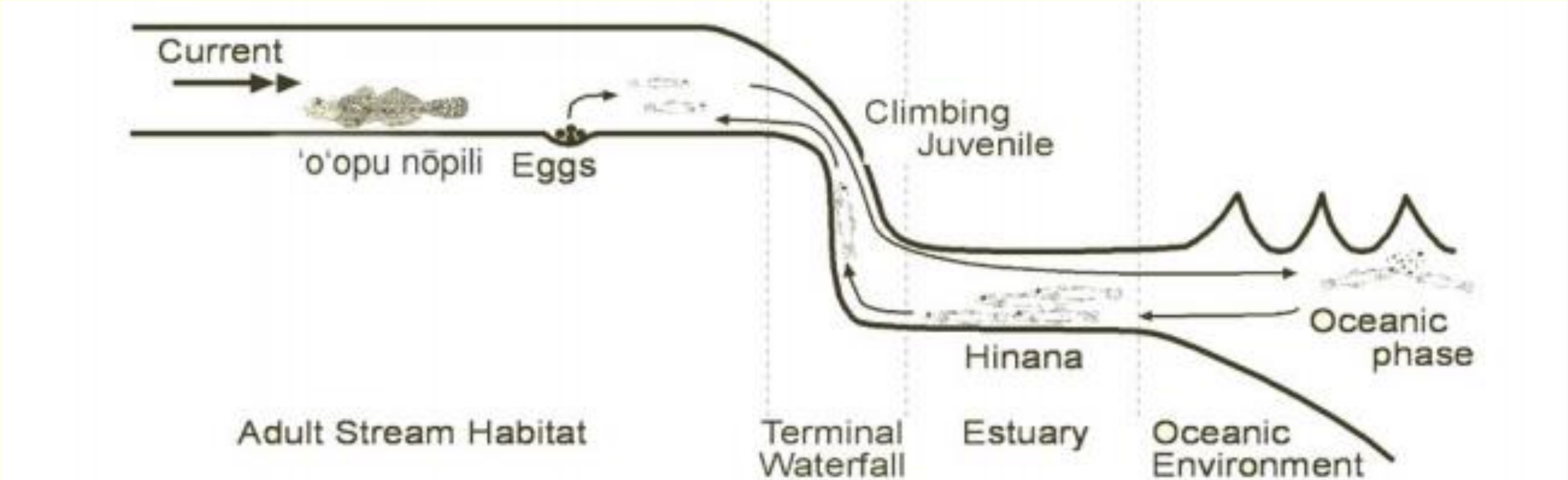
Larvae (hinana) return in large numbers into the streams, often after flash floods have created large freshwater plumes that extend far into the ocean

Goby Life History



Adaptations - Amphidromy

One species, 'o'opu alamo'o (*Lentipes concolor*), migrates up the 420 feet high Akaka Falls on the Big Island



Life history of ‘o‘opu nōpili

Adaptations for Climbing

Small, nearly scaleless bottom dwellers as adults. The fused pelvic fins, at least for the gobies, are adapted to the rocky, steep, flashy-flow nature of Hawaiian streams

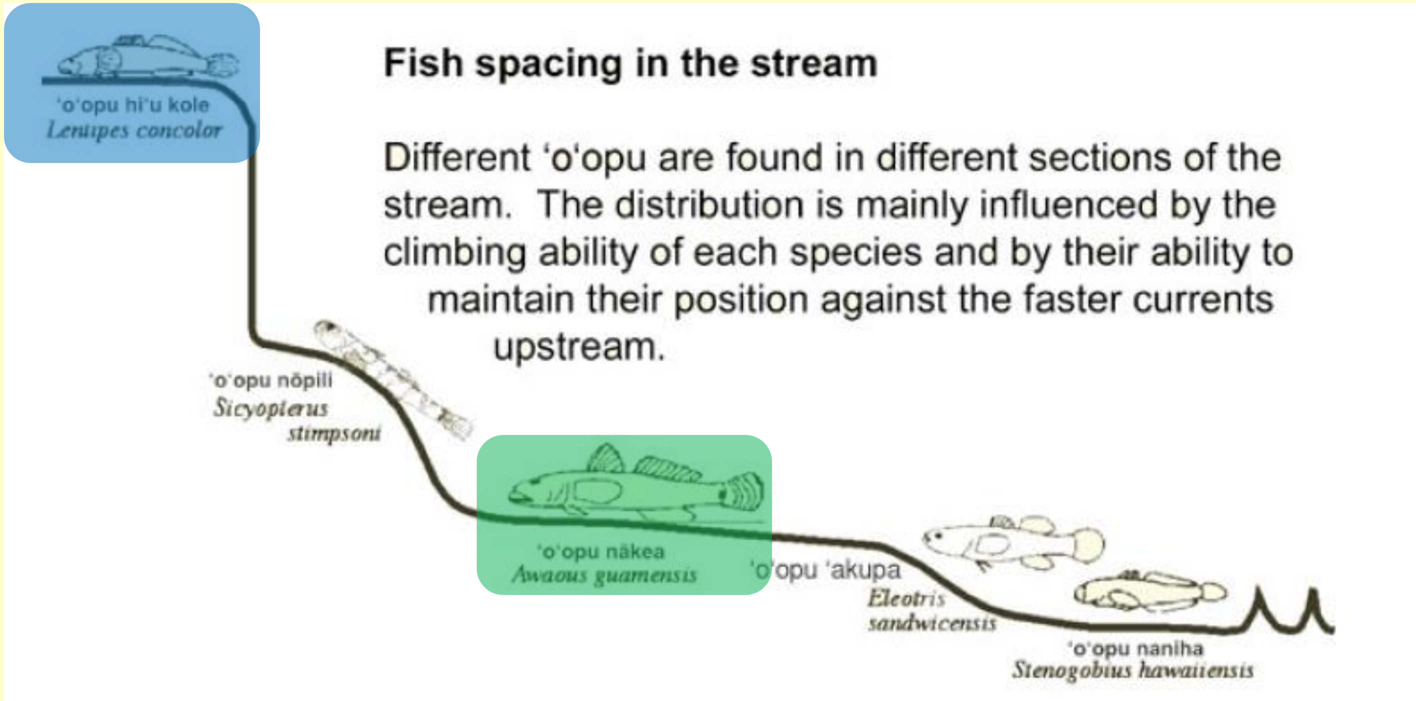
Muscular fins used for maintaining position in high water flow areas, but most spectacularly, for climbing steep waterfalls

One species, 'o'opu alamo'o (*Lentipes concolor*), migrates up the 420 feet high Akaka Falls on the Big Island

Adaptations for Climbing

Different species occupy different sections of the rivers, Depending on their climbing abilities

Only 'o'opu alamo'o (*Lentipes concolor*), found at the higher elevations, above steep waterfalls



Adaptations for Climbing

In this review, use the ichthyofauna of Hawaiian Islands to demonstrate how the habits, habitat, and in-stream distribution of five amphidromous fish species relate to the functional morphology of locomotion and feeding

Furthermore, evaluate how performance limitations related to functional morphology affect each species under changing environmental conditions

Table 1. Comparison of life history traits of five amphidromous Hawaiian gobies.

	Eleotris sandwicensis	*Stenogobius hawaiiensis*	*Awaous guamensis*	*Sicyopterus stimpsoni*	*Lentipes concolor*
Oceanic phase	3–5 months	3–5 months	3–5 months	6 months	3-5 months
Larval diet	planktivore	planktivore	planktivore	planktivore	planktivore
Recruit size*	13.5 mm	14.1 mm	16 mm	23.6 mm	14.5 mm
Adult diet	carnivore	detritus feeder	omnivore	herbivore	algivore & insectivore
Adult size*	130 mm	40–50 mm	140 mm	75 mm	67 mm
Climbing ability	none	none	weak	good	excellent
Station holding	weak	weak	larvae: good adults: weak	good	excellent
Adult habitat	estuary	estuary	low/mid-stream	mid-stream	upper-stream

*Mean standard length.

(Schoenfuss and Blob 2007)

Adaptations for Climbing

Functional capabilities of species influence their ability to maintain their populations in altered environments

This is especially true among freshwater ichthyofaunas on small oceanic islands, where fishes frequently traverse boundaries between different ecosystems

Many aspects of functional performance in fishes relate Directly to morphological features and limitations

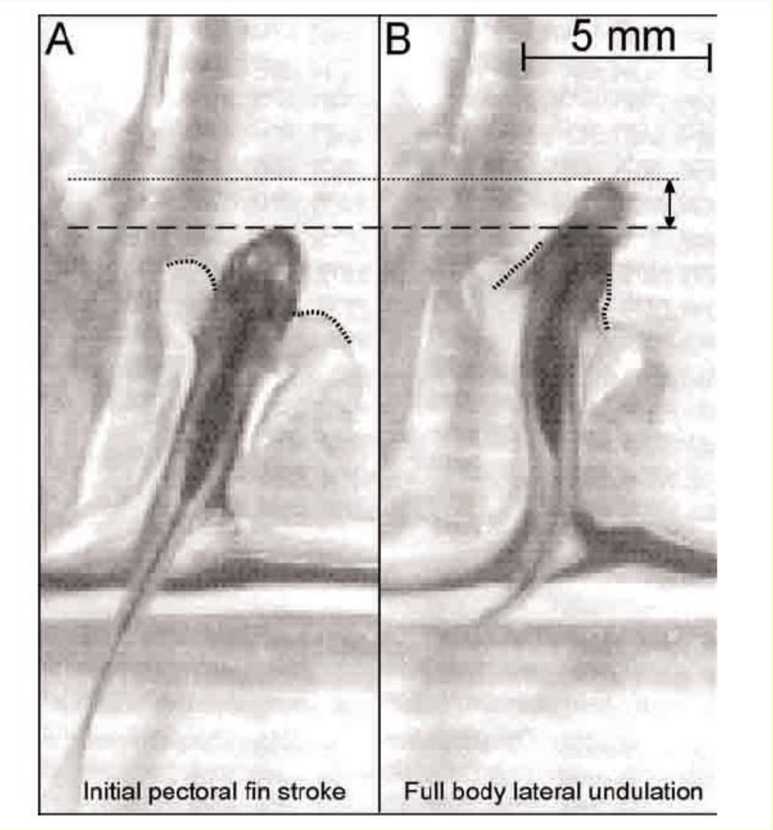
Table 2. Climbing speed (cm/sec; mean ± standard error) for larvae of *Awaous guamensis* and *Lentipes concolor* on three substrates of increasing coarseness (modified after Blob *et al.*, 2006).

Substrate	*Awaous guamensis*		*Lentipes concolor*	
	n	climbing speed	n	climbing speed
Smooth	12	0.068 ± 0.0041	8	0.59 ± 0.024
Fine grained	12	0.21 ± 0.028	17	0.82 ± 0.084
Coarse grained	12	0.71 ± 0.22	10	1.2 ± 0.27

(Schoenfuss and Blob 2007)

Adaptations for Climbing

"Powerburst" climbing of *Awaous guamensis* and *Lentipes concolor* as recorded on a nearly vertical sheet of Plexiglas



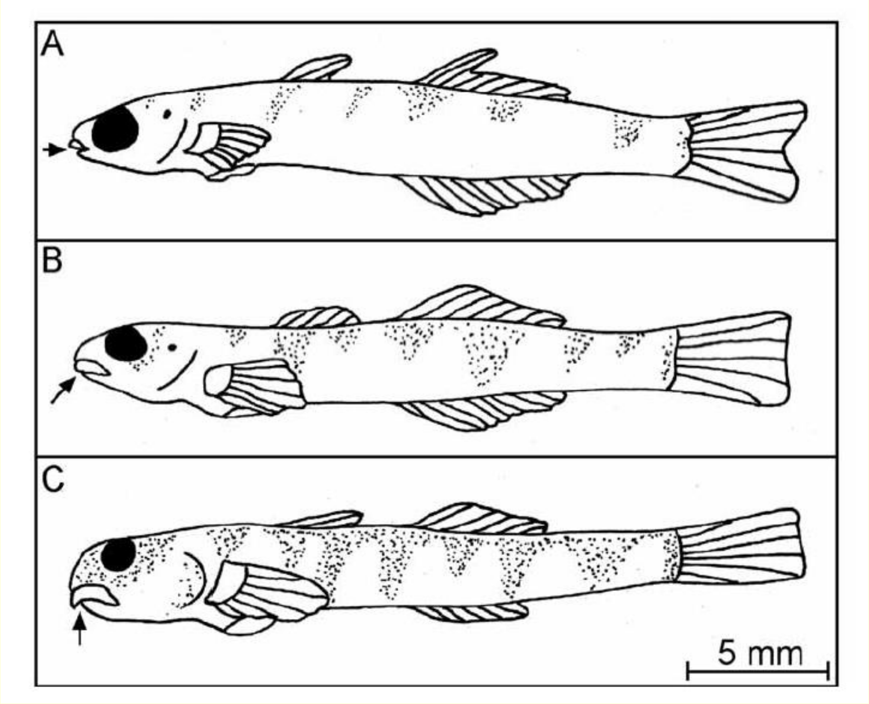
(Schoenfuss and Blob 2007)

A) Fish attached to substrate via the pelvic suction disc. Pectoral fins (dotted line) outstretched in advance of rapid adduction that begins the locomotory bout

B) The fish advances through rapid axial undulations of the entire body after rapid pectoral fin adduction. Arrow indicates total advancement during one climbing cycle.

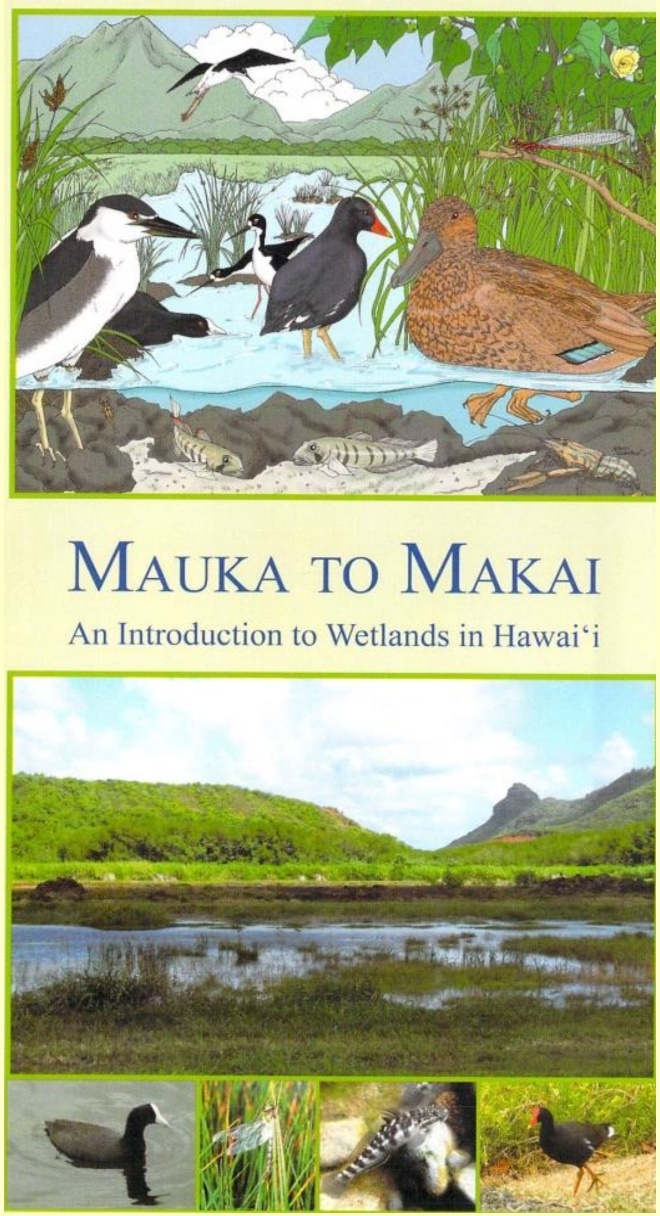
Adaptations for Climbing

Anatomical changes in larval *Sicyopterus stimpsoni* entering the freshwater system (arrows in drawings indicate mouth position)



A: Incoming recruit captured at the stream mouth;
B: Larvae in fresh water for 16 h;
C: Juvenile *Sicyopterus stimpsoni* 36 hours after entering freshwater and able to climb vertical barriers.

Hawaiian Wetlands



Wetlands are lands periodically covered or saturated by fresh or salt water and characterized by:

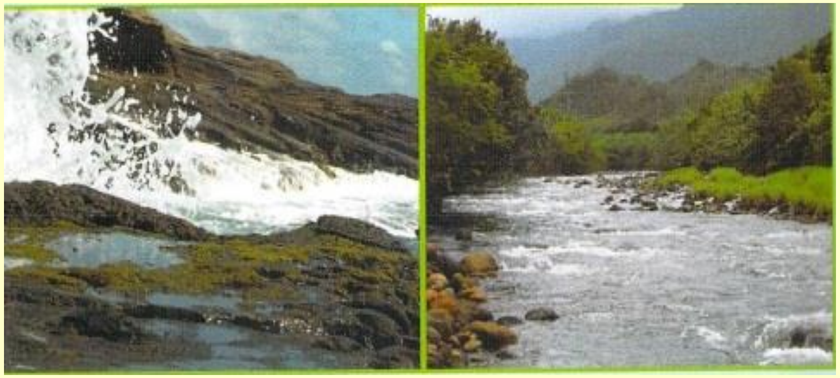
Hydrology (water): from precipitation, surface flow or shallow groundwater.

Soils: poorly drained and saturated or covered with water for at least two weeks a year

Vegetation (plants): adapted to grow, reproduce, and persist in water or saturated soils

Hawaiian Fresh Waters

Wetlands can be seasonal or permanent, and occur in a variety of landscapes:



Depressions
Coastal shorelines
Fringes along running water
Fringes along standing water
Cloud forests

Human-created ponds

Hawaiian Wetlands

Riverine wetlands are surface water systems found along edge of rivers or streams. These areas critical to seabirds

Palustrine wetlands, such a marshes and bogs, are found in depressions where rain or groundwater collects

Estuarine wetlands, such as swamps and mudflats, occur on coasts where streams empty into the ocean. These tidally influenced brackish areas provide habitat for fish, shellfish and waterbirds

'Alae 'Ula
~ Hawaiian

'Ae'o
~ Hawaiian Stilt

Koloa
~ Hawaiian Duck

Hawaiian Wetlands

Marine wetlands, such as intertidal shorelines, seagrass beds, or tidepools, are saltwater systems, and provide habitat for many fish species harvested for food

Batis maritima
(pickleweed)

Rhizophora mangle
(mangrove)

Introduced Species

More than 50 species of alien fishes, invertebrates, reptiles, amphibians and plants are established in Hawaiian streams, reservoirs and freshwaters

Many species were intentionally released with the hope that they would become established, and harvested

Others were simply introduced accidentally

Some are having large economic
And ecological impacts

Introduced Species

Some of earliest introductions occurred during 1800's and accompanied first Asian immigrants to the islands

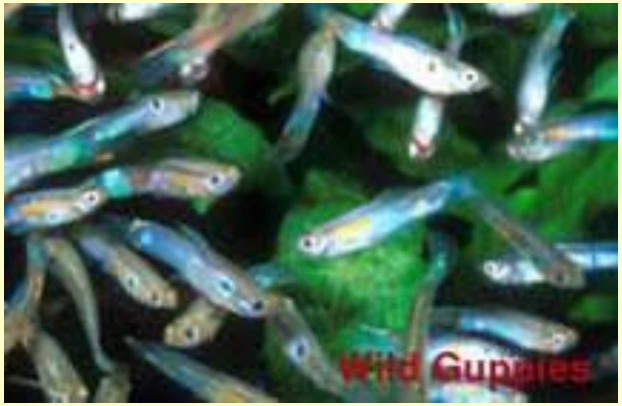
The Chinese catfish, rice paddy eel, soft-shell turtle, carp, goldfish and the Japanese weather fish (dojo) were brought for food, but a few, like the goldfish, were also brought for ornamental purposes

Introduced Species

During early 1900's, and through the 1960's, several species of top-minnows (known as medaka or tabai) were released in streams and reservoirs for mosquito control

Various Tilapia species brought help the sugar plantations control weeds in their irrigation systems and to provide baitfish for the aku (skipjack tuna) fishery

Gamefish, such as the largemouth and smallmouth bass, trout and tucunare were brought to provide sport and recreation



Introduced Species

During 1980's and 1990's more alien species began appearing in Hawaiian streams and reservoirs

Species such as the Convict cichlid, Midas cichlid, Johanni cichlid, Jewel cichlid, Suckermouth catfish, Armored catfish, Stickfish, Apple snail, and Grass shrimp can all trace origins to aquarium fish and aquaculture industries

The Asiatic clam, widely distributed in streams, reservoirs and taro patches on Kaua'i, Maui and O'ahu, was smuggled for food

An alien goby arrived to Hawai'i via a ship's ballast tank

Many Impacts on Native Species

Some impacts these alien species are having on our native stream animals and habitats are readily apparent:

Smallmouth bass are voracious predators that feed on native 'o'opu (gobies) and 'opae (shrimp)

Catfish and crayfish dig holes in stream banks, causing erosion, increasing silt, and decreasing water clarity

Even seemingly harmless species, like the guppy and swordtail carry parasites that infect 'o'opu

Helping Native Species

Maintaining natural patterns of water flow is the most important requirement for protecting Hawaiian streams

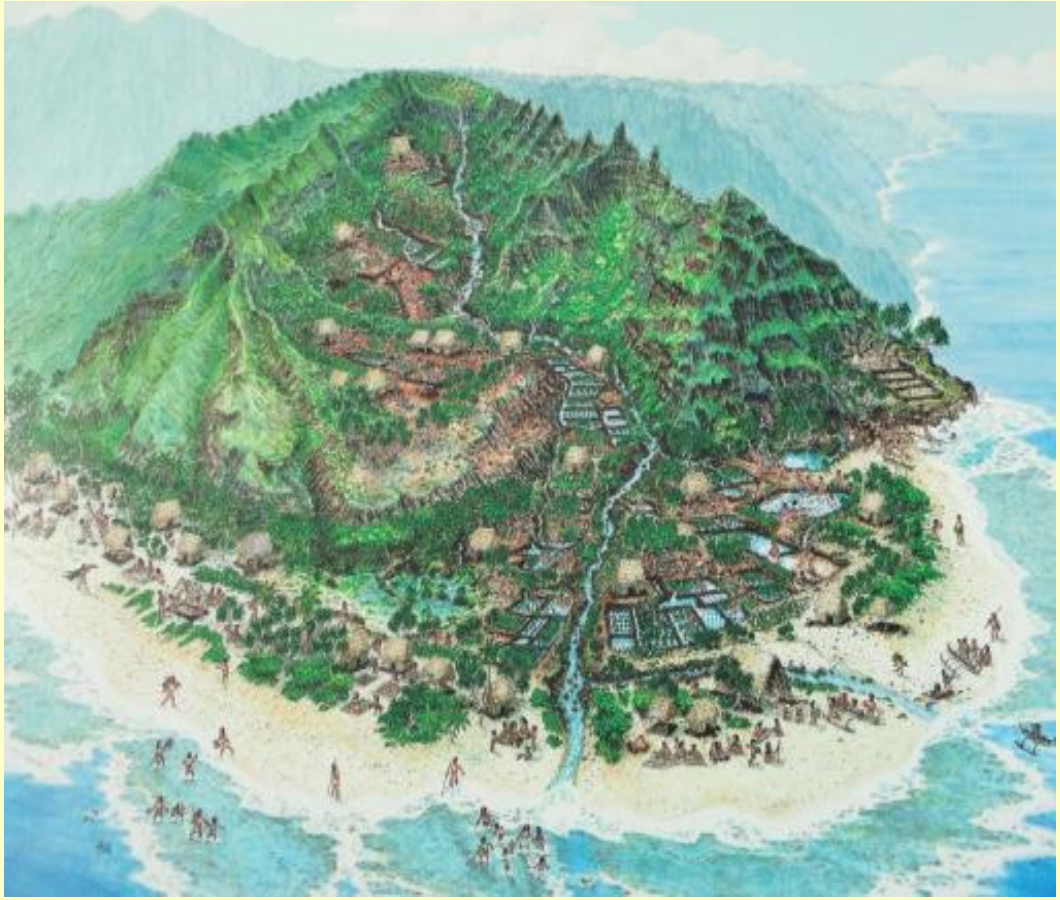
These natural flows keep the river mouth open and provide the gateway for precious native stream animals to complete their life cycle

Acknowledge the connectivity of diverse freshwater habitats … from the mountain peaks to the sea

Ahupua`a

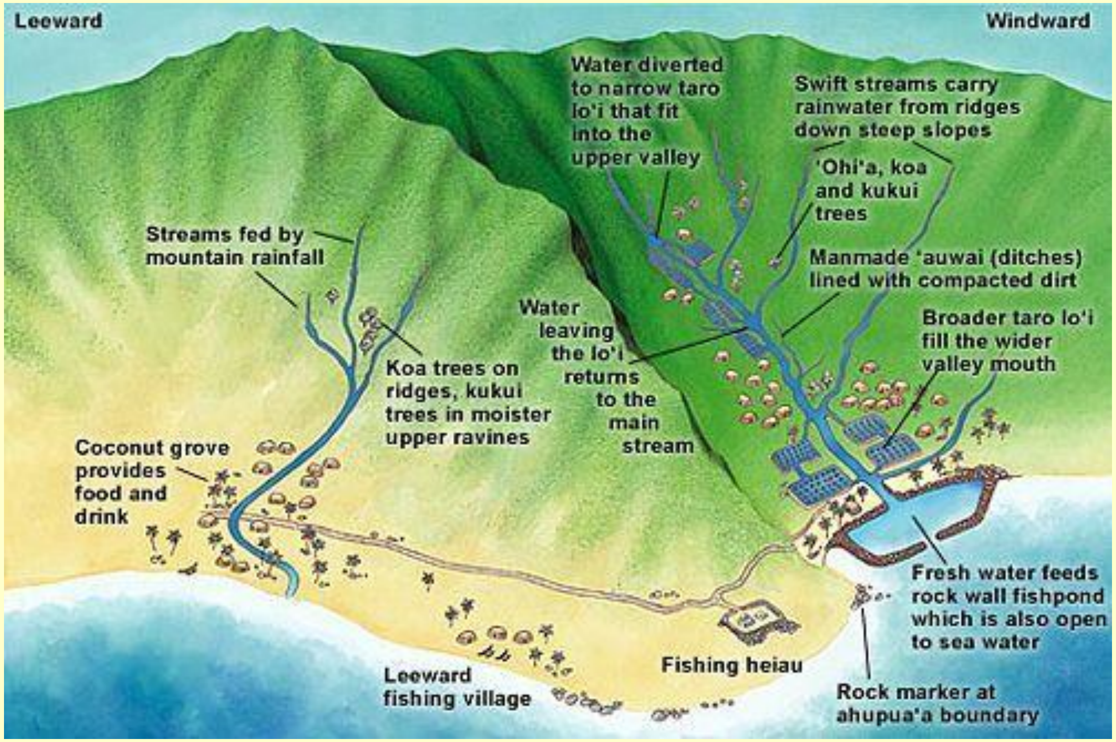
In traditional Hawai'i, islands divided into ahupua`a, narrow wedge shaped land sections that ran from the mountains to the sea

Shaped by island geography, each ahupua`a followed the natural boundaries of the watershed



Ahupua'a

The ahupua'a included all essential activities, and a variety of fresh waters: mountain streams and ponds (lo'i)



Fish Ponds

Ocean fishing depends upon weather conditions.

High surf, storms, and other weather phenomena influence and interrupt most fishing practices.

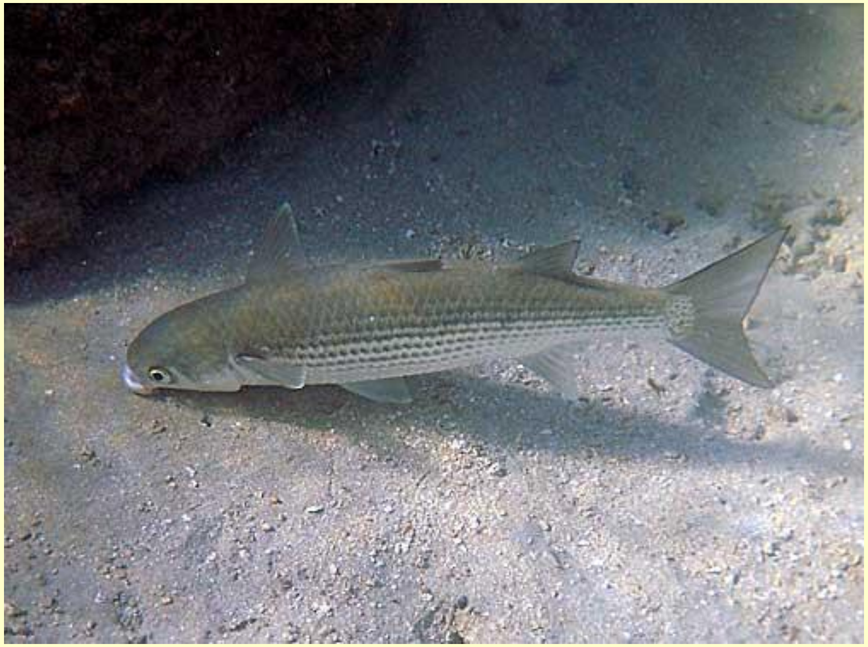
Therefore, fishponds provided Hawaiians with a regular supply of fish when ocean fishing was not possible or did not yield sufficient supply (Kelly, 1976).

Fish Pond Species

The fish most frequently raised in *loko kuapa* ponds were:

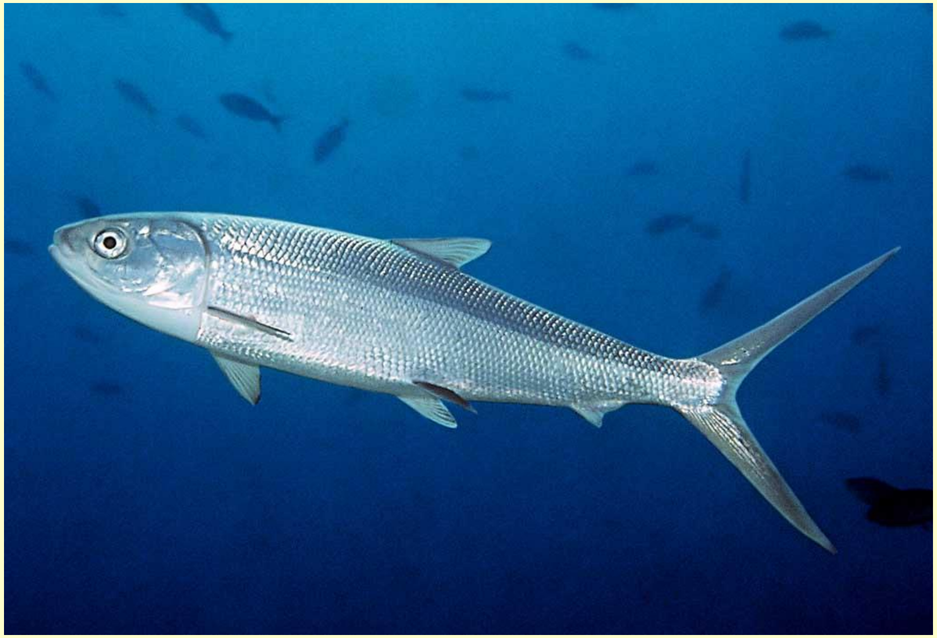
mullet *('ama'ama)*

Mugil cephalus



milkfish *(awa)*

Chanos chanos



- Herbivores, complex life cycle with coastal / ocean migration

Management of Fish Ponds

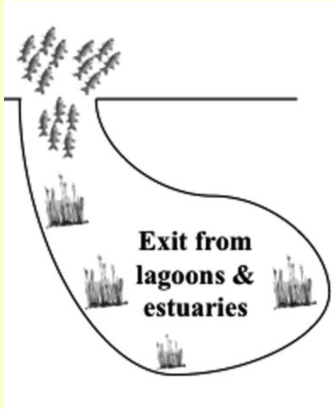
Adults live in brackish (nearshore) environment, but spawn in the ocean.

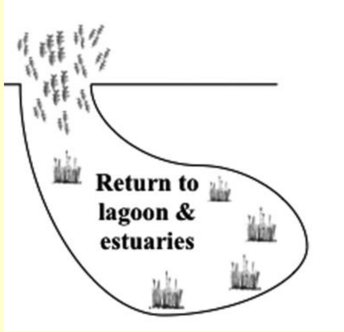
Eggs hatch at sea and the larvae recruit back to the adult habitat as fingerlings.

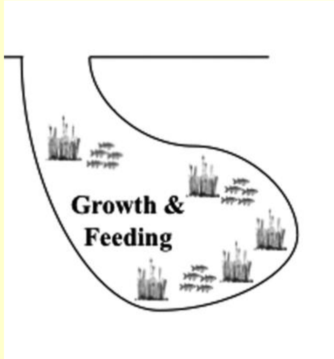
Fishponds provide a rich ands safe environment for fingerlings to grow.

- Management:

- Recruit fingerlings
- Provide food for growth
- Protect from predators
- Allow adult spawning migration



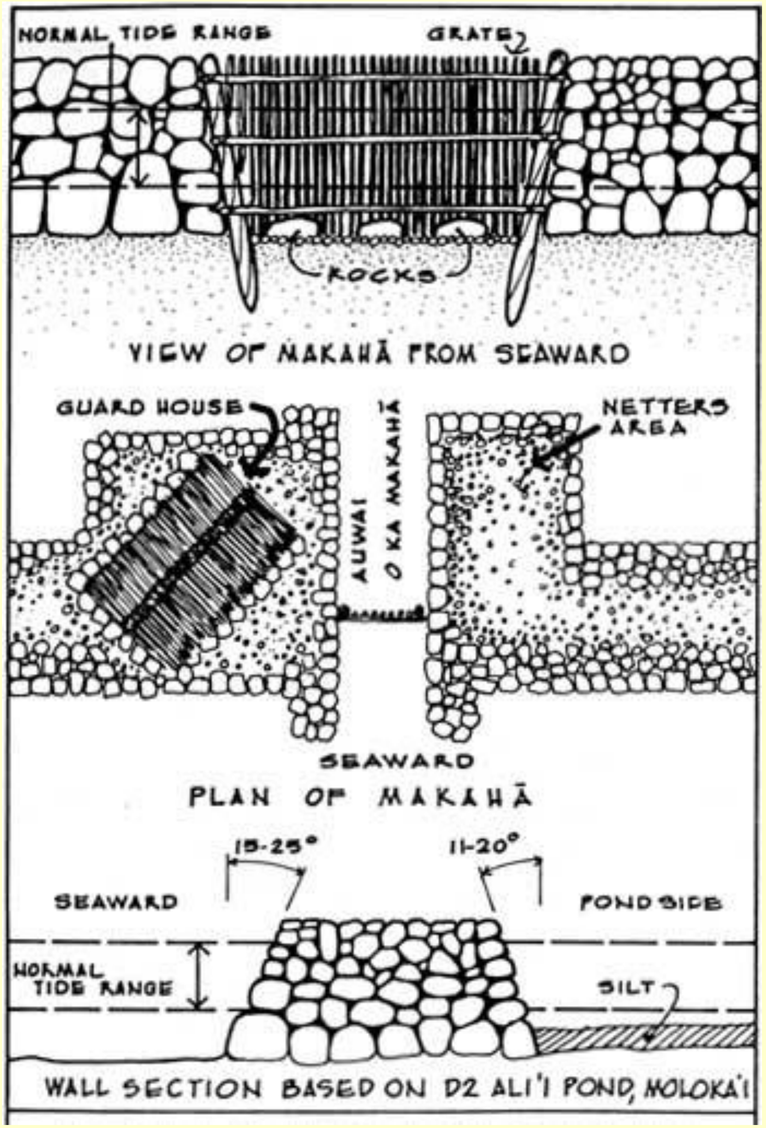




Fish Pond Design

Kuapā is a 12 – 15 ft wide compact wall with two outer volcanic rock walls parallel to one another and an inner ~8 ft wide section filled with mostly coral and in some places rock and dirt.

This compact wall slows water flow, allowing pond to maintain a base water level even at lowest tides, and forces water to flow through the mākāhā or gates.



Fish Pond Design

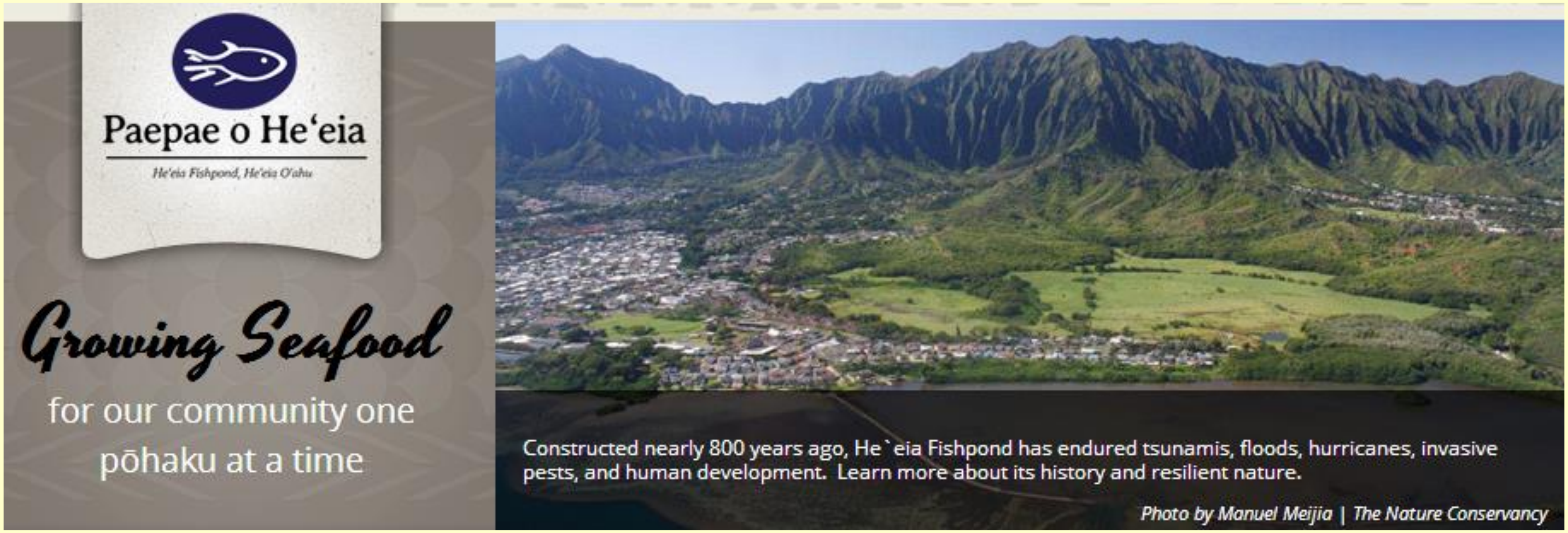
The sieve-like nature of makaha grates allowed many organisms to enter and to exit fishponds.

Fingerlings recruited into the pond, through the grated gates.

Mature fish congregated on the pond side of the grate during incoming tide and on the sea side during outgoing tide.

Fishing involved hand nets, dip nets, seines, or surround nets on the pond side of the gate during the incoming tide.

He'eia Fish Pond - loko i`a



He'eia Fish Pond

He'eia Fishpond is a walled (kuapā) style fishpond enclosing 88 acres of brackish water. On the Malauka`a fringing reef, that extends from shoreline out into Kāne`ohe Bay.

Built approximately 600-800 years ago, this is the longest kuapā in Hawai'i, measuring about 1.3 miles (7,000 ft) long and forming a complete circle around the pond.

Shape is unique. Most fishpond walls are either straight or half circles connecting one point of shoreline to another.

Monitoring physical – chemical conditions throughout the site

www.nakilohonuaoheeia.org

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Manoa Cliff Field Trip – Sunday 17th

https://manoacliffreforestation.wordpress.com/volunteering/

Depart HPU at 8.00 Return by 14:00

Park at the Round Top Drive parking area where the Mānoa Cliff Trail intersects Round Top Drive

On google map:

Manoa Cliff Trailhead & Parking
Round Top Dr
Honolulu, HI 96822

Manoa Cliff Field Trip - Sunday 17th

It takes ~ 45 minutes to hike into the site.

We will work on weeding or planting, until 12 pm.

At 12, we break for lunch and all volunteers are welcome to join in - we each bring our own lunch.

Volunteers should be prepared:

bring your own water, snacks, and appropriate clothing - long pants and long-sleeve shirts (for working off-trail), rain gear, warm clothing and work gloves if you have them.

You may also want to bring insect repellent.