Impact of Coastal Groundwater to Aquatic Resources

Richard Brock

Three Subjects Covered:

- Synopsis of changes to coastal groundwater with development
- Impacts to Anchialine Pools
- Impacts of groundwater on nearshore marine resources

Background

- Some data are from the Kohanaiki project site just north of the KAHO.
- The Kohanaiki water quality monitoring program is the most comprehensive program in West Hawaiʽi to monitor non-potable ground and ocean water.
- Sampling 6 times/year during dry periods and also after high rainfall events (1.5 inches/24hrs or more).

- Samples are collected from mauka and makai wells, anchialine pools and in the ocean fronting the project site.
- Ocean samples are also collected at control sites.

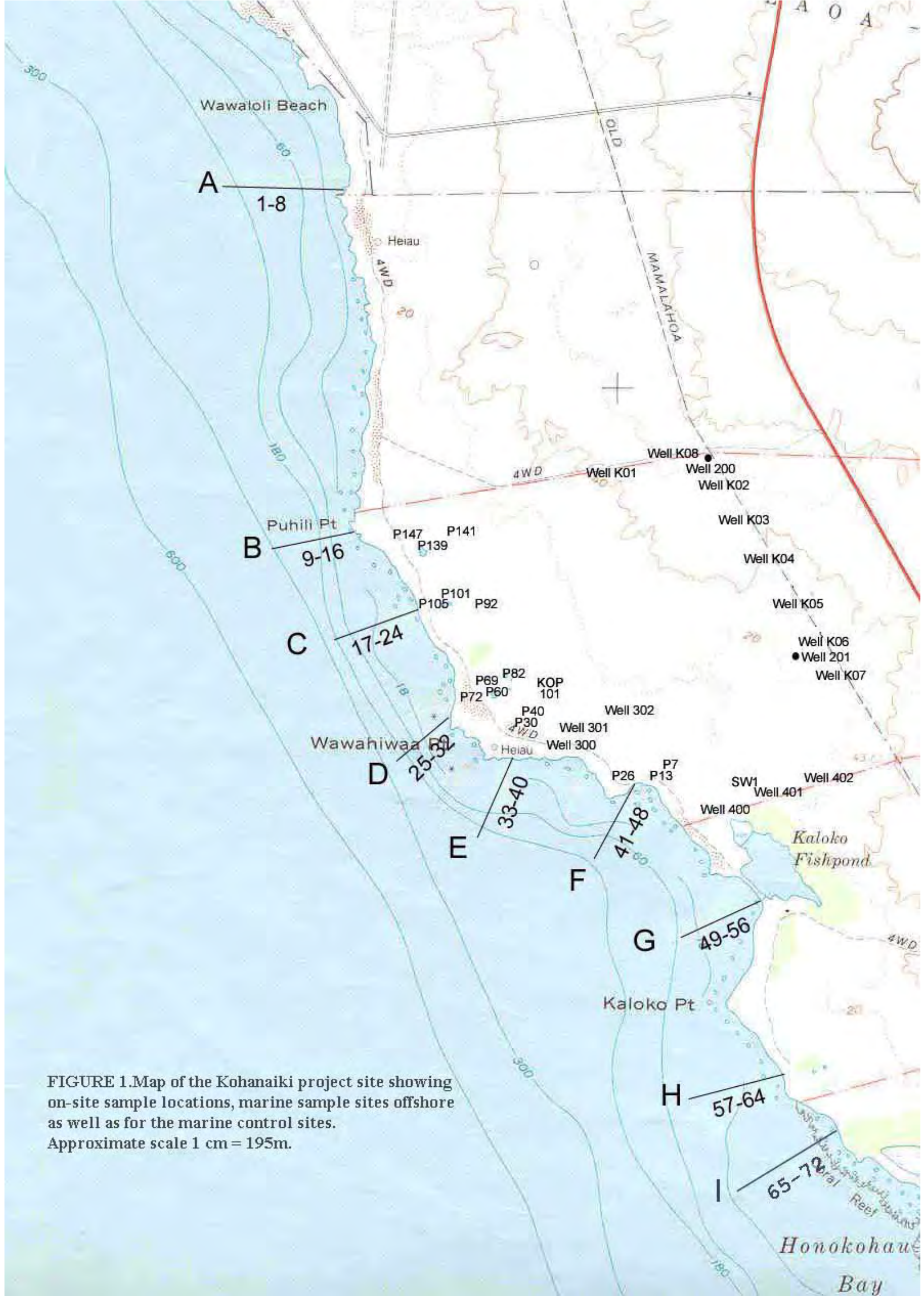


FIGURE 1.Map of the Kohanaiki project site showing on-site sample locations, marine sample sites offshore as well as for the marine control sites. Approximate scale 1 cm = 195m.

- Each survey collects ~110 samples
- Sampling started in 2005 thru today
- So we have preconstruction data and during construction data
- There have been 57 surveys collecting and reporting on 5,683 samples
- Parameters measured are those required by the State Department of Health

What We Have Found - Predevelopment

- Nutrient concentrations are naturally elevated in mauka groundwater.
- Concentrations decrease as water moves towards the ocean due to dilution with seawater.
- Concentrations may be modified up and down by physical and biological processes in the anchialine pools.

Predevelopment Continued

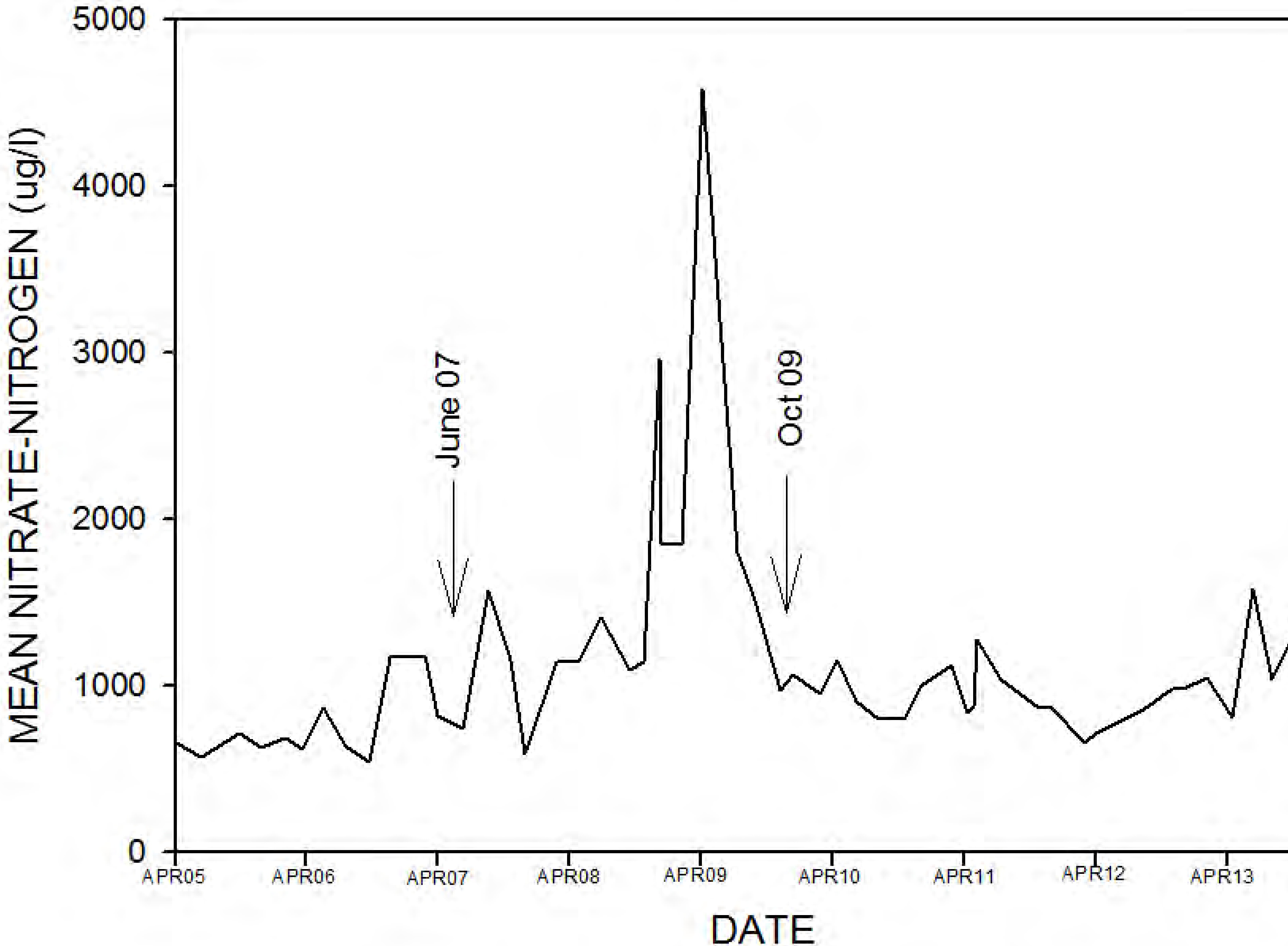
- As groundwater approaches the sea concentrations decrease very rapidly because ocean water has low concentrations.
- Decreases are due to primarily simple dilution.

Predevelopment Continued

- Nutrient concentrations vary tremendously thru space and time. At some locations concentrations are naturally elevated and at others they are low, but all of them have high variability in concentrations thru time.

During Development

- Same facts hold – concentrations high inland and decrease as groundwater travels to the sea.
- But development temporarily adds nutrients primarily during the establishment of golf course turf.
- High concentrations are seen at sample points makai of the golf course – in the anchialine pools.



MEAN NITRATE-NITROGEN (ug/l)
5000
4000
3000
2000
1000
0
June 07
Oct 09
APR05
APR06
APR07
APR08
APR09
APR10
APR11
APR12
APR13
DATE

- **To expect development not to cause change is denying common sense!**
- This brings us to the anchialine pools…What is happening there?

What is the Impact of Nutrients in Anchialine Pools

- Our work on anchialine pools started in 1972 on the West Hawaiʻi coast.
- These pools contain aquatic organisms and plants.
- Some of these species are found in other brackish water habitats in Hawaiʻi – Epigeal Species (live in the lighted portions of the pools).

Anchialine Pools Cont.

- Other species are only found in the anchialine habitat forming a unique community – Hypogeal Species.
- Hypogeal species live in the pools and the watertable below.
- Hypogeal species are only found in the anchialine system and not in other aquatic habitats.
- Many of the hypogeal species are rare and are known from just a few locations.
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Does Development Impact the Pond Biota?

- Coastal development changes the quality of groundwater and sometimes the changes are large.
- Do these changes impact aquatic biota?
- No for three reasons:
- (1) Changes are often less than those found at some non-developed sites;
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Impact to Ponds?

- (2) When nutrients are in excess, adding more does not cause a response;
- (3) The native anchialine biota have evolved in this system where there is high variability in nutrient concentrations so they are insensitive to the changes at the concentrations we have measured.

The Take Home Message Is:

- Anchialine biota have evolved under a highly variable environment insofar as water chemistry is concerned. This is why these organisms are insensitive to the concentrations we have measured in our Kona coast studies.
- No decline or impact found in biota at our project sites connected with water quality.

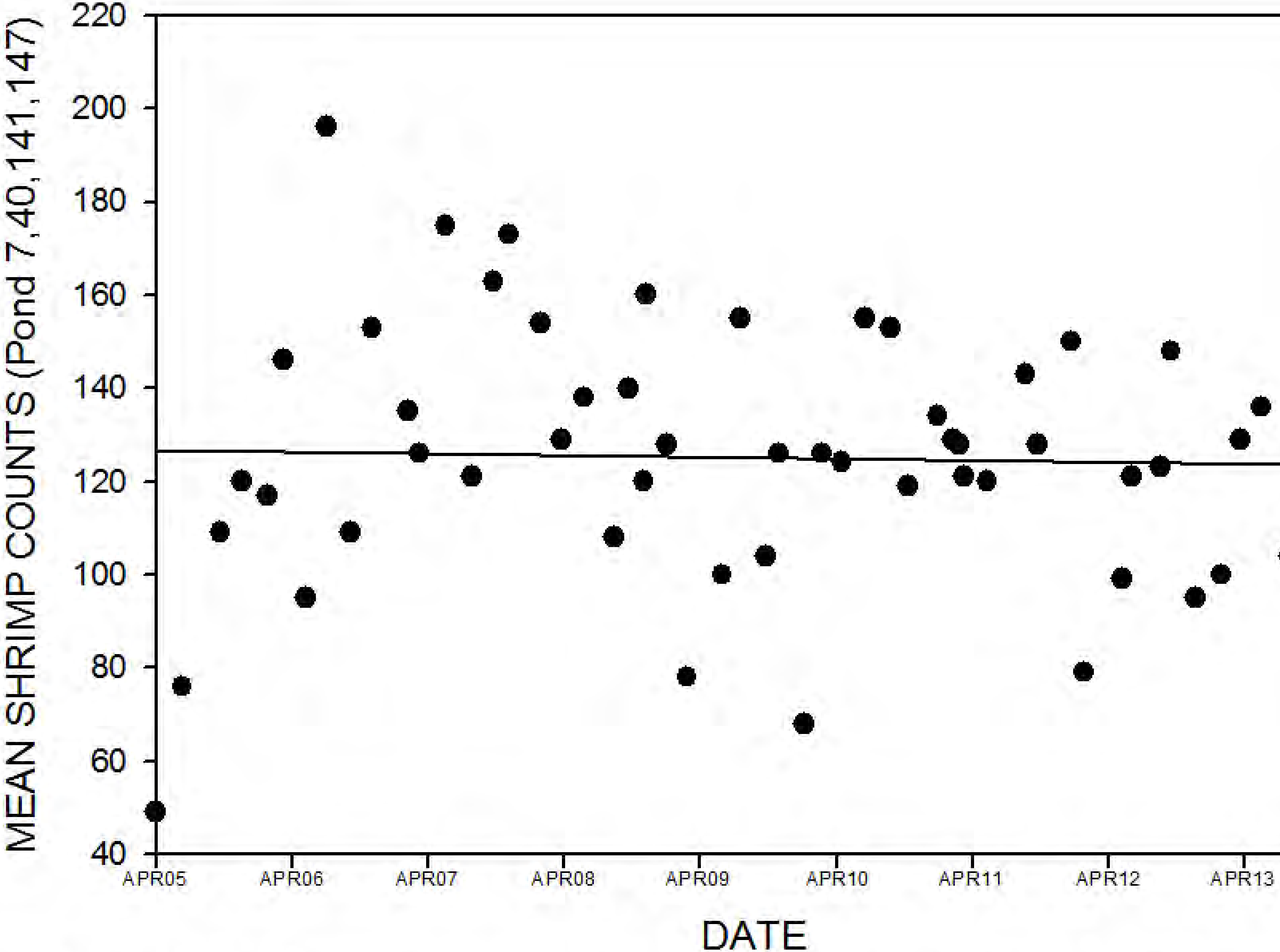

FIGURE 8. Plot of mean opae'ula shrimp counts by date in anchialine pools at Kohanaik
through 2013. Also shown is the fitted regression line to those data having almost no slope

What Impacts Anchialine Biota?

- Spread of alien fish (tilapia, mosquito fish)!
- These fish are predators on native biota.
- They are able to complete lifecycles so once in a pond, they are present forever.
- They cause change in ecological succession by removal of native keystone species.


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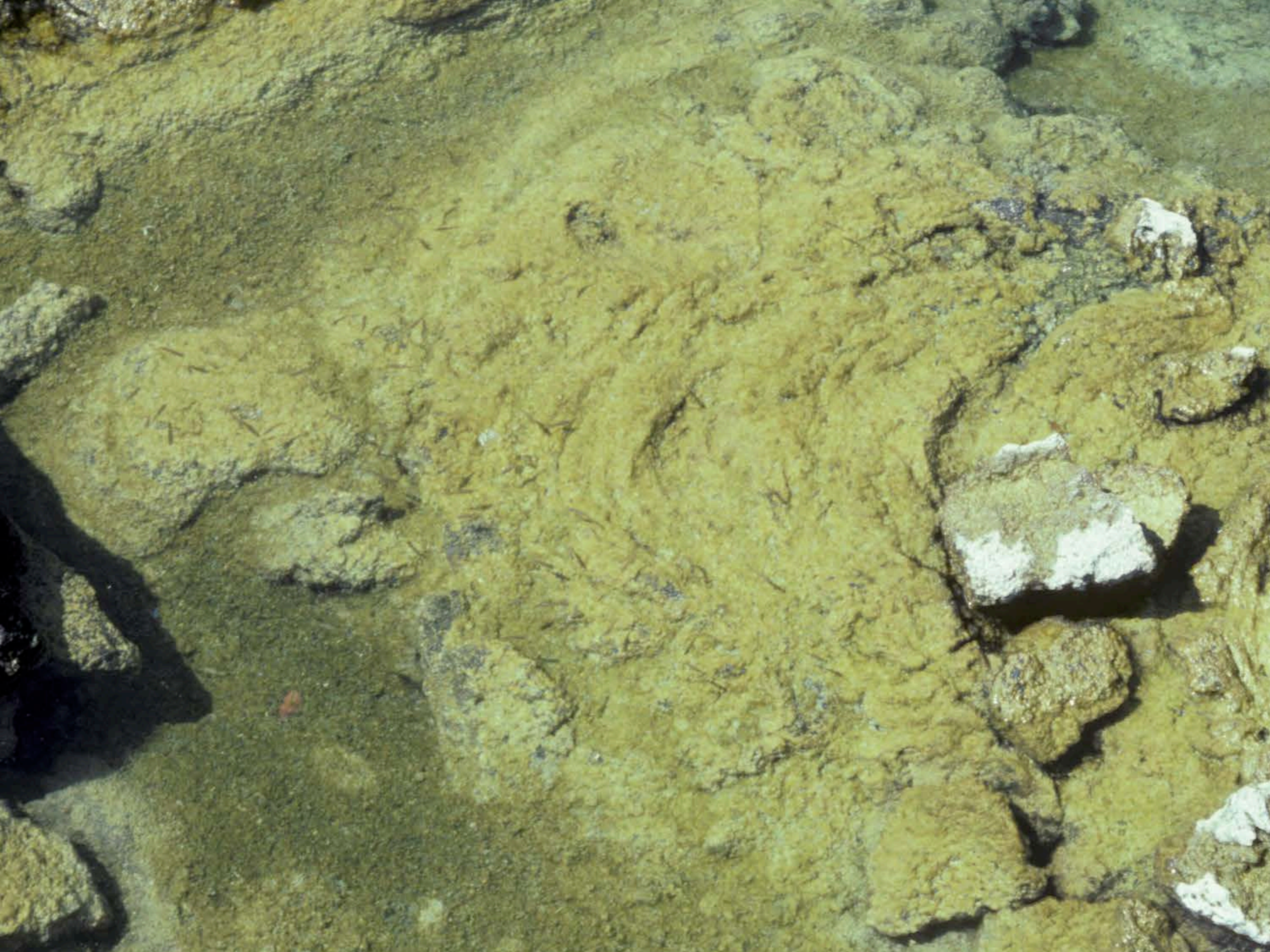

Impact of Alien Fish

- 1972 we estimated 15% of West Hawaiʻi ponds were infested with alien fish.
- 1985 the estimate was 46%.
- Today it is probably about 95%.
- There are no successful remedies for removing alien fish from anchialine pools that are legal.

Anchialine Ponds - Conclusion

- The rate at which we are going, native anchialine biota will be gone from the lighted portions of ponds in the next 20 years.
- Concern should focus on the real problem (alien fish) and not on the perceived problem (water quality changes).

Salinity and Anchialine Biota

- Most Kona ponds salinity ~5 to 13 ppt.
- Some of the more common anchialine species (opaeʻula) are found in salinities from 1 to 30 ppt.
- Some epigeal species (damselfly and some aquatic vegetation) in anchialine pools live at lower salinity – but all of these are found in many other Hawaiian brackish water habitats on other islands.

- The very rare hypogeal shrimp species are found exclusively in ponds with salinities from 15 to 30 ppt and some are known from 1 or 2 ponds only and nowhere else in the world.
- Any increase in salinity in Kona coast anchialine pools due to overuse of freshwater, would increase the available habitat for these rare species if alien fish are absent.

SGD = Submarine Groundwater Discharge

A. Physical Characteristics

- 1. SGD has lower salinity so it initially overlies seawater when it flows into the sea.
- 2. Wind, waves & currents serve to mix it with the underlying seawater.
- 3. Nutrient concentrations are greater in SGD relative to seawater.

B. Biological Characteristics

- 1. Corals are stenohaline meaning that they CANNOT tolerate low salinity water. How low??
- 2. Reduce salinity from 35 ppt to one-half (17.5 ppt) killed all 23 Hawaiian coral species within 6 days and most dying within 1 day; 25% salinity reduction killed 15 of 21 species (Edmondson 1928).

Biological Characteristics Cont.

- 3. Higher nutrient concentrations in SGD can enhance growth of limu and corals (zooxanthellae).
- 4. However, if nutrient concentrations are too high, negative impacts may occur to corals.
- 5. SGD serves to attract many marine fish species (young primarily) – aholehole, pua, awa, papio, moiliʻi, etc.

Biological Characteristics Cont.

- Where SGD enters the sea at a discreet point (stream mouth = muliwai or fishpond channel = mākāhā), small fishes follow the lower salinity gradient and swim inland seeking food and shelter from predation by larger fishes.

C. Keauhou Aquifer/Kona Coast

- 6. No muliwai and few mākāhās but plenty of diffuse SGD along much of the coast so the SGD at KAHO is not unique.
- 7. Kohanaiki – KAHO Comparison:
- Mean Salinity is significantly less offshore of the Park (33.686 ppt, n=1,863) than offshore of Kohanaiki (34.638 ppt, n=2,449) ($p>0.0001$) simply because of greater groundwater flow at KAHO.

C. Kona Coast Cont.

- 8. However, there are no significant differences with mean temperature: Kohanaiki = 25.6°C (or 78.1°F) and KAHO = 25.5°C (or 77.9°F)
- Thus the corals offshore of KAHO are not being kept "cool" by "freshwater" anymore than anywhere else along this section of the coast and keep in mind that freshwater will kill corals!!