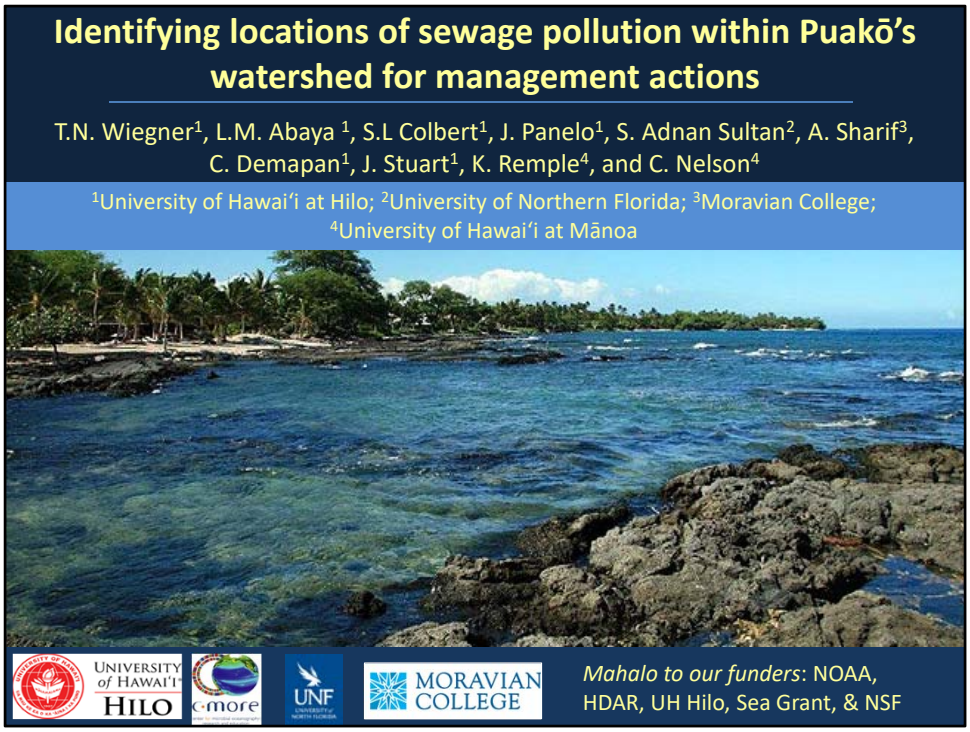
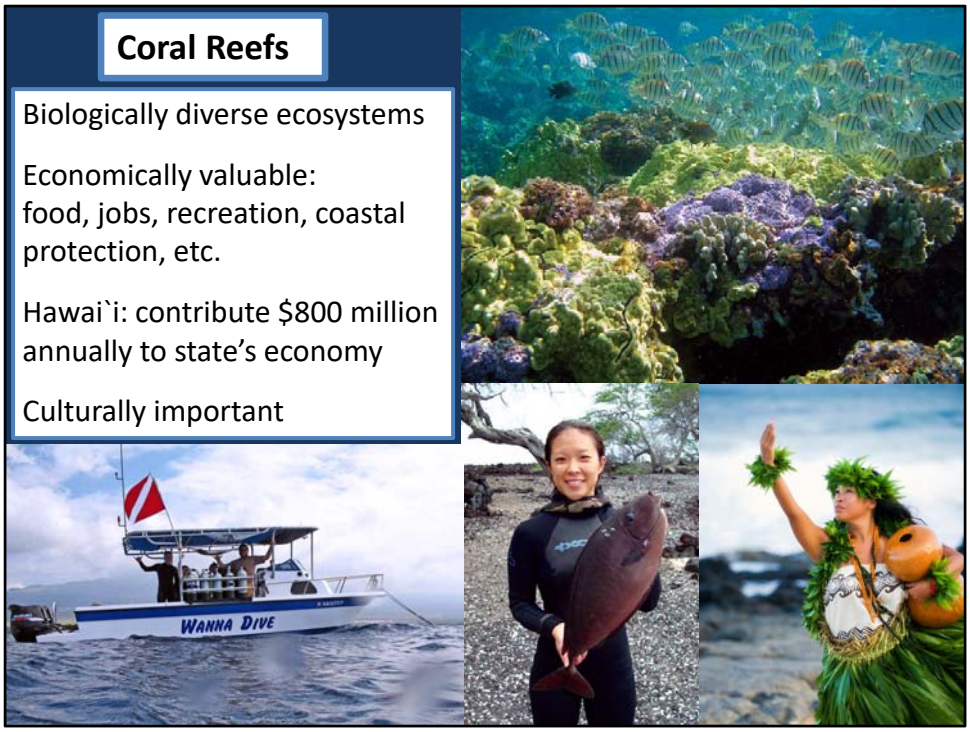
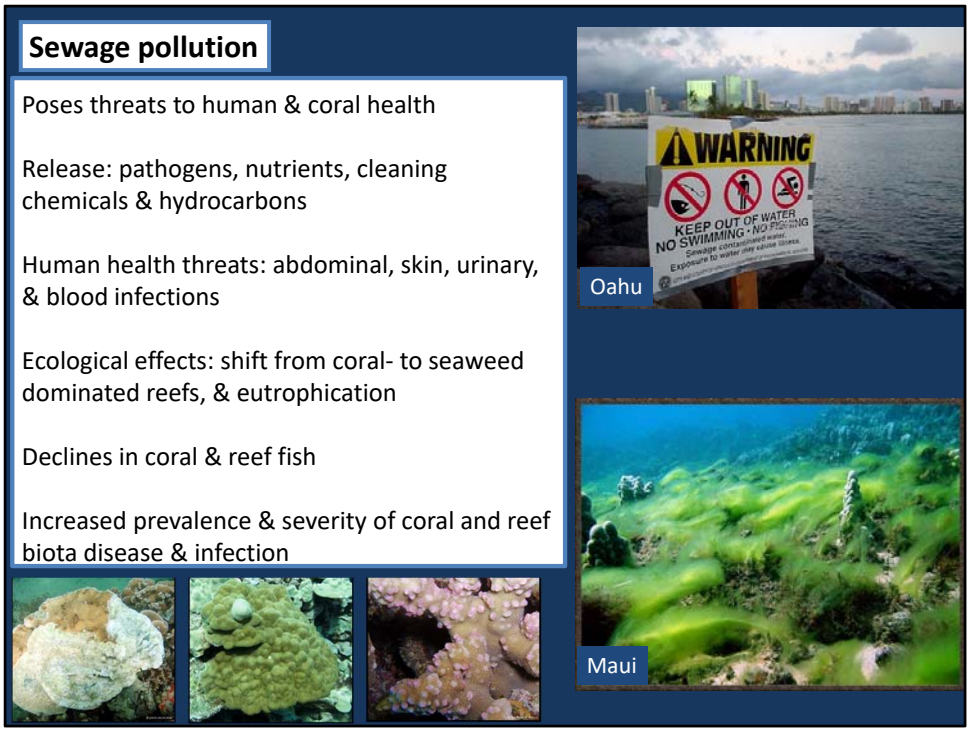


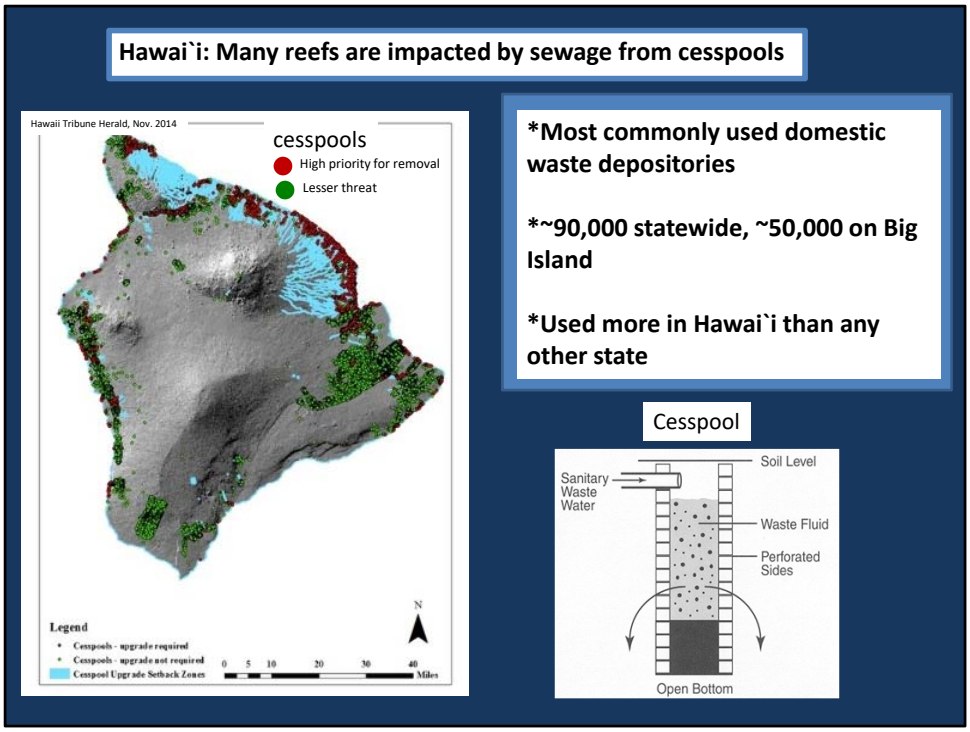
Thank you for inviting us to share our science with you and to the Coral Reef Alliance for organizing this gathering. Before starting, I would like to acknowledge my colleagues in the audience that have contributed to this research effort: Steve Colbert (UHH), Jim Beets (UHH), Courtney Couch (HIMB) and Chad Wiggins (TNC). We are excited to share our findings with you today and, after our brief presentation, we will do our best to answer your questions.



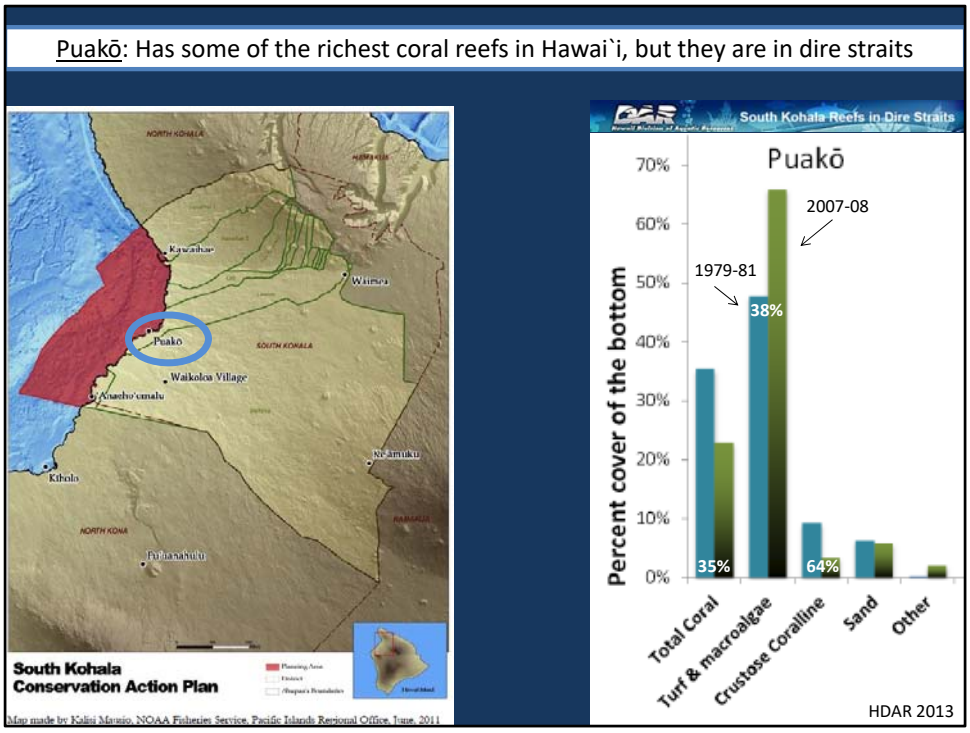
Coral reefs are among the most biologically diverse and economically valuable ecosystems on Earth, providing hundreds of billions of dollars in food, jobs, recreational opportunities, coastal protection, and other valuable services. In Hawai‘i alone, for example, coral reefs are estimated to contribute $800 million dollars annually directly to the state's economy. Coral reefs are also culturally important; for example, the Kumulipo, the Hawaiian Creation story, starts with the creation of coral polyp.



Sewage pollution poses a threat to human and coral reef health, with discharge of pathogens, nutrients, cleaning chemicals, and hydrocarbons into nearshore waters. Human health effects from sewage inputs range from abdominal infections, to skin, urinary, and blood ones. Ecological effects of sewage pollution include shifts from coral- to seaweed- dominated reefs, eutrophication, declines corals and reef fish, as well as high occurrence of diseases and infections of reef biota.



Unbeknown to visitors, but well known by residents, Hawai‘i’s coral reefs are impacted by sewage primarily through a diffuse, widespread source—cesspools. These are the most commonly used domestic wastewater depositories in Hawaii, and they are used more widely here than any other state in the nation. Hawai‘i Department of Health estimates that there are presently 90,000 cesspools in the state, with 50,000 are on Hawaii Island. Fall 2016, HDOH finally banned new cesspool construction in the state, the last state in the nation to do so; Rhode Island the second to last state to do it, did it in 1968.

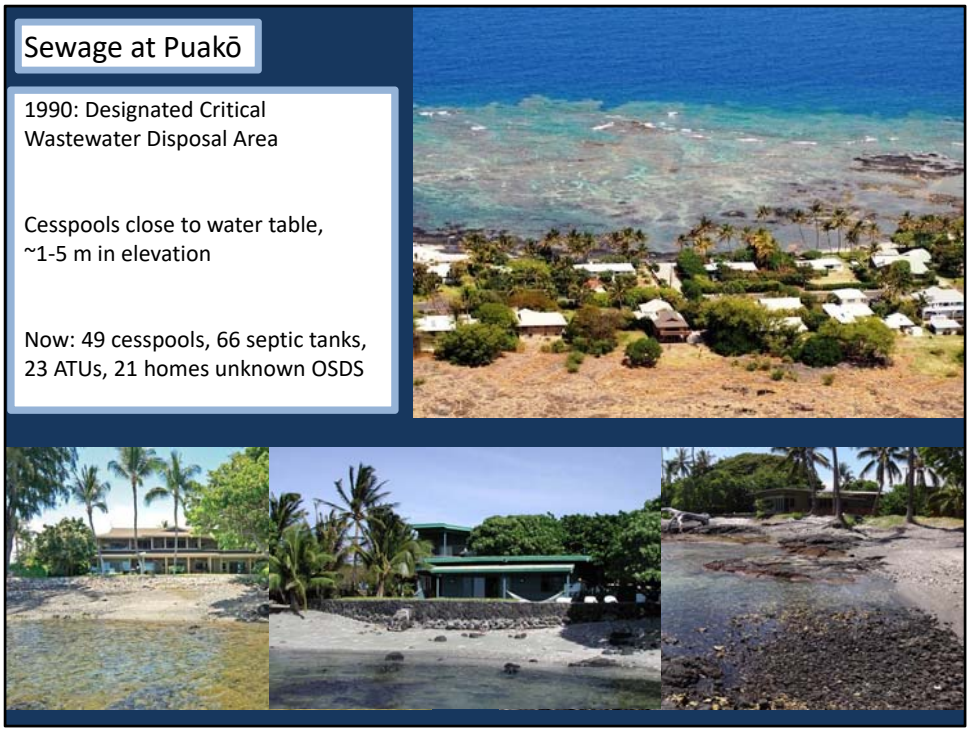


Symptoms of sewage pollution are becoming more apparent on the outer Main Hawaiian Islands in rural areas, such as Hawai‘i Island. In these areas, coral reefs are still relatively healthy, underscoring the urgency for improved sewage disposal management.

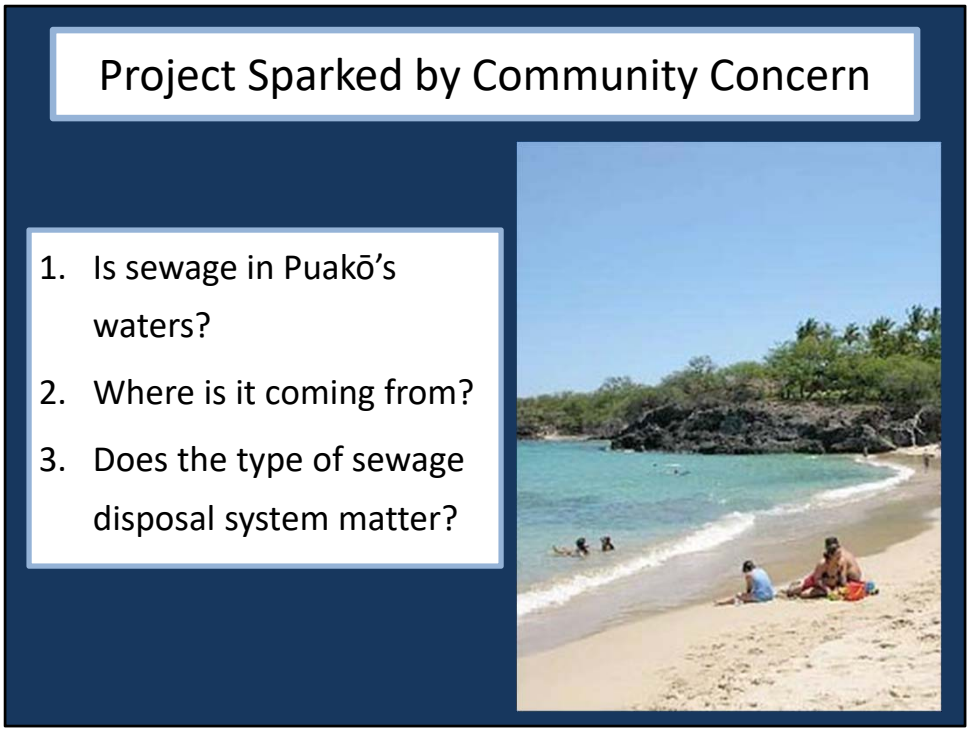
Hence, Hawai‘i State’s Coral Reef Strategy, Objective 1, is to reduce key anthropogenic threats to nearshore coral reef sites.

Pūako is located in one of two priority sites identified for site-based actions. Pūako’s coral reefs are considered some of the richest in the state.

But, according to a recent Hawaii’s Division of Aquatic Resources report – Puako’s reefs are in dire straights. Coral cover has decreased 35% up to 50%, with algal cover increasing 38% in the last 30 years. It is suspected that sewage pollution maybe one contributing factor to these documented changes to Puako’s reefs.



Concern over sewage pollution at Puako is not new; residents have been worried about its impacts to the reef since the 1960s. As a result, in 1990, Pūako was designated as a Critical Wastewater Disposal Area. These are areas where the disposal of wastewater has or may cause adverse effects on human health or the environment due to existing hydrogeological conditions. The condition at Pūako is that cesspools are in close proximity to the water table, which is 1 to 5 meters in elevation. As a result, homeowners building new homes or renovating existing ones are required to install septic tanks. Presently, there are 49 cesspools, 66 septic tanks, 23 ATUs, and 21 home where the type of OSDS is unknown.



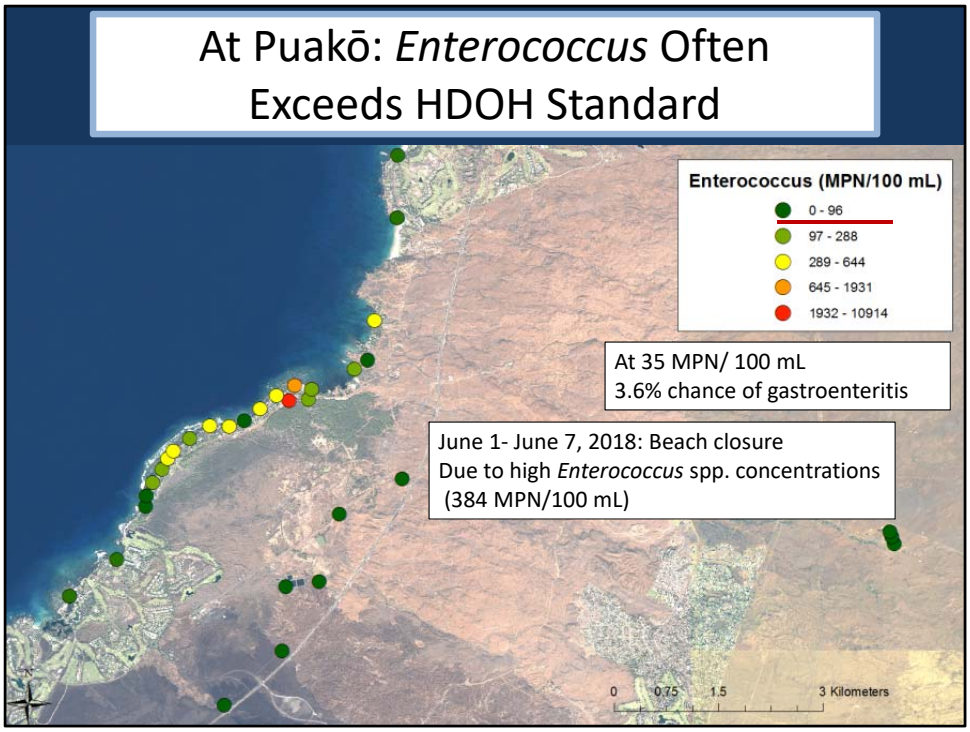
In 2013, the Puako Community Association enlisted UH Hilo and TNC to help answer the questions: Is sewage in Puako's waters? And since then, we have been collecting information through several different research projects to address this question, and the answer is yes.

How do we know this? Over the last three years, we have made measurements of sewage indicators (fecal indicator bacteria, stable nitrogen isotopes, nutrients), as well as conducted dye tracer tests. From this research, we have shown that sewage is present, and traveling from homes to the shoreline within hours to days.

And although we have documented this, many community members have asked us whether upslope communities or adjacent resorts could also be contributing sewage pollution to Puako's waters. Our most recent efforts have sought to answer this question, and to address whether the type of sewage disposal system a property has matters with respect to nearshore water quality.

Where is the Sewage Coming From?

We sampled waters from groundwater wells at Waikoloa Village and Mauna Lani, and from resorts' shorelines at Mauna Kea, Hapuna Prince, Fairmont Orchid, and Mauna Lani – analyzing them for sewage indicators. Here is what we found (next slide)



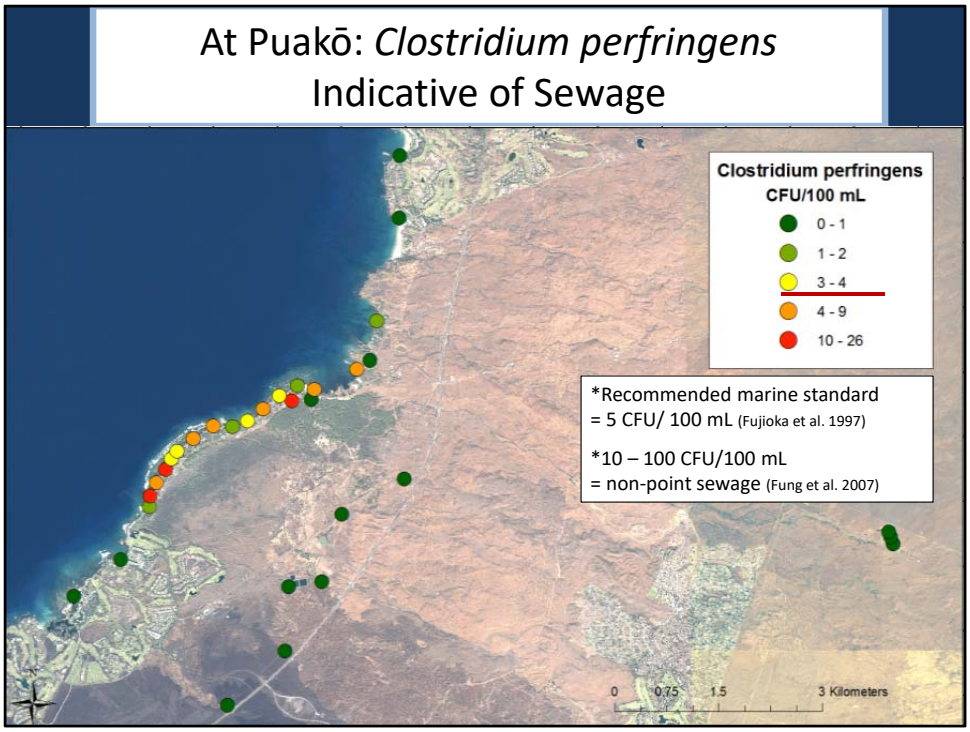
Enterococcus, a FIB, has concentrations that often exceeded HDOH single sample maximum of 104 MPN/ 100 mL.

Upslope wells and resorts' shoreline waters had low concentrations that were all below HDOH's standard.

The US EPA's marine waters recreational standard is 35 MPN/ 100 mL (geomean), and at this level, your chance of getting gastroenteritis is 3.6%.

Most concentrations at Puako are 2 to 3 orders of magnitude higher than this standard

Earlier this month (June 2018), HDOH closed the beach at their sampling site (betweeen Puako Beach Drive 56 and 58) for six days due to elevated concentrations (I think this is one of our stations near the point).

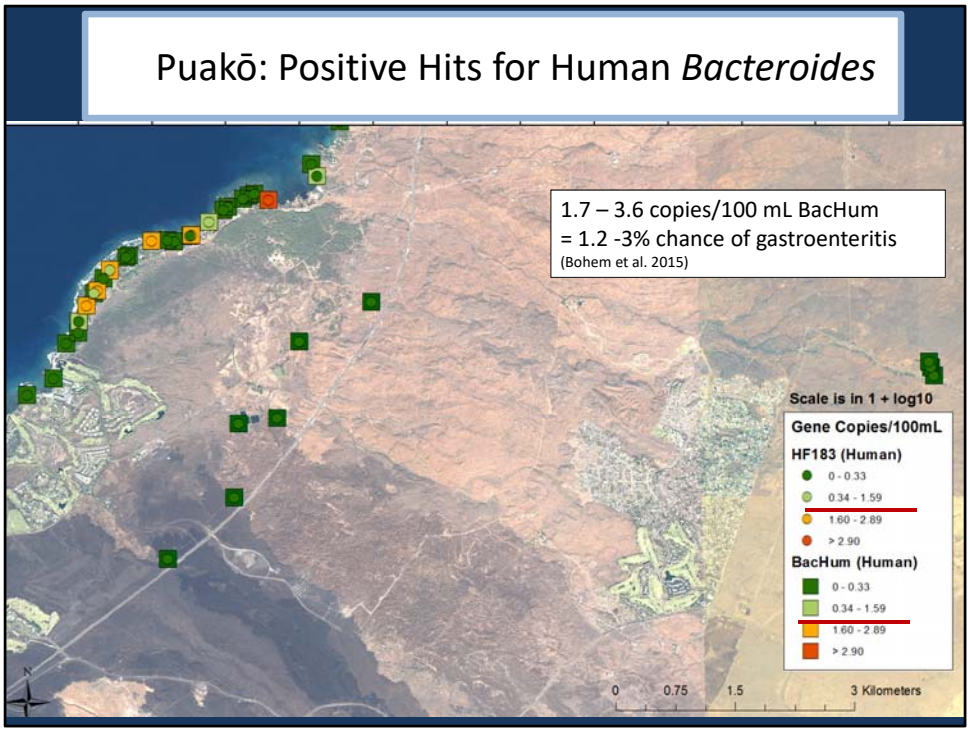


Because Enterococcus can naturally occur in Hawaiian soils, HDOH uses a secondary FIB – Clostridium perfringens which is thought to be a more specific indicator of sewage pollution.

Clostridium perfringens concentrations at Puako often exceeded the recommended marine recreational waters standard of 5 CFU/ 100 mL,

With several stations having values indicative of non-point source sewage pollution (10 -100 CFU/100 mL).

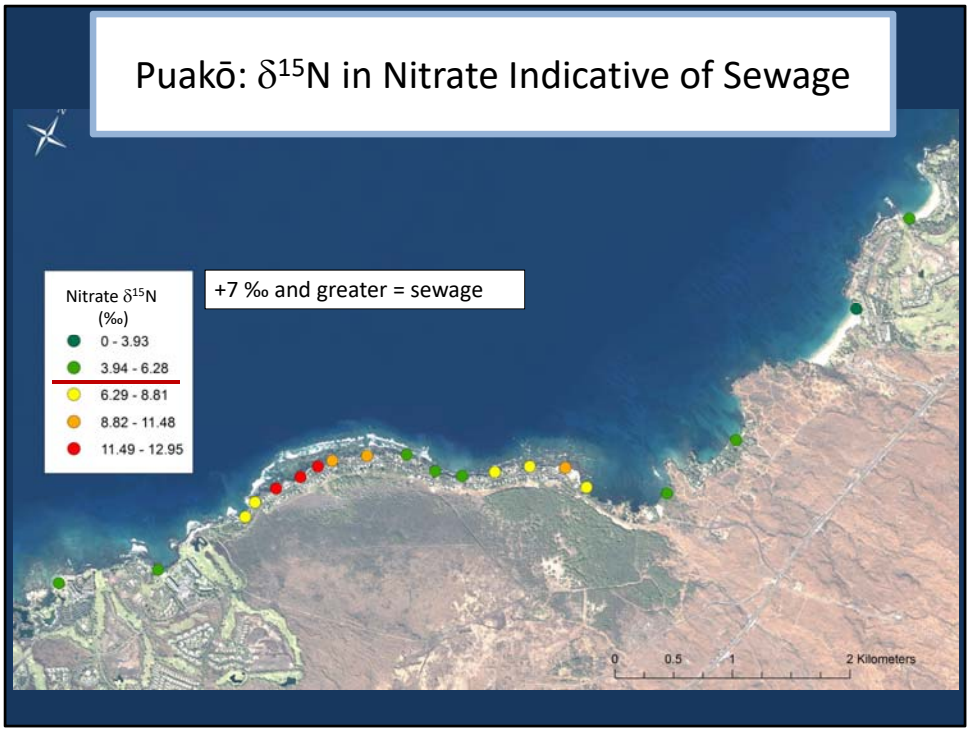
Concentrations upslope and at adjacent resorts were low.



Over the last 10 years or so, more specific methods have been developed to identify fecal bacteria sources to waters. Specifically, molecular markers have been developed for the bacteria Bacteroides, which is the most abundant bacteria in the human gut. We now have methods that can identify ones of human origin in the water.

Positive hits for human bacteroides (using two different markers) only occurred at Puako.

Also, it has been found that when the concentrations are 1.7 -3.6 copies/ 100 mL, your chance of getting gastroenteritis is 1.2-3%. Concentrations were within this range at some stations within Puako.



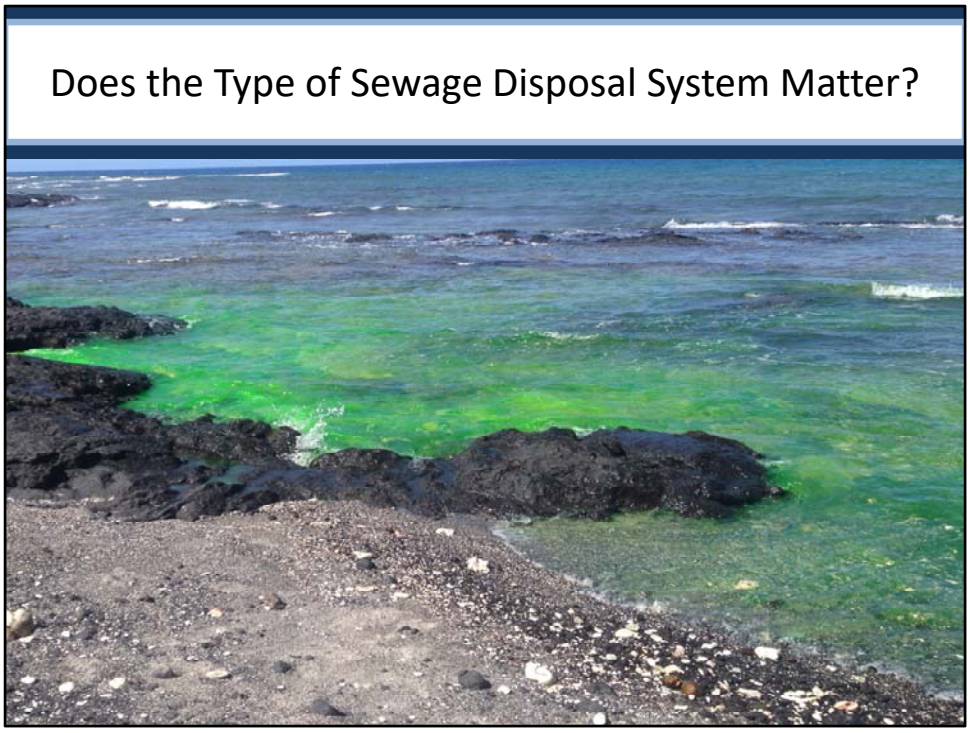
We also measured stable nitrogen isotopes in nitrate. Nitrate is a nutrient.

We found that values at Puako were indicative of sewage (>+7), while values upslope and at adjacent resorts were indicative of soil and fertilizers.

(do we have an updated map which includes resort values?)

Take Home Message #1

- Sewage indicator values were highest along Puakō's shoreline
- Sewage is largely entering the water table at Puakō, and not at the other locations



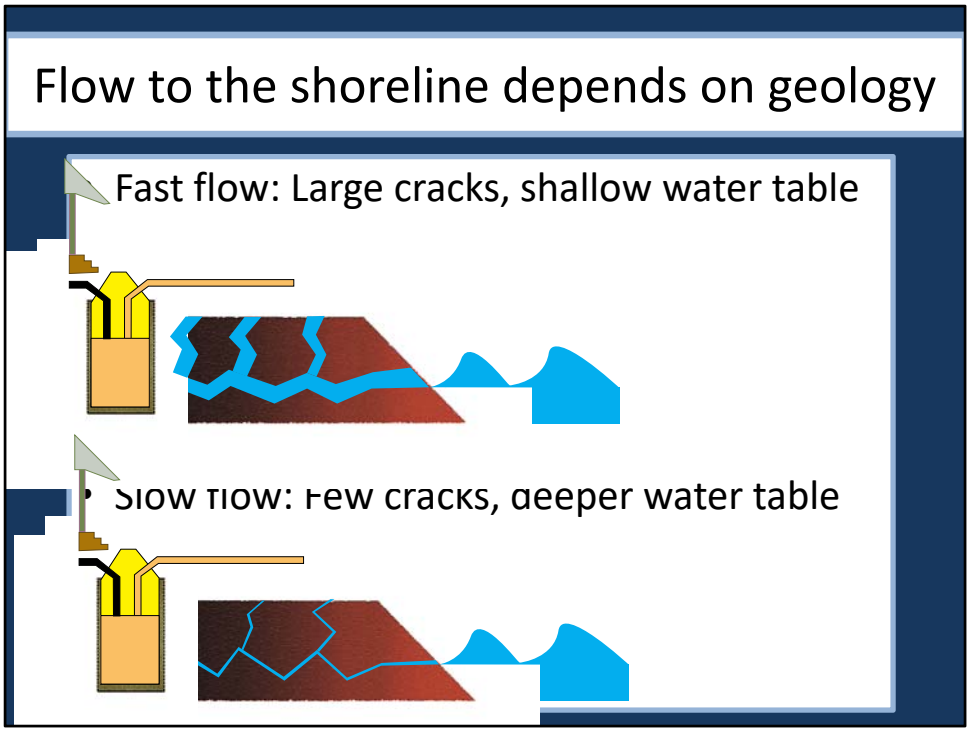
Second question, does the type of sewage system matter? Do they all leach into the water table? Do they differ in their time of travel from the home to the shoreline?

Over the last year and still ongoing, we have been working to answer these questions.

Dye Reached Shoreline Quickly

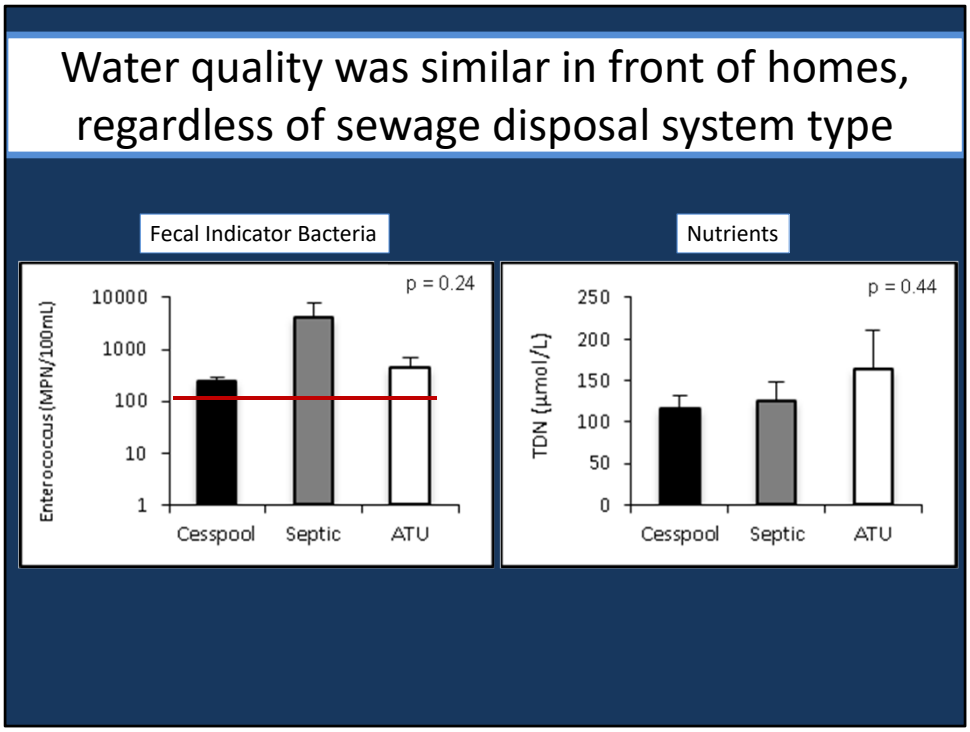
- 9 dye tracer tests:
  - 4 Cesspools
  - 2 Septic Tanks
  - 3 ATUs
- Dye reached shoreline in < 5 h, up to 10 d
- ***No difference among systems***

We have now tested how fast water travels to the shoreline from cesspools, ATUs, and septic tanks. Our dye tracer studies documented dye reaching the shoreline in less than 5 hours up to 10 days. Both the shortest and the longest travel times came from homes with ATUs!



How is this so? Well travel time largely depends on the geology. Dye traveled fast in areas where there are large cracks in the basalt and the water table is close to the ground's surface. Greater chance for dye to hit a crack and reach the water table faster.

Where the cracks in the basalt are smaller and/or fewer and the water table is deeper, there a smaller chance for the dye to seep into a crack and reach the water table. So, the dye travel time is greater.



We also assessed water quality in front of the homes with different types of OSDS. We found that water quality was similar in front of all the homes where we sampled, regardless of the system type. For example, Enterococcus was similar in front of homes with different OSDS, and concentrations were greater than the HDOH single sample maximum. A similar pattern was observed for nutrients too. Here is an example of Total Dissolved Nitrogen, concentrations were all greater than 100 umol/L.

Take Home Message #2

- Dye reached shoreline
  - 5 h – 10 d
  - Time affected by geology, not system type
  - No difference among system type
    - flow time
    - water quality

CONCLUSIONS

- Sewage indicator values greatest at Puakō
- Dye from sewage systems reached shoreline
  - 5 hrs – 10 days (cesspool, septic tanks, ATUs)
  - No difference in system type
    - Flow to shoreline
    - Water quality
    - Geology more important
- Paramount to minimize land-based pollution for human and coral reef health

This is a transition slide for CORAL to present their work.

Questions?

Mahalo

<u>To our collaborators</u>: Puakō Community Association, TNC, South Kohala Conservation Action Plan Program Coordinator, Coral Reef Alliance, HDOH, Cornell University, UHH Analytical Laboratory, Louise Economy, Melia Takakusagi & all our PIPES and CMORE interns

<u>To our funding sources</u>: Hawaii Division of Aquatic Resources Coral Reef Working group, NOAA Coral Reef Conservation Program, UHH PIPES Internship Program (NSF REU) , Center for Microbial Oceanography and Education (NSF), UHH Research Council and Marine Science Department

Lastly, I would like to mention that this project of documenting sewage pollution and working with the Puako community to investigate solutions to their problem would not be feasible for one group to do; we have been able to accomplish so much so far from our collaborations with PCA, TNC, Coral Reef Alliance, and Cornell University. It has been an amazing opportunity to work with them, as well as our many other collaborators and funding agencies. Mahalo you for your attention. I'd be happy to take any questions