Water Quality and Waller Creek

Dr. Kinney &
UTBIOME Collaborators

The Visible
&
The Invisible

What is in Waller Creek?

A Wide Variety of Biota!

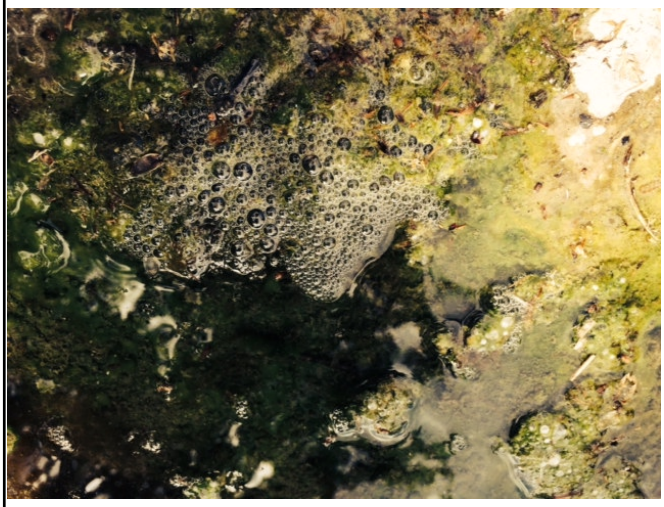
The Visible!

Yellow-crowned Night Heron
at 24th Street Bridge
June 2003
Photo by Dr. Ed Theriot

http://www.utexas.edu/tmm/sponsored_sites/waller/news.htm

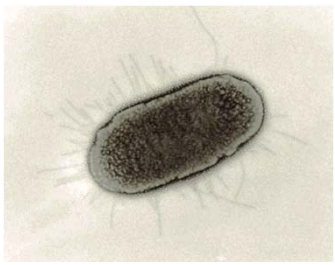
Snake
UTBIOME Station 2
Waller Creek Sampling
by CE 341 Class
October 2013

What *Else* is Visible?

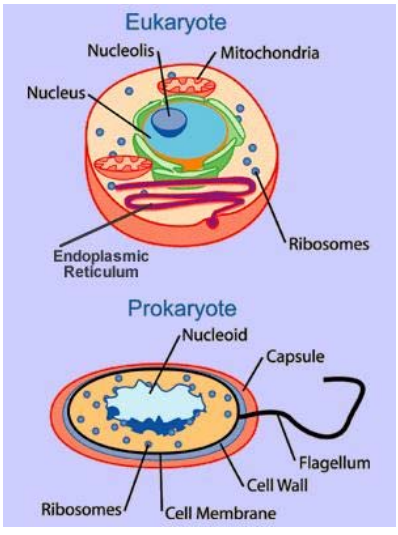


Algae
UTBIOME Waller Creek Sampling
by CE 341 Class
March 2013

What Else is Not Visible? (to the human eye)



Bacteria,
Fungi
Viruses
Protozoa



http://www.fas.org/irp/imint/docs/rst/Sect20/A12.html

Focus on Bacteria

- Hugely diverse
  - Thousands of species possible in single sample
- Important to Ecosystem Function
- Metabolically diverse
  - Decomposers (Nature's vacuum cleaner/filter)
  - Nutrient transformations
  - Anaerobic, Aerobic

Focus on Bacteria

- Adaptive
  - Antibiotic resistance
    - Higher levels of triclosan-resistant organisms found downstream from combined sewer overflows
      http://www.caryinstitute.org/newsroom/antibacterial-products-fuel-resistant-bacteria-streams-and-rivers
- Most bacteria present in surface waters are not known human pathogens
  - although the **full range of bacteria** present is just now being revealed with **DNA sequencing** …more on this later
- Percent of total that were potential pathogens in one study of urban runoff water: Approx. 8 %
  http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0079490

Why do we care about what microorganisms are present?

Protect Human Health

Protect Ecosystem Health

(e.g., contaminants can shift microbial community from algae to cyanobacteria)

Slide courtesy of Steve Werner, Water For People, 2004

Drinking Water and Sanitation: Global

- Some sobering statistics from the World Health Organization
- Approximately 1.5 million deaths per year due to poor water quality, poor sanitation and hygiene.
  - Equivalent to the deaths of the entire population of Austin metropolitan area (approx. 1.6 million)

Who are the Culprits?

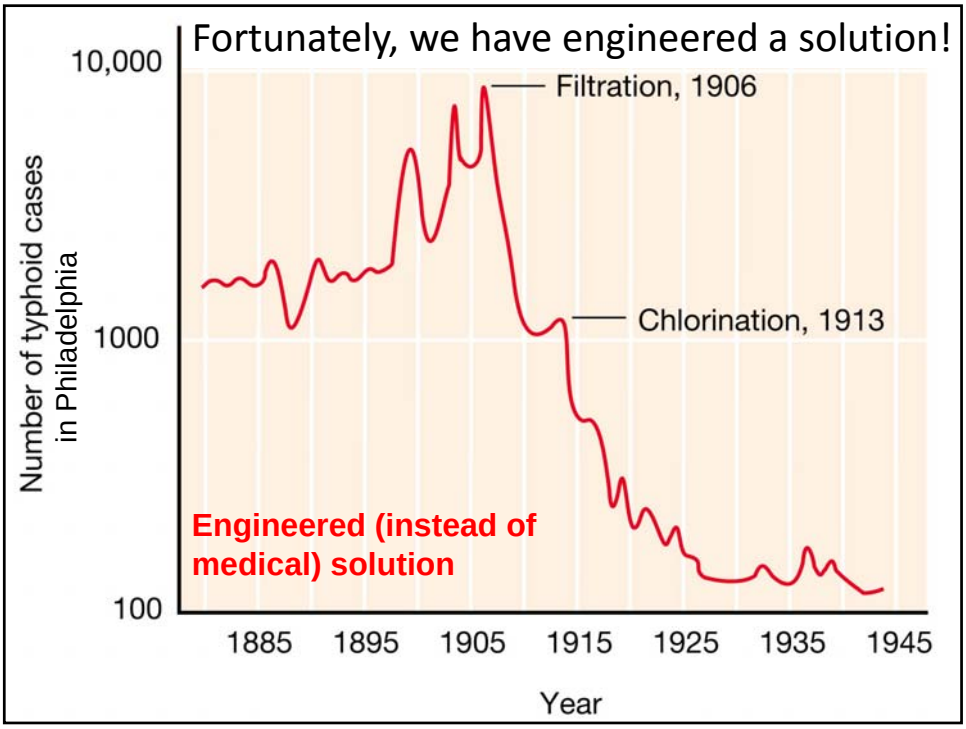
- Bacteria, viruses, protozoa and occasionally worm infections and amoeba.
- Example diseases
  - Bacteria cause typhoid, cholera and dysentery
  - Protozoa cause dysentery
  - Viruses cause infectious hepatitis and polio

Typhoid Epidemic in 1897-1898 in Philadelphia

soon be forgotten. The epidemic was the result of a careless—almost criminal—flooding of the big Manayunk intercepting sewer, which, having been done in a bungling manner, caused the sewer to burst and discharge its contents into Wissahickon Creek, whence it was swept into the Schuylkill River close to the point where the pumping station supplying the Queen Lane Reservoir is situated. The sewage, containing millions of typhoid germs, was pumped into the reservoir, and thus was a deadly peril placed directly in the way of thousands of consumers of the water served from that reservoir.

The flooding of the sewer occurred on Dec. 16, and in that month alone over 500 cases of typhoid fever were reported to the Board

From *The Philadelphia North American*, April 18, 1898



How to determine the biological safety of water for bacteria

V. cholerae

http://remf.dartmouth.edu/images/Micromondilmages/source/32-cholera.html

1. Assay for particular pathogens
   - Problems
     - Assay specific to each type of organism
       - Culturing techniques
       - Molecular techniques
     - **Detection difficult due to low pathogen counts**
     - Tests might be difficult, time-consuming, expensive

2. **Test for indicator organisms**
   - **Presence of indicator organism suggests presence of pathogens**

Desirable Properties of Indicator Organisms in Water

1. Suitable for analysis of all types of water
   - **Tap, river, ground, waste, etc.**
2. Be present whenever enteric pathogens present
   - **Enteric = intestinal**
3. Indicator should be harmless to humans
4. Survive longer than hardiest enteric pathogens
5. Should not reproduce in the water
6. Concentration of indicator should have direct relation to degree of fecal pollution
7. Assay should have high specificity/sensitivity
8. Assay should be easy to perform

Coliforms

Freshwater indicator bacteria

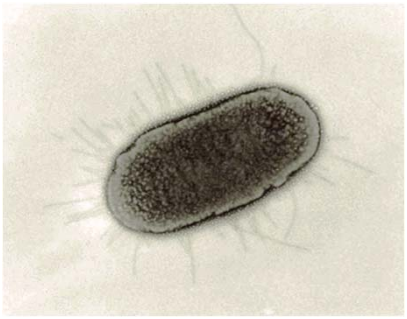
- They comprise
  - **10% of animal intestinal microbes**
- Members of the family *Enterobacteriaceae*
- They lose viability at slower rates than most bacterial intestinal pathogens in fresh water.
- **Poor indicators of pathogenic viruses or protozoa**

Coliform Definition

- Aerobes or facultative aerobes
- Gram-negative
- Non-spore forming
- Rod-shaped
- Ferment lactose with gas production
  - 48 hours at 35°C

Operational definition

E. coli



The average bacterium is
1,000 nanometers long.

www.its.caltech.edu/~boozer/symbols/ self_replication.html

What are the sources of coliforms?

The coliform family is made up of several groups of bacteria that originate as organisms in soil or vegetation and in the intestinal tract of warm-blooded animals (fecal coli).

One subgroup, is the fecal coliform group, which is found in the intestinal tracts of warm-blooded animals including humans.

Some coliforms are found naturally in soil and water. Fecal coliforms are a sub-group of total coliforms that are passed through the fecal excrement of humans, livestock and wildlife. They aid in the digestion of food. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals.

E. coli is a sub-group of the fecal coliform group. Most *E. coli* are harmless and are found in great quantities in the intestines of people and warm-blooded animals. The presence of *E. coli* in a drinking water sample almost always indicates recent fecal contamination. One particular *E. coli* strain called 0157:H7 can cause severe diarrhea and kidney damage. Most outbreaks have been related to food contamination, caused by a specific strain of *E. coli* known as ***E. coli O157:H7***.

Total versus Fecal Coliforms

- Some coliforms are not of intestinal origin
- Differentiate between total and fecal coliform

Environment and intestines

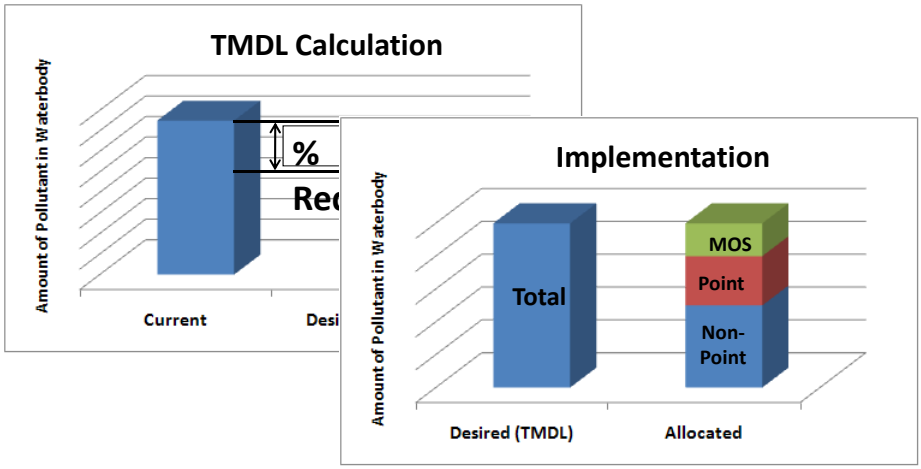
Intestines of warm-blooded animals

- Fecal coliforms grow at more restrictive temperature
  44.5 ^{o}C
- Total coliforms > fecal coliforms

What does this mean for us in TX?

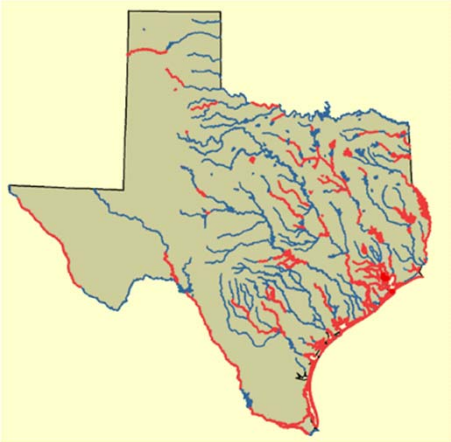
- Water quality monitoring
- Indicator bacteria
- Total Maximum Daily Load (TMDL) requirements
  - List of waters not meeting standards
  - Submitted to EPA every 2 years
  - Listed waters must have TMDL study

TMDL: **Maximum quantity of a pollutant that can enter a water body and still meet WQ standards**



TMDL =
Point-source allocation + Non-point source allocation + Margin of Safety (MOS)

Causes of Impaired Waters in Texas



- A **total of 568** impairments are now included in Category 5.
- Impairments due to **elevated bacteria** represent the highest percentage (45%) included in Category 5.

http://www.tceq.texas.gov/waterquality/assessment/12twqi

Status of Waller Creek

303 (d) List of Impaired Waters

Categories

- 5a – TMDL, watershed action plan
- 5b – Evaluate water quality standard
- 5c – Additional data needed

SegID: 1429C **Waller Creek (unclassified water body)**
From the confluence of Town Lake in central Austin in Travis County to the upstream portion of the stream in north Austin in Travis County

Parameter(s)		*Category*	*Carryforward*
bacteria			
1429C_01	From the confluence with Town Lake to East MLK Blvd.	5a	No
1429C_02	From East MLK Blvd. to East 41st Street	5a	No
1429C_03	Upper portion of creek	5a	No
Parameter(s)		*Category*	*Carryforward*
impaired macrobenthic community			
1429C_01	From the confluence with Town Lake to East MLK Blvd.	5c	Yes

Waller Creek: E. Coli

SEGID: 1429C **Waller Creek (unclassified water body)**
From the confluence of Town Lake in central Austin in Travis County to the upstream portion of the stream in north Austin in Travis County

AUID: 1429C_01 ***From the confluence with Town Lake to East MLK Blvd.***

Bacteria Geomean

NS	E. coli	NPS - Municipal (Urbanized High Density Area) Runoff; NPS - Non-Point Source; PS - Point Source Unknown; UNK - Source Unknown

AUID: 1429C_02 ***From East MLK Blvd. to East 41st Street***

Bacteria Geomean

NS	E. coli	NPS - Municipal (Urbanized High Density Area) Runoff; NPS - Non-Point Source; PS - Point Source Unknown; UNK - Source Unknown

AUID: 1429C_03 ***Upper portion of creek***

Bacteria Geomean

NS	E. coli	NPS - Municipal (Urbanized High Density Area) Runoff; NPS - Non-Point Source; PS - Point Source Unknown; UNK - Source Unknown

NS - Non-Supporting; CN - Concern for Near Non-attainment; CS - Concern for Screening Level;
SEGID - Segment ID; AU ID - Assessment Unit ID; PS - Point Source; NPS - Nonpoint Source; UNK - Source Unknown

Water Quality Regulations

Recreational Use Categories & Corresponding Criteria

High Contact

No Contact

Recreation Uses	*E. coli* (FW) Geometric Mean Criteria (colonies/100 ml)	Enterococci (SW) Geometric Mean Criteria (colonies/100 ml)
Primary contact	126	35
Secondary contact 1	630	175
Secondary contact 2	1030	--
Noncontact	2060	350

http://www.anra.org/divisions/water_quality/crp/pdfs/meetings/2013_Steering_Committee_Meeting/2_WQS_and_Texas_Integrated_Report.pdf

Water Regulations?

http://www.tceq.texas.gov/assets/public/waterquality/standards/tswqs_2014/TSWQ2014Rule.pdf

(49) **Primary contact recreation 1**--Activities that are presumed to involve a significant risk of ingestion of water (e.g., wading by children, swimming, water skiing, diving, tubing, surfing, handfishing as defined by Texas Parks and Wildlife Code, §66.115, and the following whitewater activities: kayaking, canoeing, and rafting).

(50) **Primary contact recreation 2**--Water recreation activities, such as wading by children, swimming, water skiing, diving, tubing, surfing, handfishing as defined by Texas Parks and Wildlife Code, §66.115, and whitewater kayaking, canoeing, and rafting, that involve a significant risk of ingestion of water but that occur less frequently than for primary contact recreation 1 due to:

(A) physical characteristics of the water body; or

(B) limited public access.

Water Regulations?

http://www.tceq.texas.gov/assets/public/waterquality/standards/tswqs_2014/TSWQ2014Rule.pdf

(56) **Secondary contact recreation 1**--Activities that commonly occur but have limited body contact incidental to shoreline activity (e.g. fishing, canoeing, kayaking, rafting, and motor boating). These activities are presumed to pose a less significant risk of water ingestion than primary contact recreation 1 or 2 but more than secondary contact recreation 2.

(57) **Secondary contact recreation 2**--Activities with limited body contact incidental to shoreline activity (e.g. fishing, canoeing, kayaking, rafting, and motor boating) that are presumed to pose a less significant risk of water ingestion than secondary contact recreation 1. These activities occur less frequently than secondary contact recreation 1 due to physical characteristics of the water body or limited public access.

(40) **Noncontact recreation**--Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic.

Do we have any more recent data?

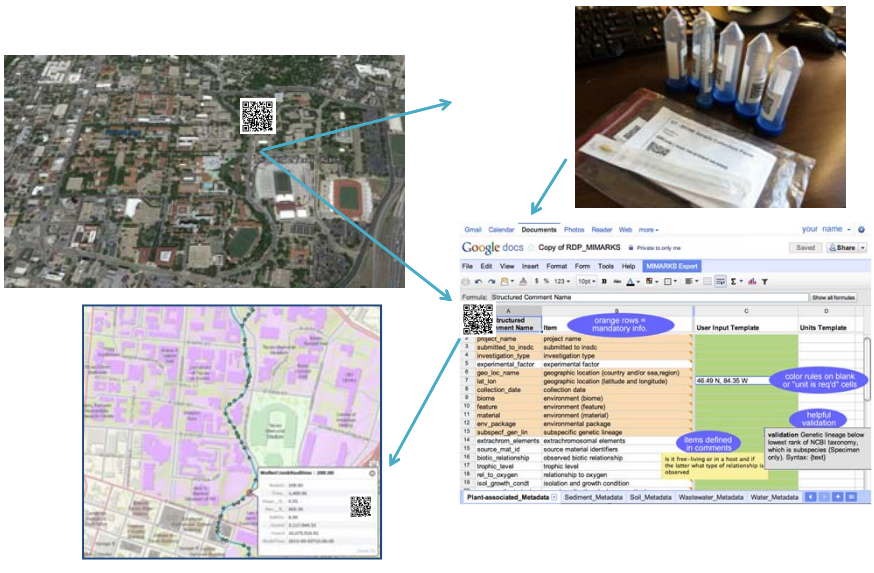
Yes!
Mapping the UT Biome

K. Kinney, P. Passalacqua, H. Sangireddy and J.P. Maestre

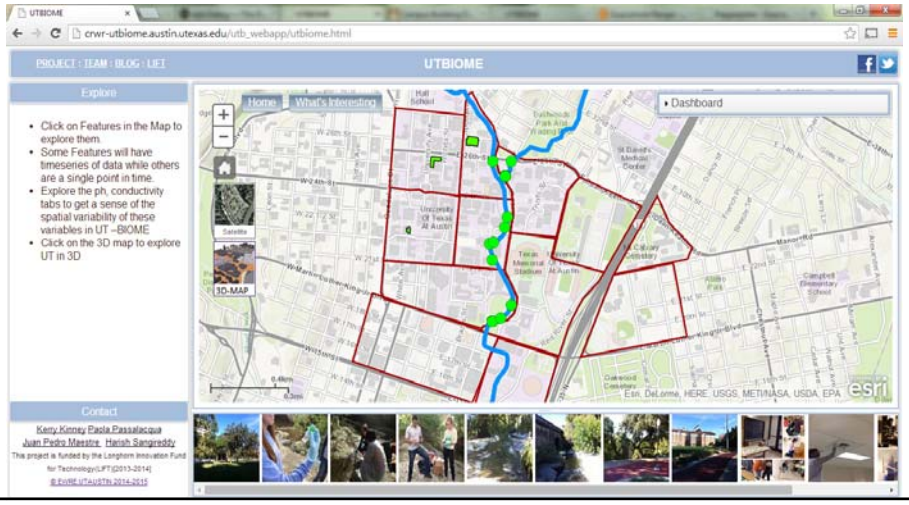
Longhorn Innovation Fund for Technology

Waller Creek Sampling Campaigns

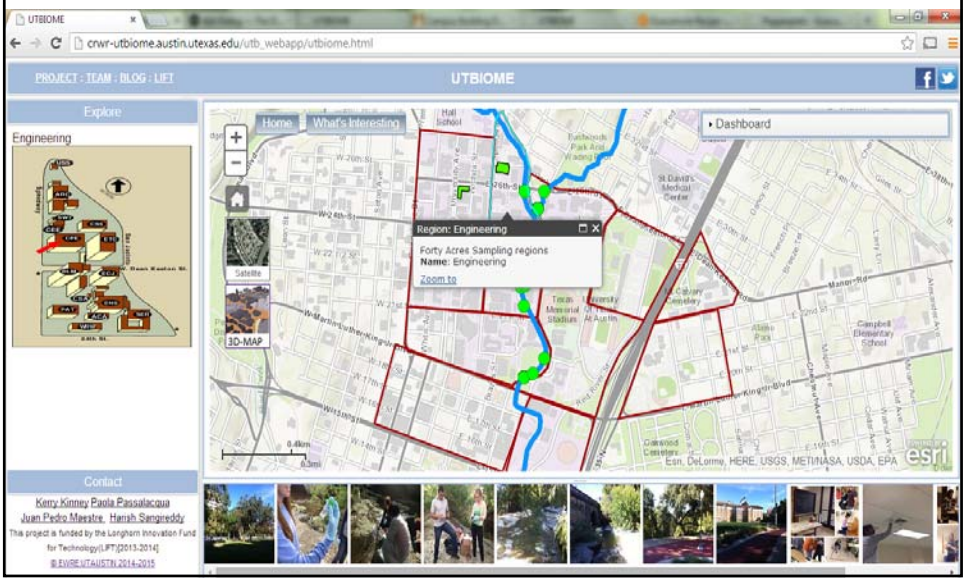
Sample Tracking System



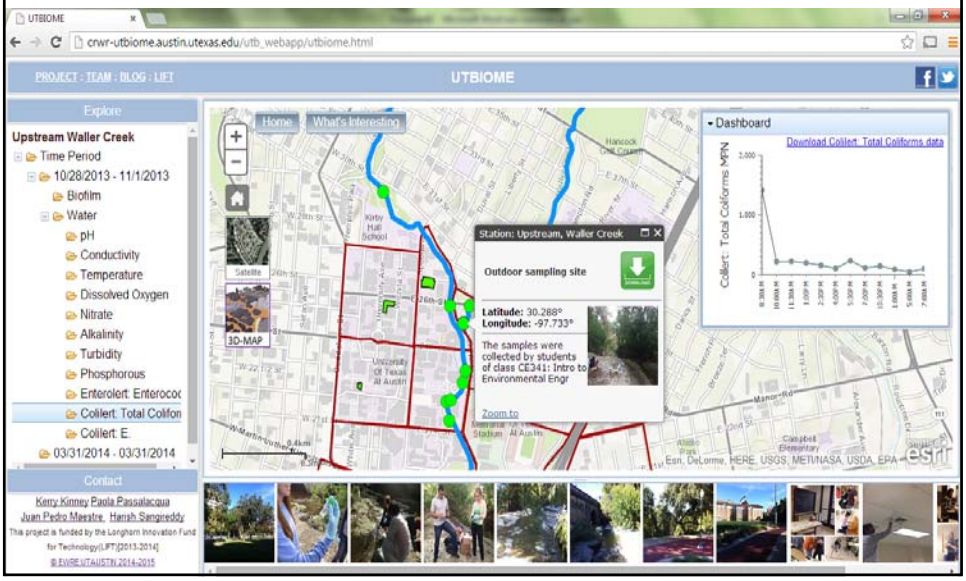
Interactive Mapping Platform Under Development



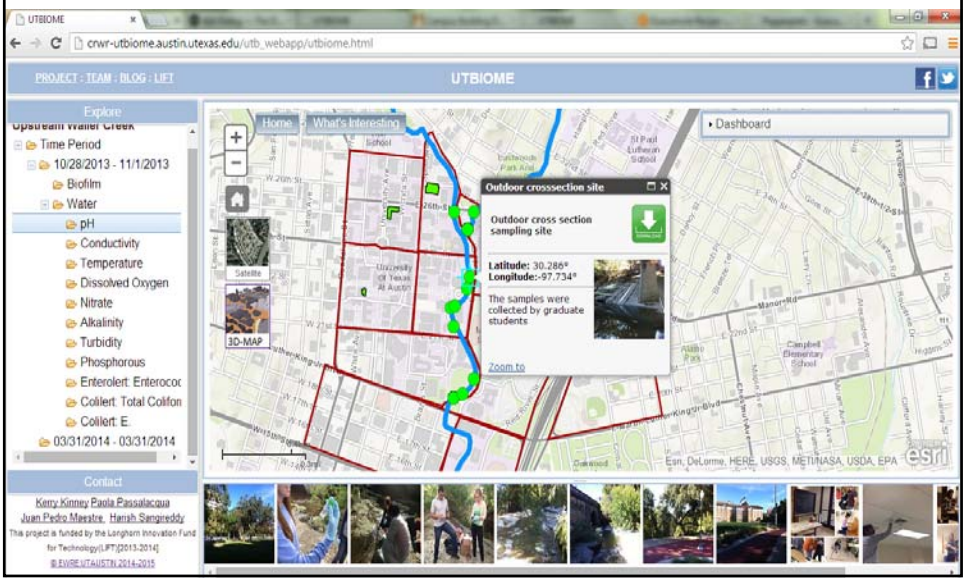
Regions of The University of Texas at Austin



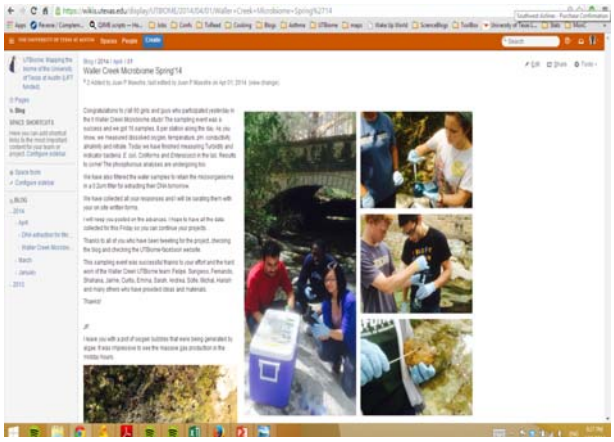
Time series at Upstream Station on Waller creek.



Waller Creek Transect



Waller Creek Sampling Events



https://wikis.utexas.edu/pages/viewrecentblogposts.action?key=UTBIOME / or / www.tinyurl.com/UTBiome

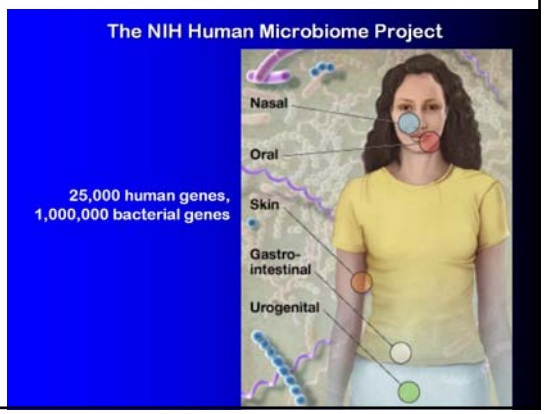
- **Blog in Wikis.utexas.edu @UTBiome**
  Posted relevant information for the project, updates, videoposts with analytical procedures,

What other microorganisms are present?

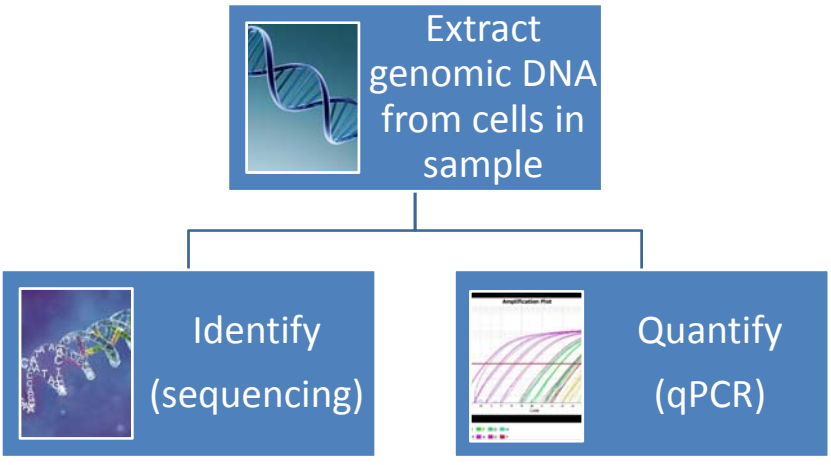
- "Old" School: Fecal Indicator Bacteria
  - Culture Dependent
  - Persistence in Environment?
    - Affected by UV light, presence of particulates, temperature Some studies show die off in a few hours;
    - Much longer (e.g., days) persistence when particles are present
    - Regrowth of FIB possible under some conditions!
      - Eelgrass example!
      - http://digitalcommons.uri.edu/srhonorsprog/139/

What other microorganisms are present?

- "New School": Culture Independent Methods!
- DNA Sequencing
- Have you heard of the Human Microbiome Project?
- We can now apply that technology to water!



Culture-Independent Methods



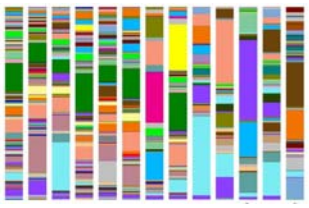
38

Identification via– DNA sequencing

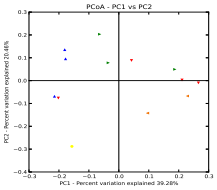
- All bacteria have ribosomes (make proteins in cell)
- Ribosomes are made up of ribosomal RNA (rRNA) molecules
- The segment of DNA (gene) that encodes for making rRNA is useful for sequencing. Also referred to as **16S rDNA.**
- **Why useful?**
  - Ideal mix of
    - "Conserved" DNA regions – allows us to align with other species
    - And Variable Regions – unique sequences that can be used to identify organisms

39

How is it done?



- Collect water sample
- Filter out organisms
- Extract DNA from organisms
- Illumina high-throughput sequencing of 16S rDNA
- Get >10,000 DNA sequences per sample!
- Analyze the data using bioinformatics software
- Identify OTUs (operational taxonomic units – closest "neighbors") that are present and in what proportions:
  - Relative Abundance not actual QUANTIFICATION!!
- Can compare the differences between microbial communities to determine their relatedness
- Where did they come from?
- SOURCE TRACKING POSSIBLE



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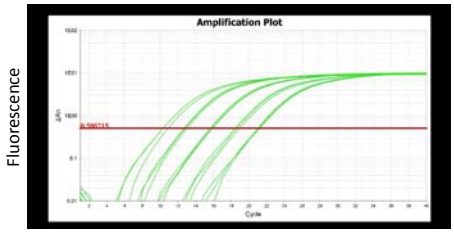
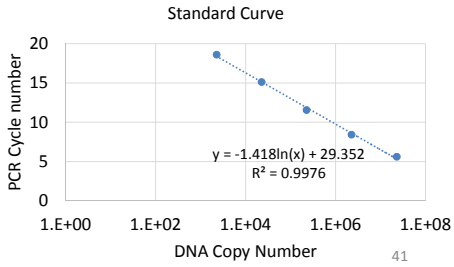
What if I want to quantify a particular species? qPCR

- Quantitative polymerase chain reaction
- Exponentially amplifies a target gene over multiple reaction cycles
- Fluorescence corresponds to target gene concentration
- Total vs. species specific counts

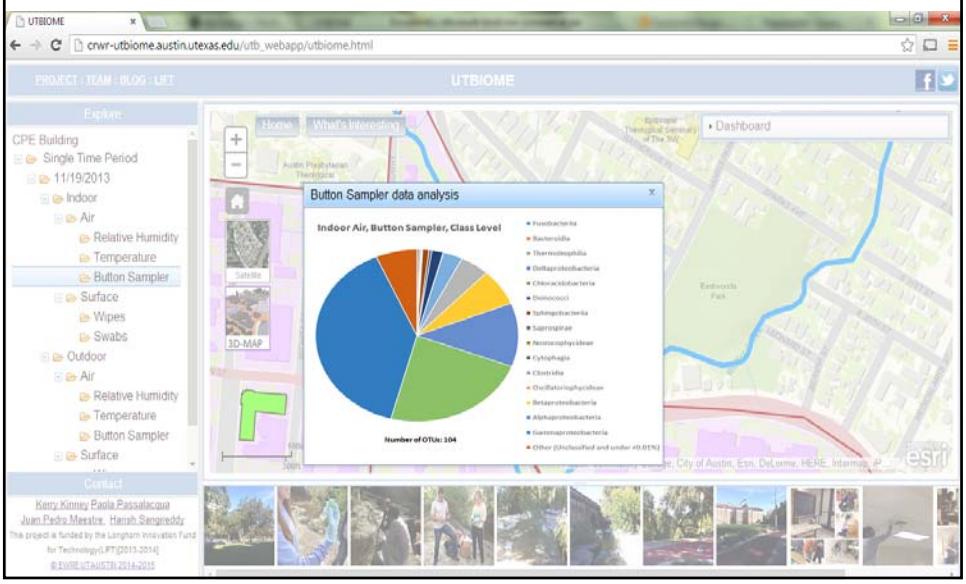


PCR cycle number

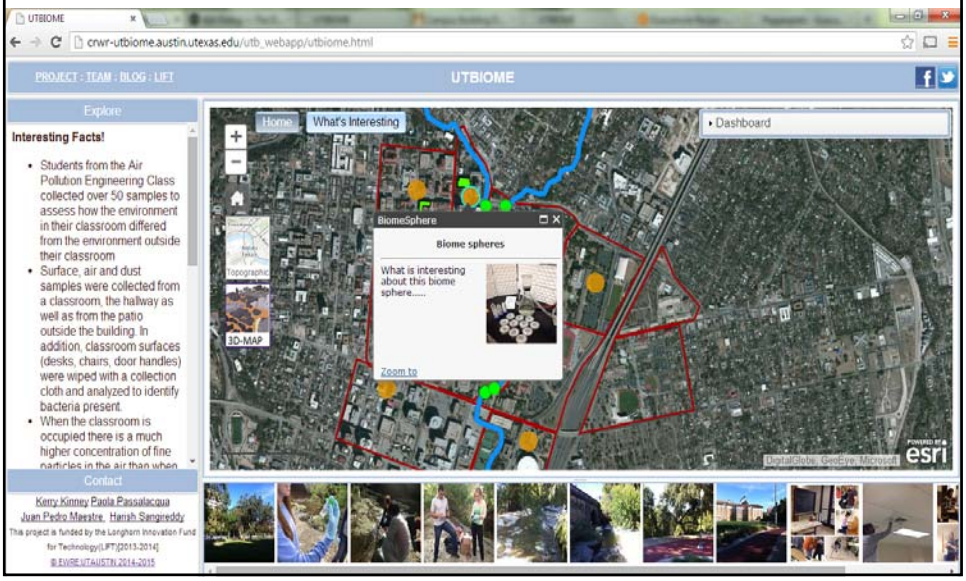


41

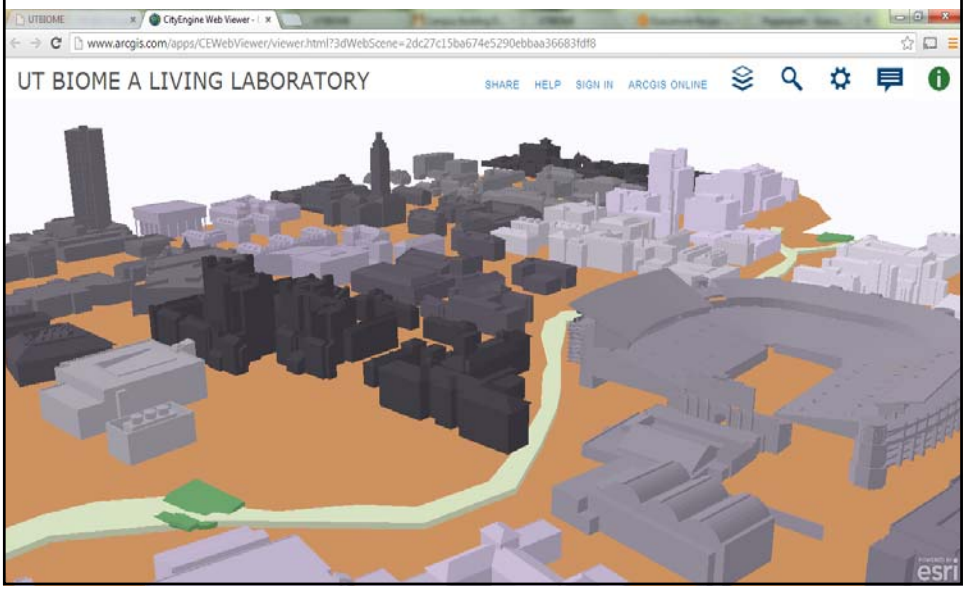
Example Sequencing Results for UT BIOME: Air Sample



Additional Mapping Features:
What is interesting about this biome sphere with satellite view as base map



The Future? UT Austin in 3D.



Mapping the UT Biome: The Future?

- Expand Engagement Across Campus and Beyond to City of Austin and other Campuses – Partners?
- Bridge Gap between GIS framework and BIM framework with visualization tools
- Extend Scope to Map Other Sustainability, Energy and Health Metrics