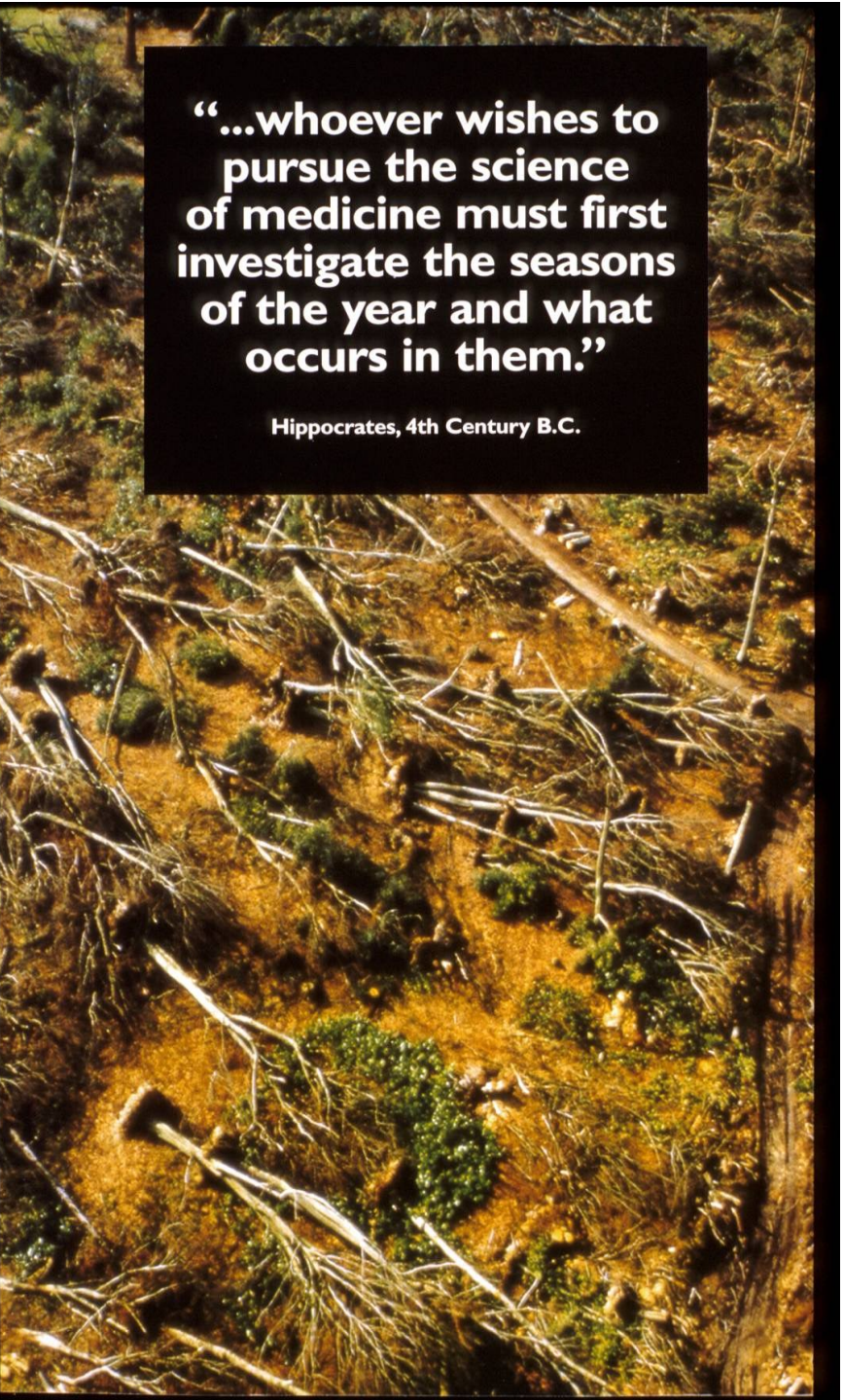

Climate, Oceans, and Human Health: What Cholera Can Teach Us About COVID-19

February 16, 2021

California State University, San Bernadino

Rita R. Colwell, Ph.D., D.Sc.
Distinguished University Professor
University of Maryland College Park

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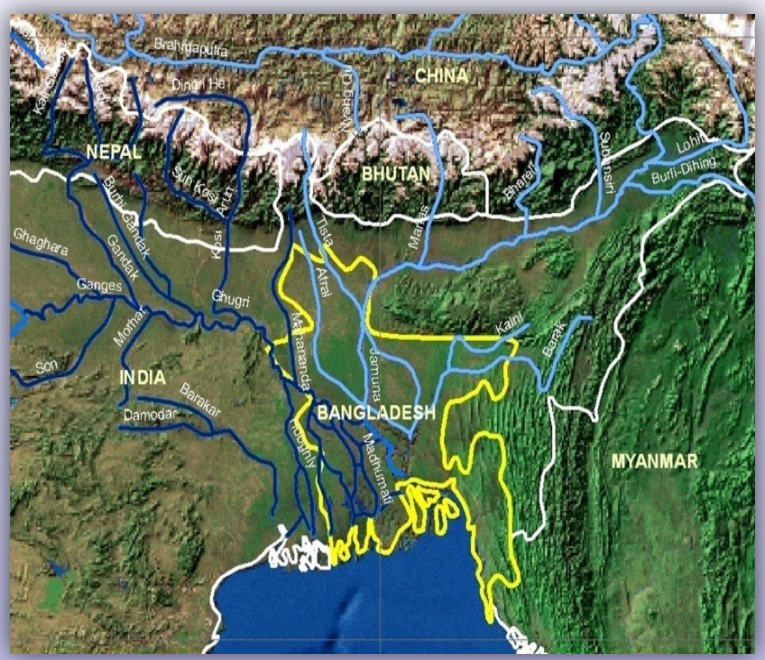
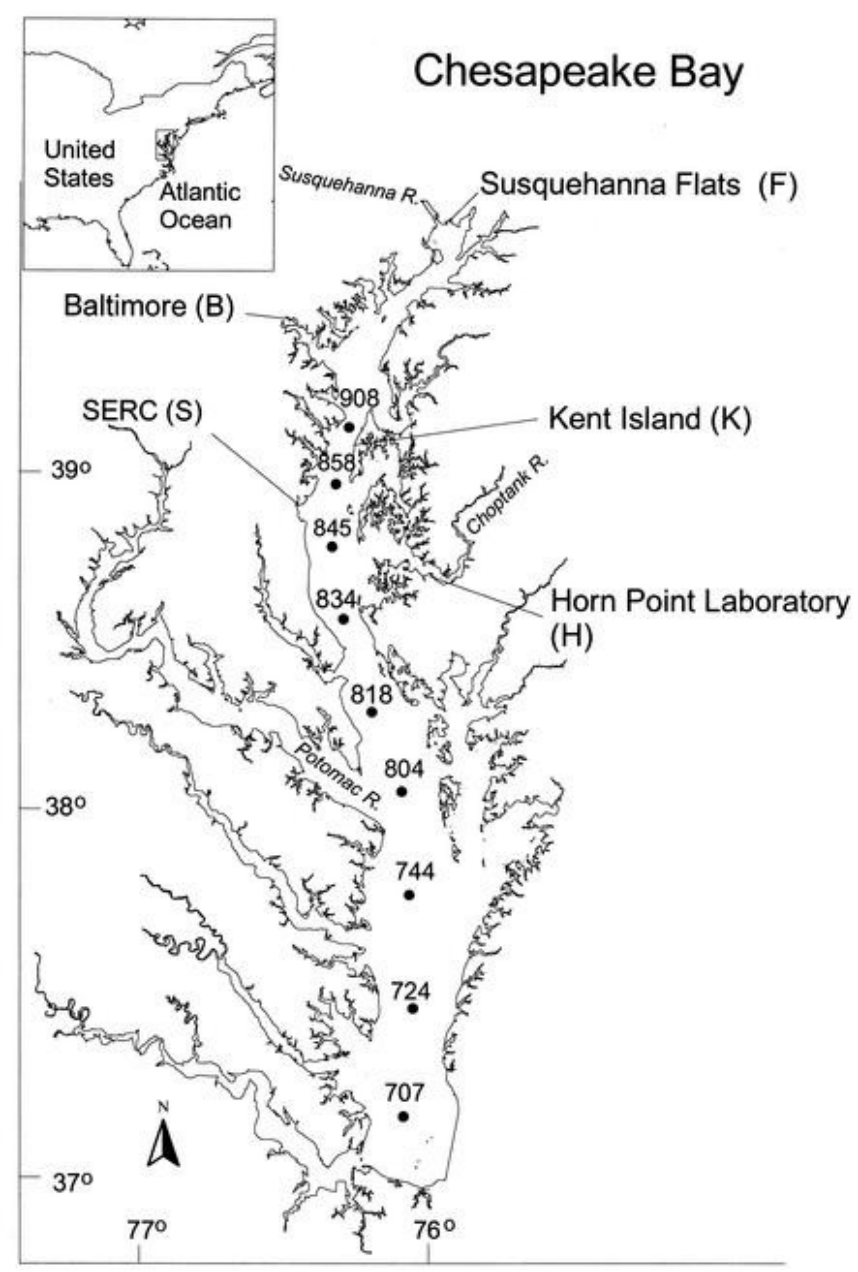
Water-related diseases

	Cases per year	Deaths per year
Amoebiasis	48,000,000	110,000
Arsenic	28-35m exposed to drinking water with elevated levels	
Diarrhoeal disease, Including cholera	1.5 billion	1,800,000
Dracunuliasis (guinea worm)	> 5000	-
Fluorosis	26 million (China)	-
Giardiasis	500,000	Low
Hepatitis A	1,500,00	-
Intestinal helminths	133,000,000	9400
Malaria	396,000,000	1,300,000
Schistosomiasis	160,000,000	> 10,000
Trachoma	500,000,000	-
Typhoid	500,000	25,000

Cholera: A Global Disease

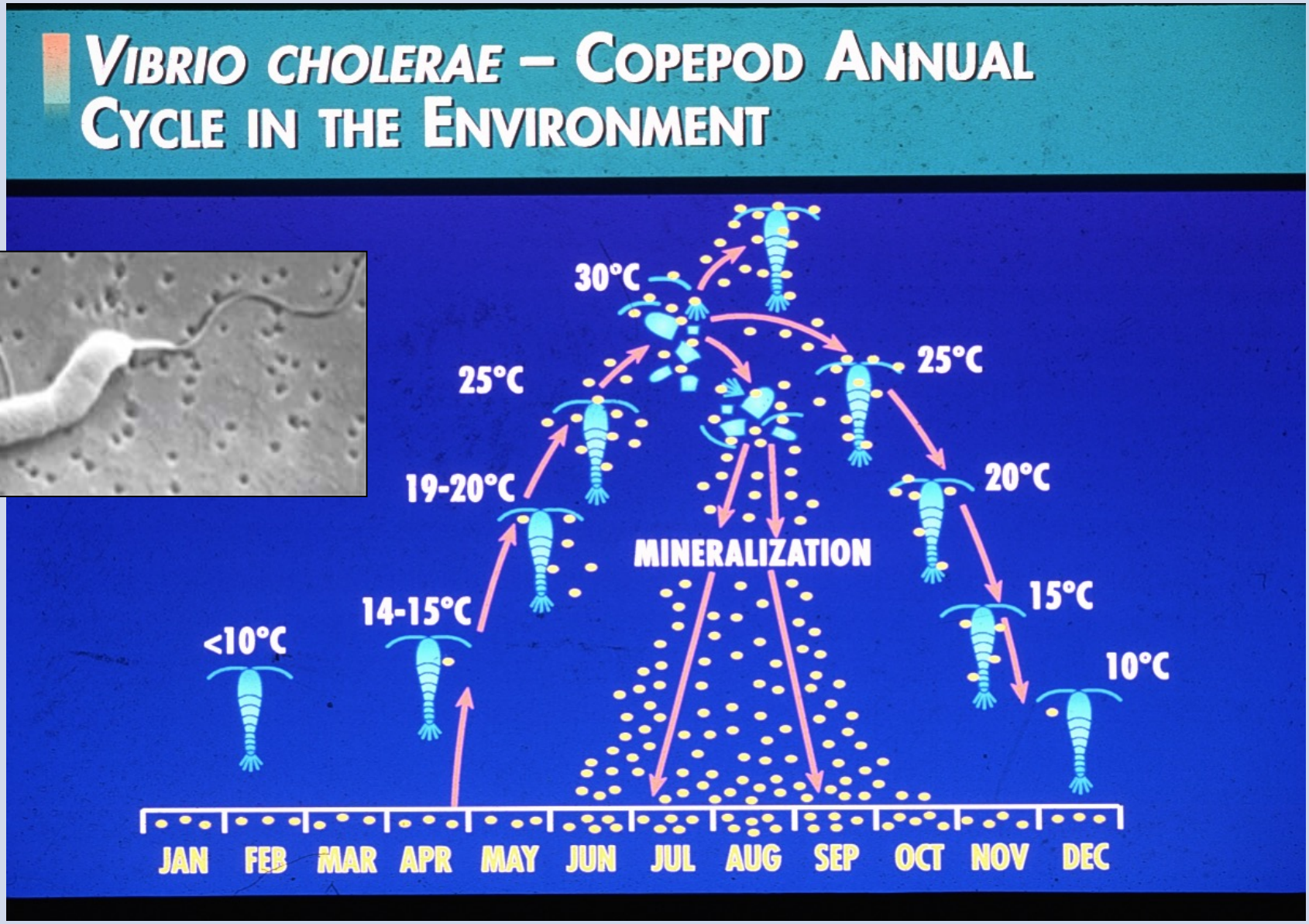
- Acute water-related diarrheal disease
- Seventh pandemic started in 1960s
- Occurs in more than 50 countries affecting approximately 7 million people
- Bengal Delta is known as “native homeland” of cholera outbreaks
- Since cholera bacteria
  - exist naturally in aquatic habitats
  - evidence of new biotypes emerging, ***<u>it is highly unlikely that cholera will be eradicated but clearly can be controlled by provision of safe drinking water.</u>***





Map of Chesapeake Bay – beginning of the cholera chronicle

1965-1975 An early contribution of marine microbiology to human health: Determination of the *Vibrio cholerae* life cycle



The culprit – *Calanus* copepod host

Model for the Transmission of *Vibrio cholerae* from the Environment to Humans

PHYSICAL & CHEMICAL CHARACTERISTICS OF WATER
- temperature
- sunlight
- rainfall
- pH
- dissolved oxygen
- salinity & nutrients

BIOLOGICAL CHARACTERISTICS
- algae bloom
- phytoplankton bloom

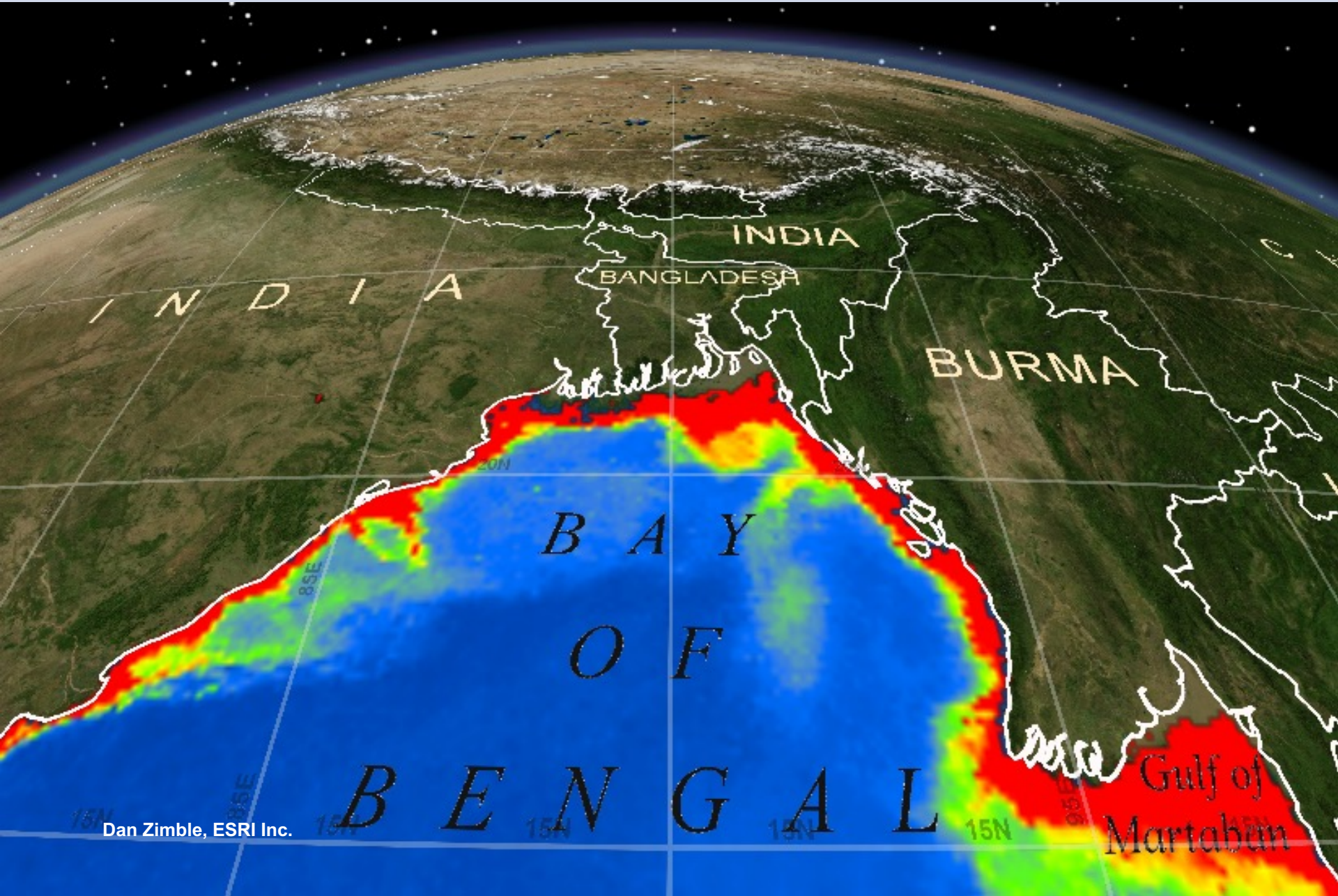
ZOOPLANKTON BLOOM
(enters into non-culturable state)

V. CHOLERAE
viable but non-culturable state in the water column & attached to particulates. Commensal or symbiotic relationships.

FECAL SHEDDING
returns *V. cholerae* to the water.

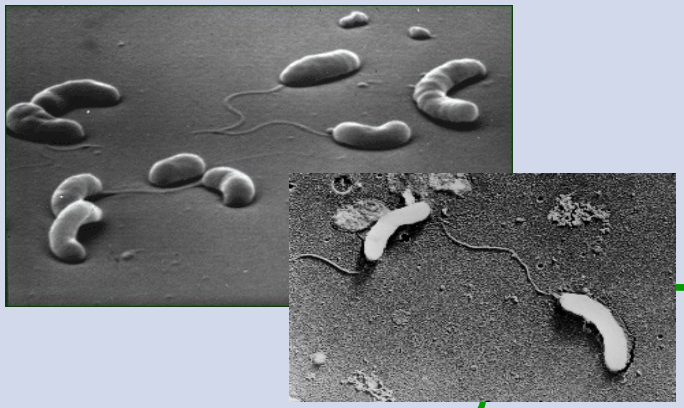
TRANSMISSION OF *V. CHOLERAE*
to humans via ingested water containing colonized copepods or other vectors.

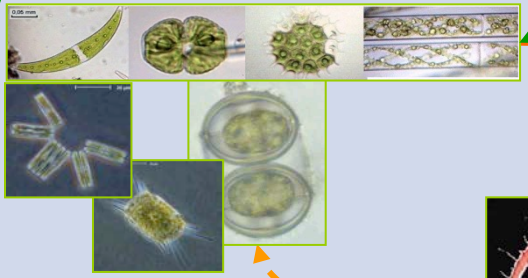
Work begins in Bangladesh in 1975

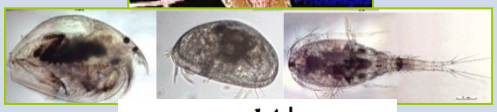


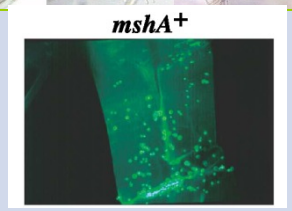
Villagers in Bangladesh collect filtered water in the same pond used for bathing

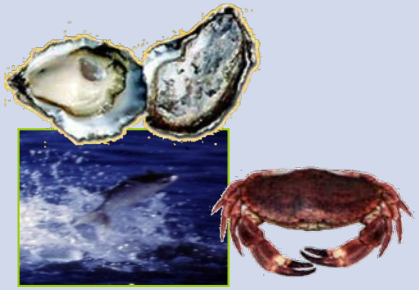
Bangladesh Model of Cholera source and Transmission



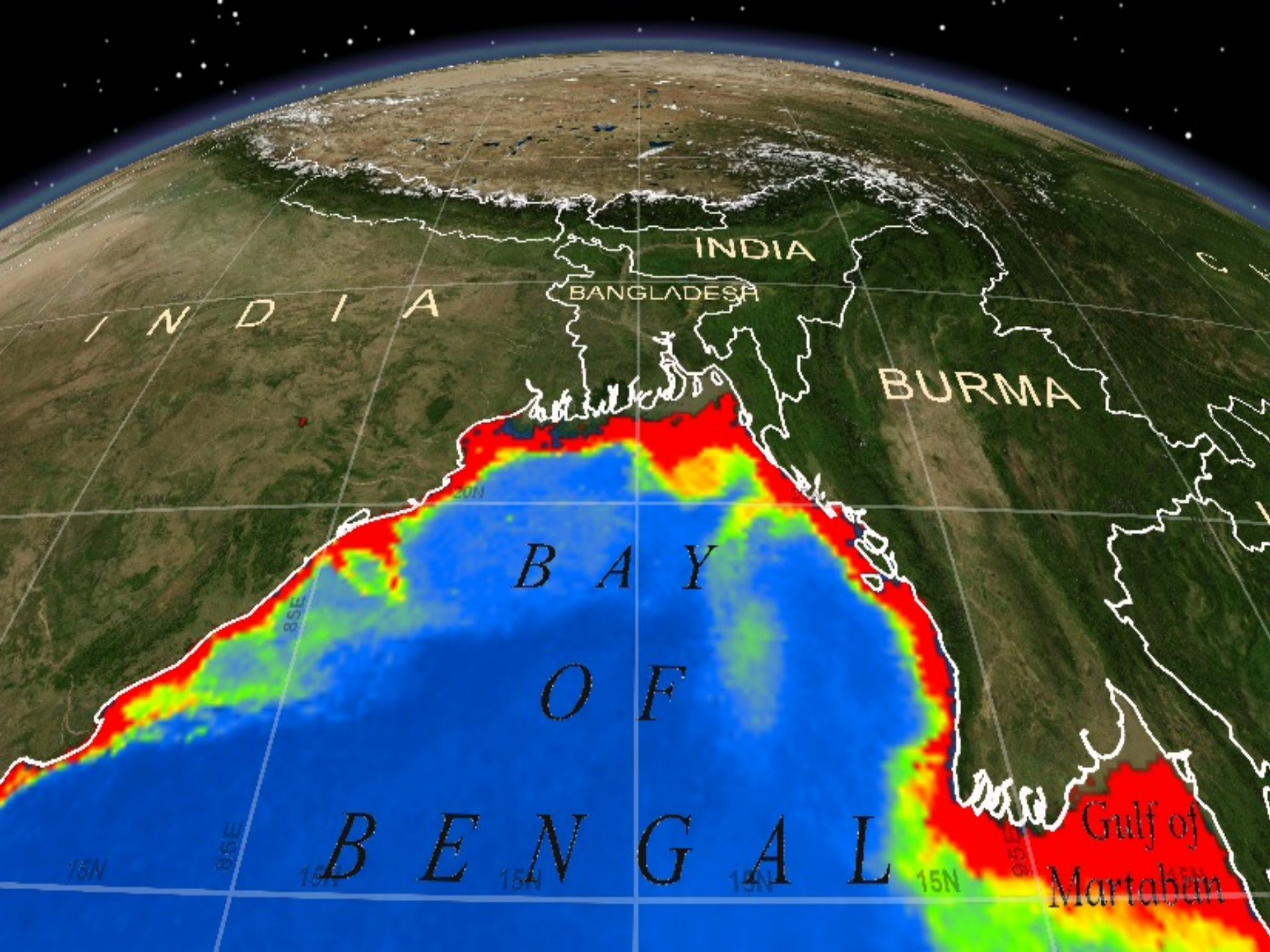






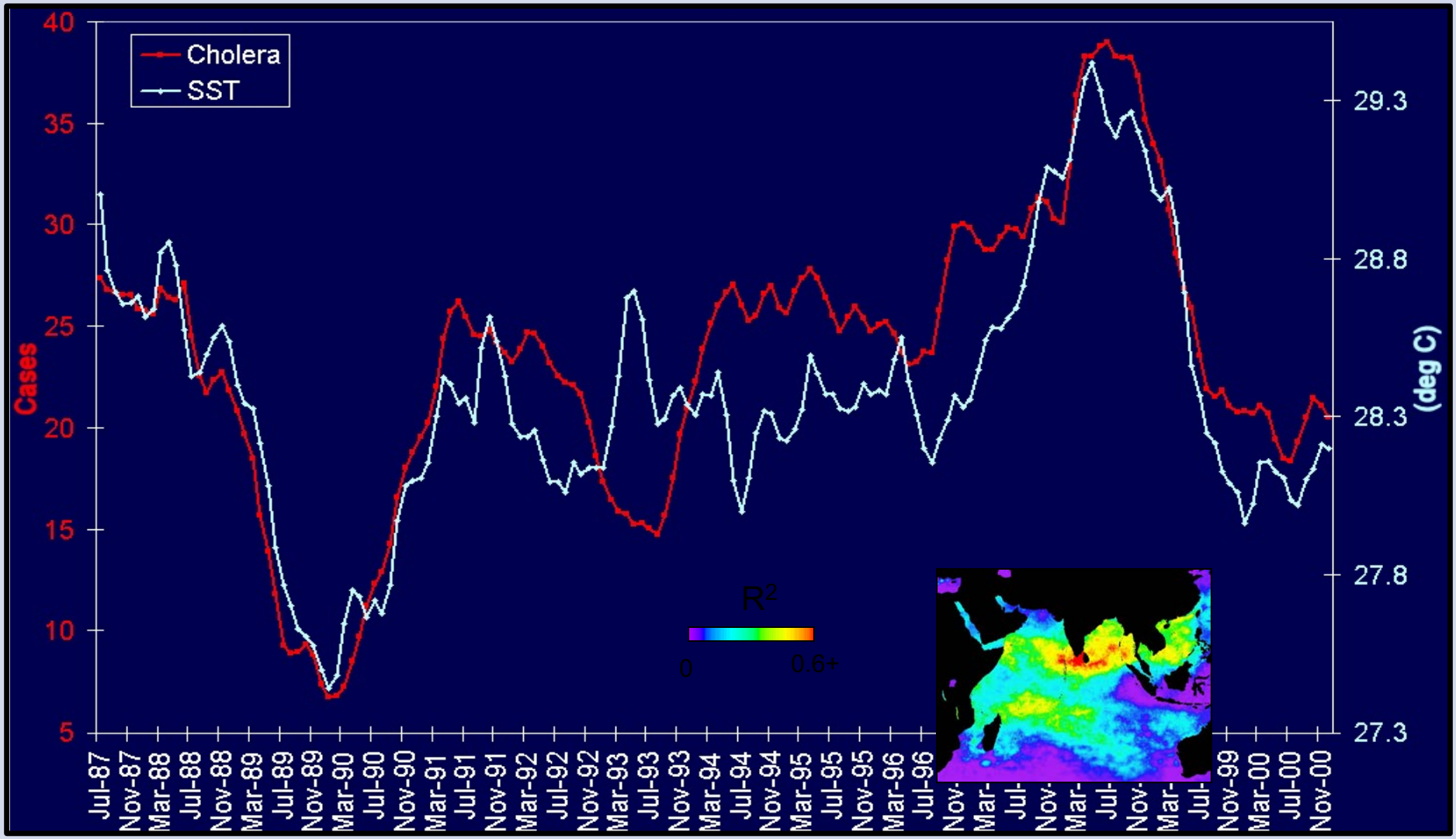


G. Constantin de Magny


INDIA
BANGLADESH
INDIA
BURMA
BAY
OF
BENGAL
Gulf of
Martaban
20N
15N
85E

Cholera and SST in the Indian Ocean 1985 - 2000

Six-month SST lead: $R^2 = 0.72$



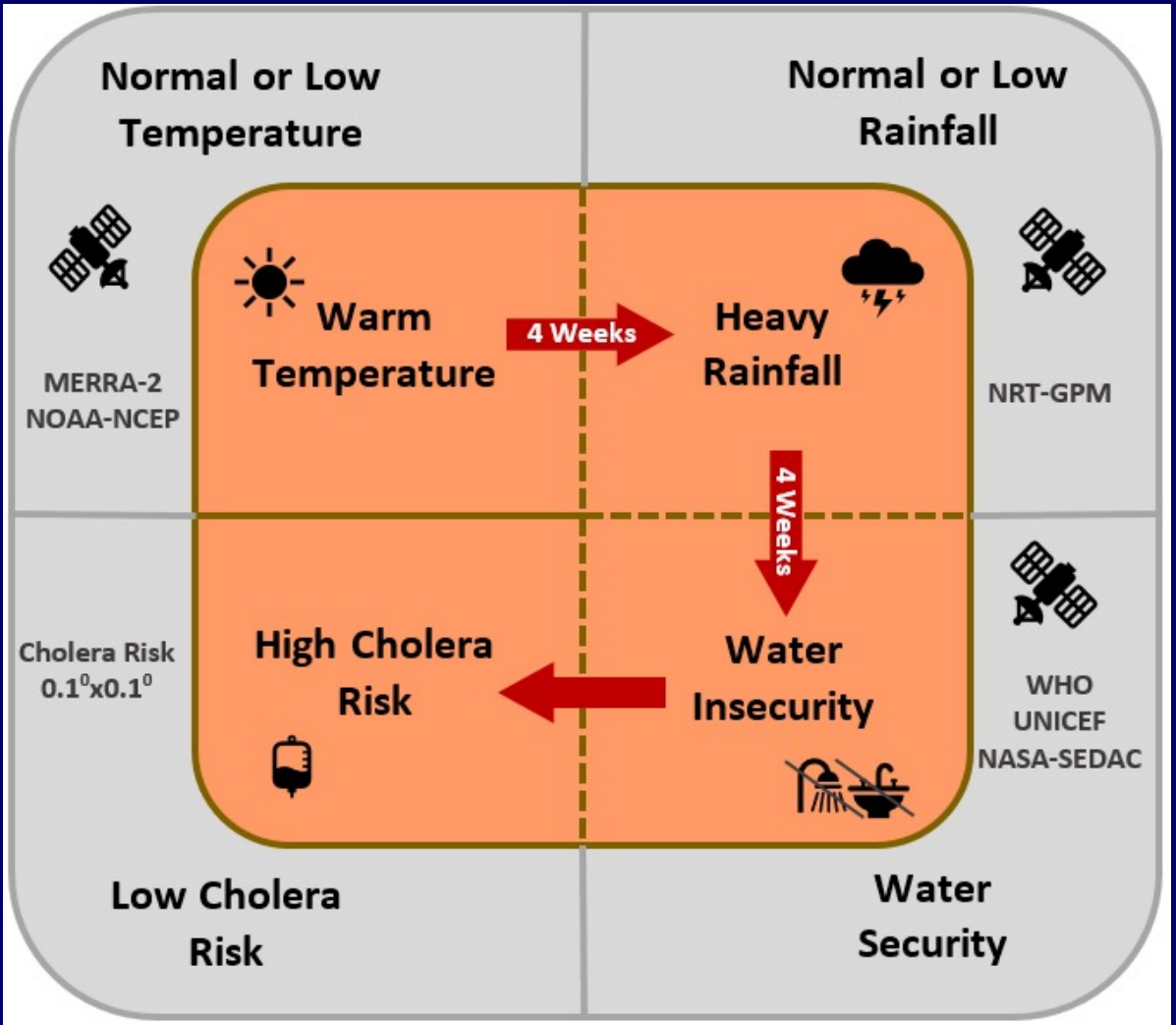
Lobitz et al., 2000, PNAS Vol. 97, No. 4 pp. 1438-1443

What is reported about cholera and macro-scale processes?

Cholera outbreaks have been linked to environmental and climate variables

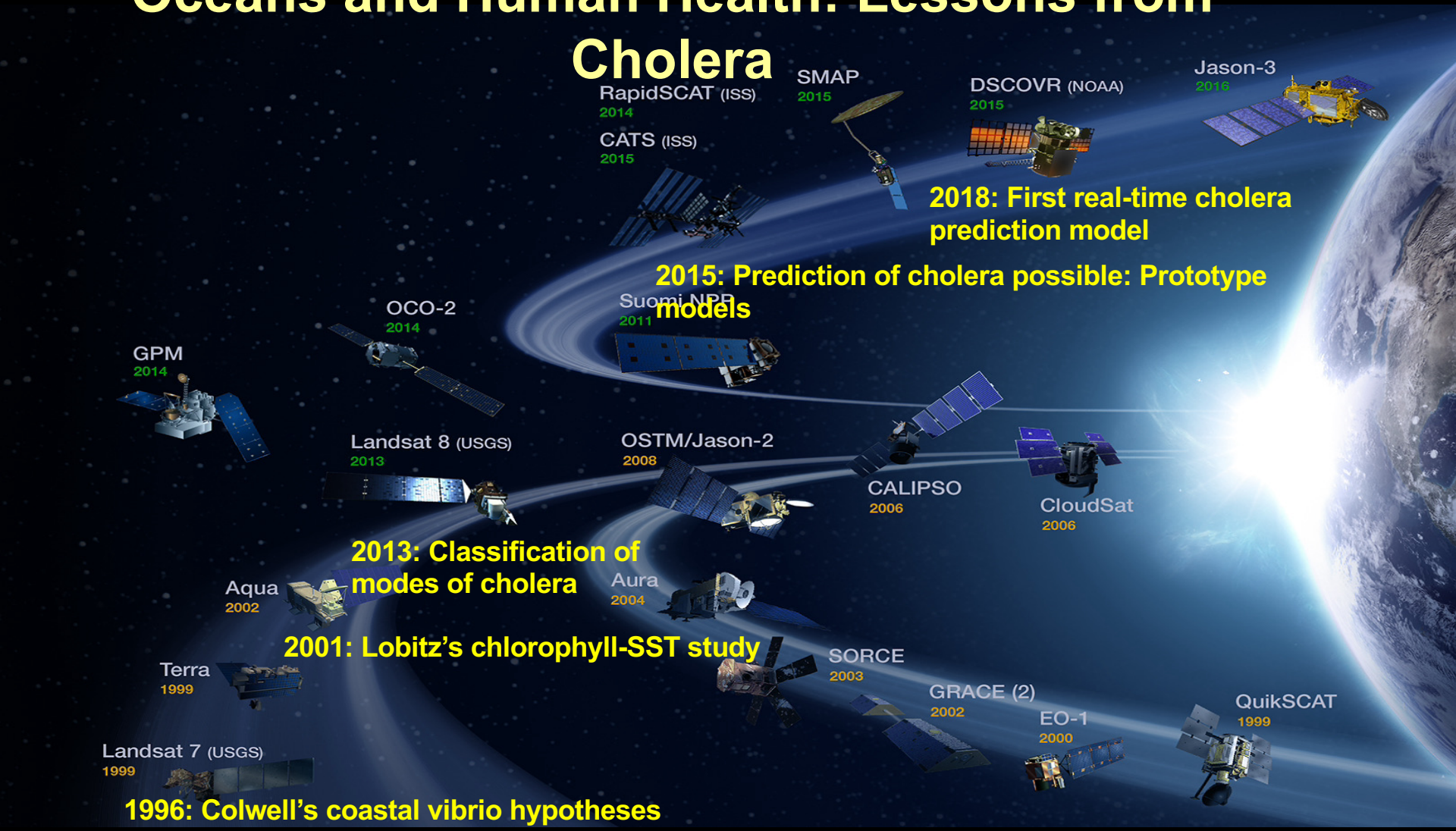
- **precipitation (*Hashizume et al. 2008*)**
- **floods (*Koelle et al., 2005*)**
- **river level (*Emch et al., 2008*)**
- **sea surface temperature (*Colwell*, 1996; *Lobitz et al., 2000*)**
- **coastal salinity (*Miller et al., 1982*)**
- **dissolved organic material (*Worden et al., 2005*)**
- **fecal contamination (*Islam et al., 2006)***
- **chlorophyll (*Lobitz et al., 2000, Magny et al., 2008)***

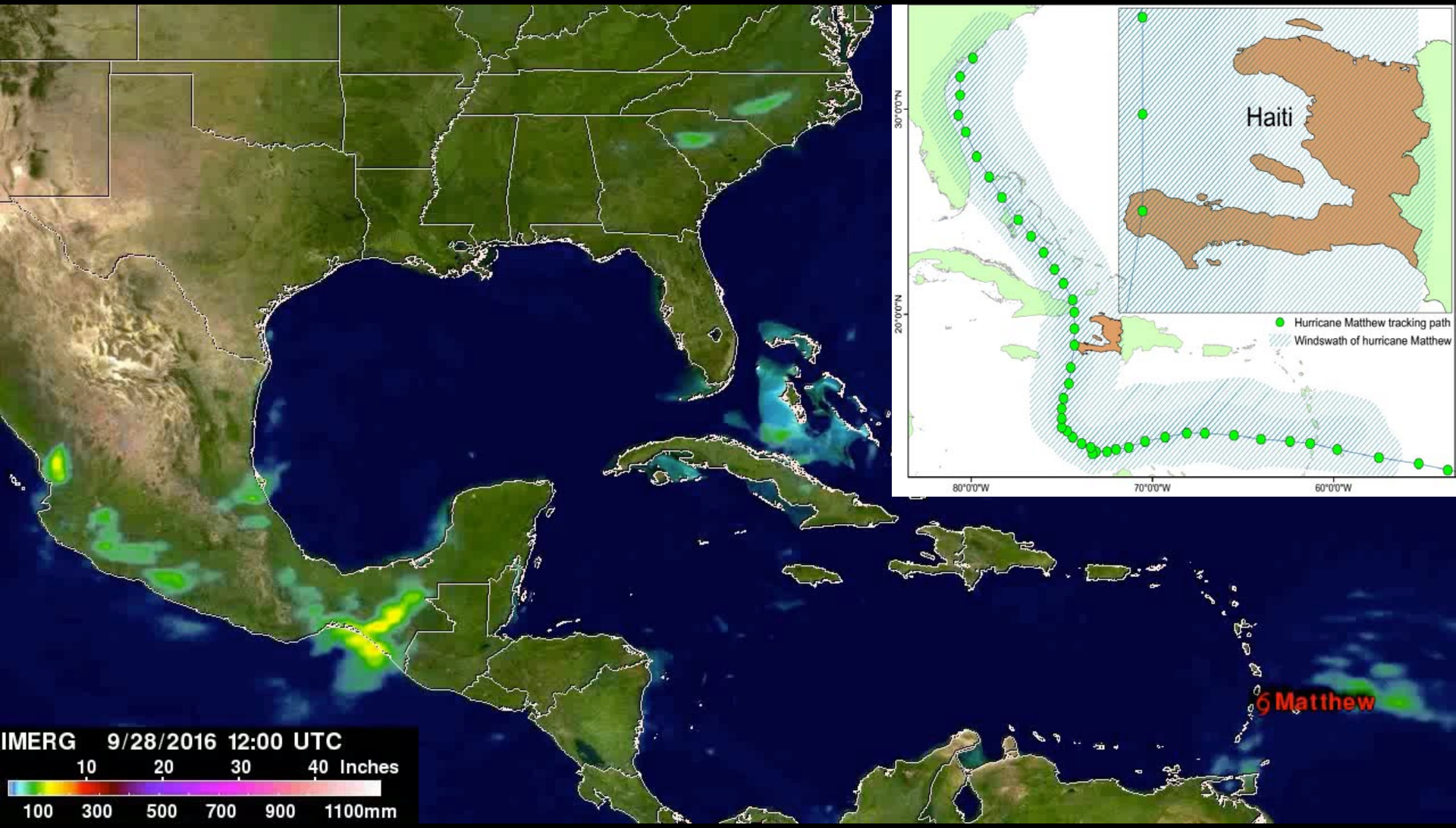
Theoretical framework for predicting cholera outbreaks in epidemic regions



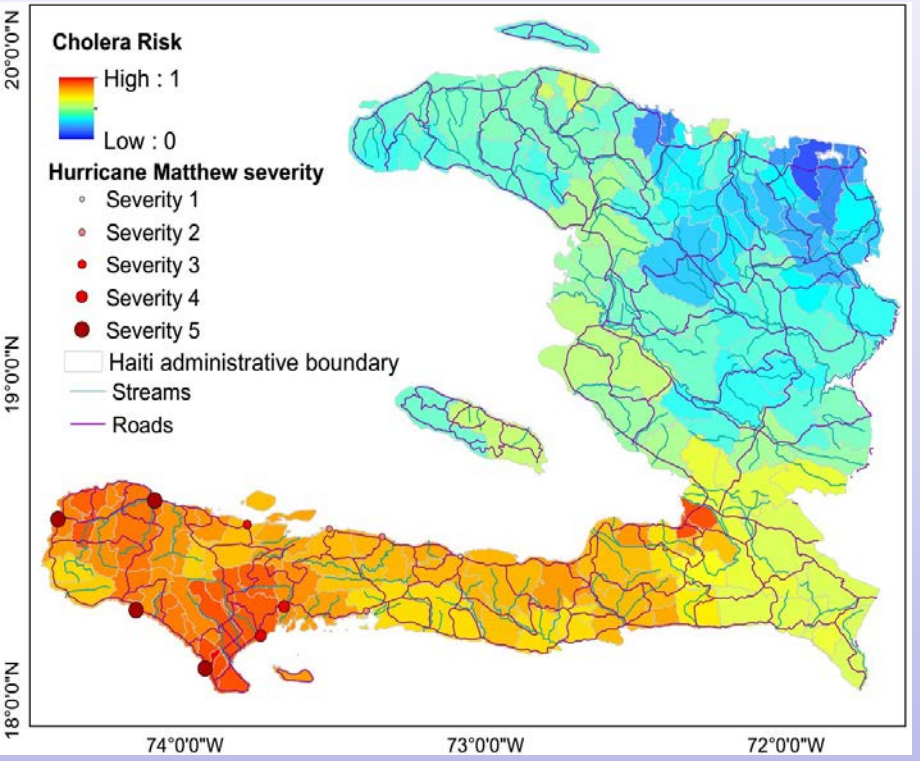
Warm temperature= above climatological average temperature
Heavy rainfall= above climatological average precipitation
Water insecurity=lack of access to water and sanitation access
High cholera risk=probability of cholera greater than 50%

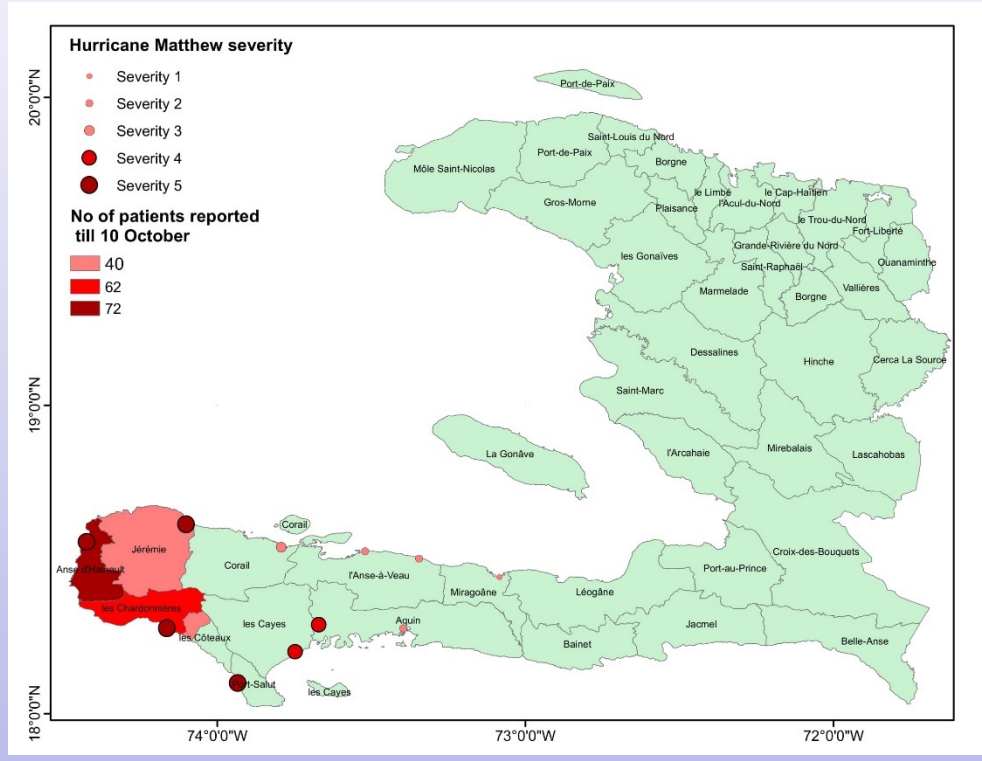
Oceans and Human Health: Lessons from Cholera




Haiti
30°0'0"N
20°0'0"N
80°0'0"W
70°0'0"W
60°0'0"W
Hurricane Matthew tracking path
Windswath of hurricane Matthew
Matthew
IMERG 9/28/2016 12:00 UTC
10 20 30 40 Inches
100 300 500 700 900 1100mm

Cholera in Haiti



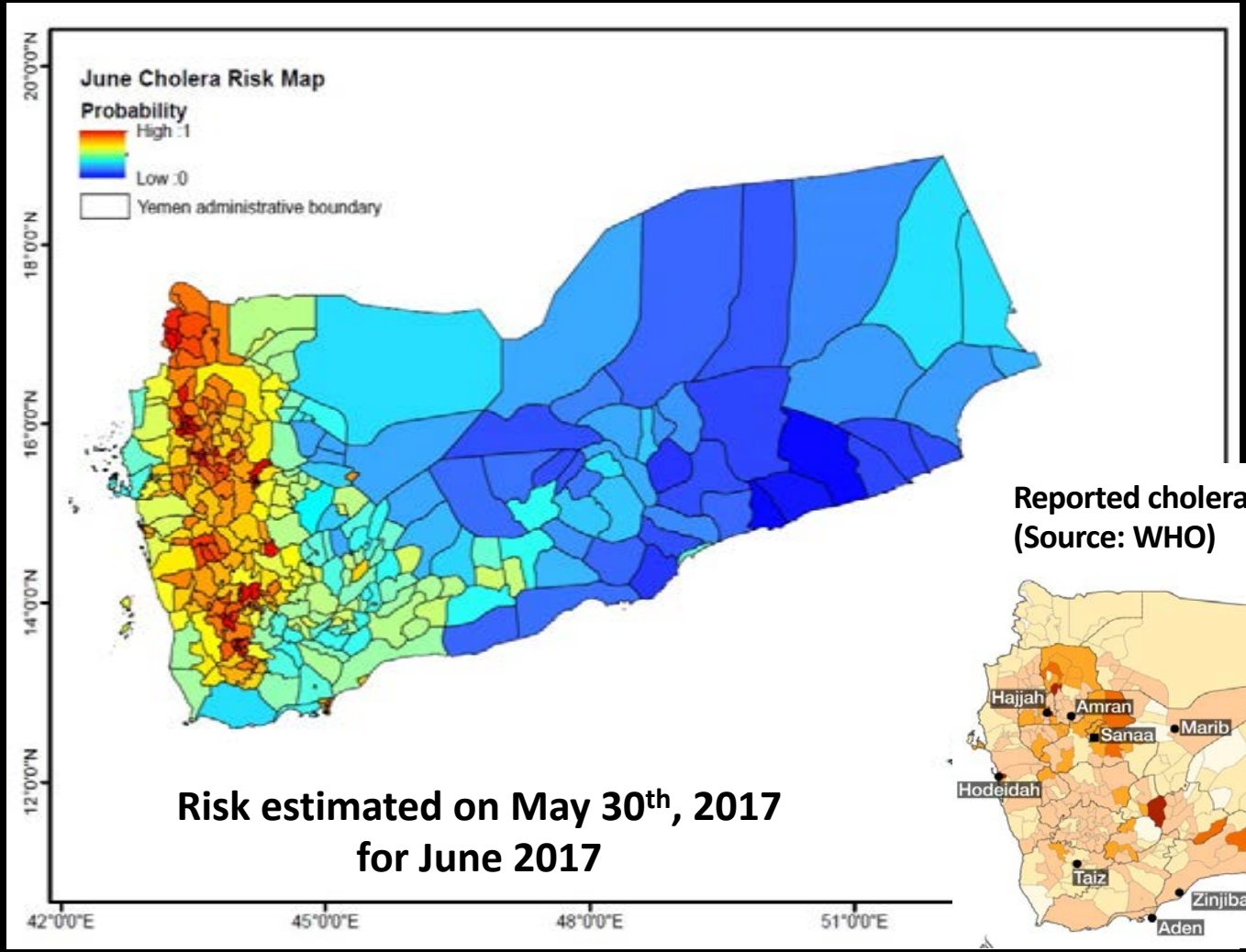


Prediction of October 2015 cholera depending on Hurricane Matthew severity

Actual cholera in October 2015 following Hurricane Matthew

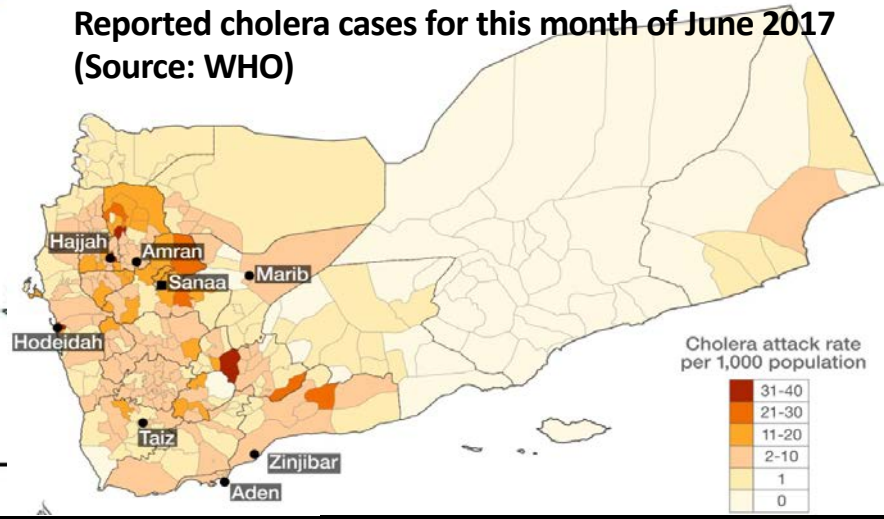
Khan et al., 2018 ASCE JWRPM

Real-time cholera prediction for Yemen



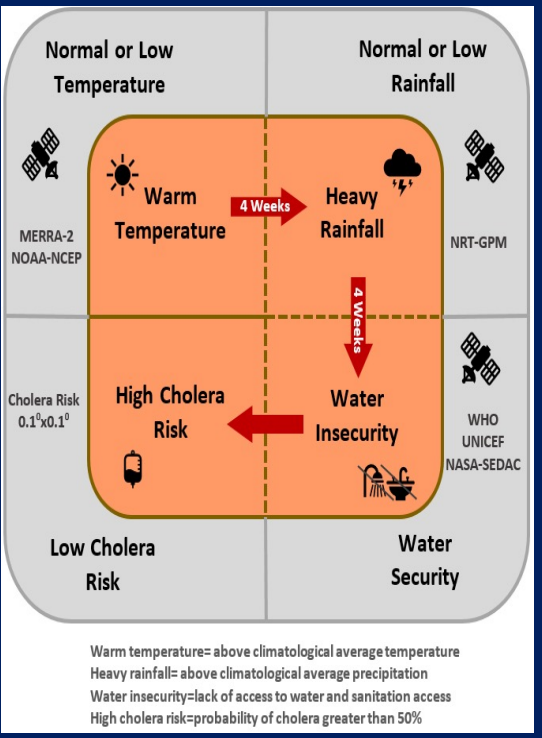
Risk estimated on May 30th, 2017 for June 2017

Reported cholera cases for this month of June 2017 (Source: WHO)

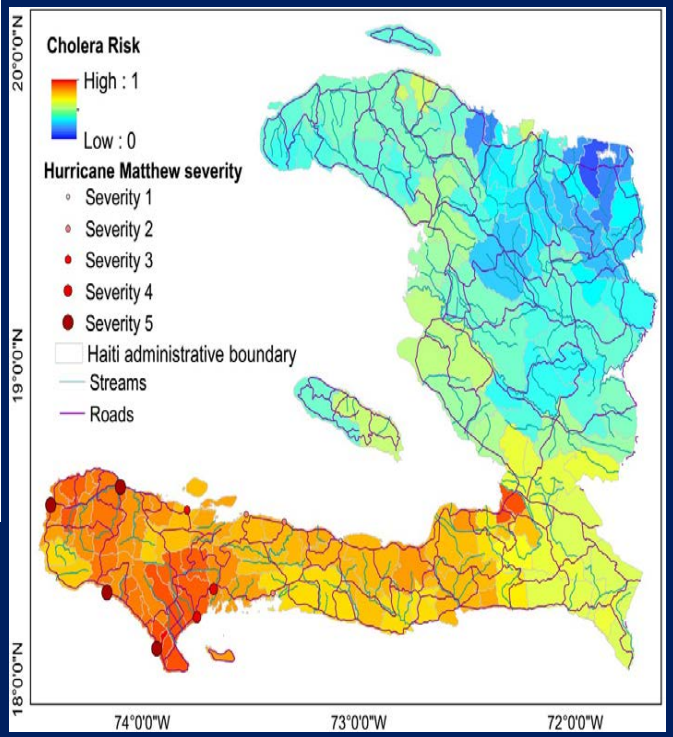


Epidemic Cholera

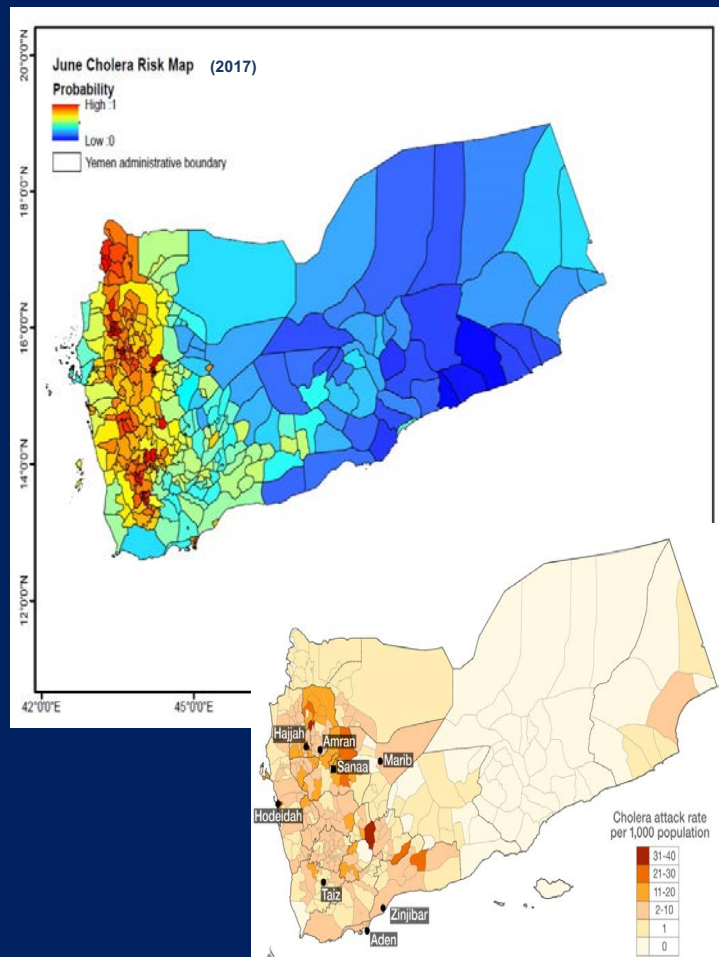
- Sporadic outbreak
- Usually occurs following floods or inundation of large landscapes
- Warm temperatures may increase growth of bacteria in aquatic bodies.

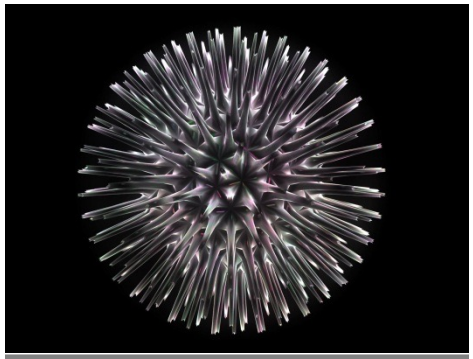


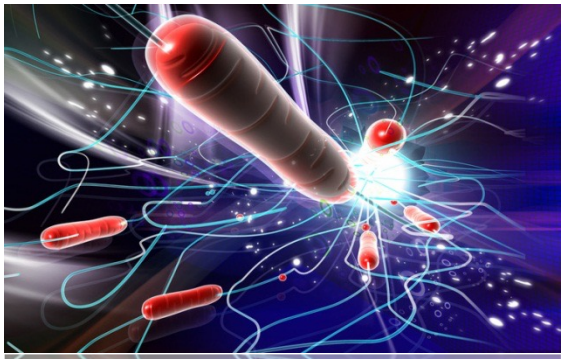
Prediction of October 2015 cholera depending on Hurricane Matthew severity



Real-time cholera prediction for Yemen



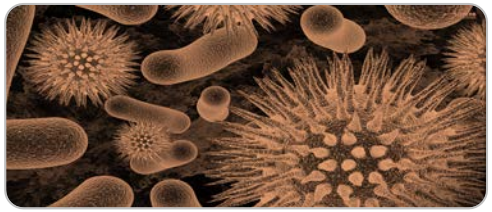




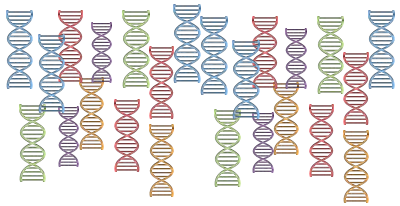
NEXT GEN SEQUENCING AND METAGENOMICS IDENTIFICATION

Shotgun whole (meta)genome sequencing

Biological specimen

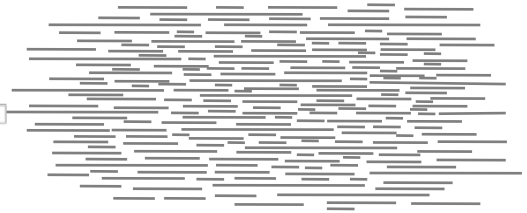


Community DNA

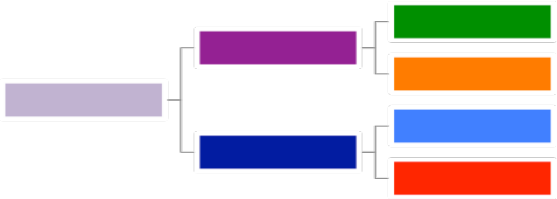


DNA Sequencing

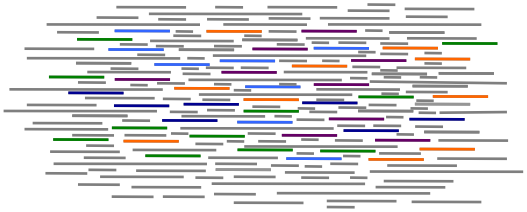
Raw Sequence Reads



CosmosID Database



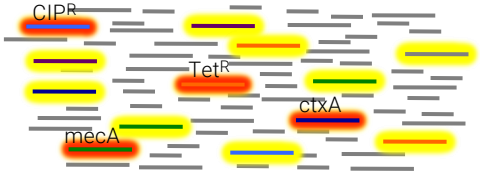
GenBook Biomarker Matching



Identified

All Microbes

CosmosID AR/VF Database



Microbial Identification & Pathogen Characterization

COSMOSID®
Unlocking The Microbiome

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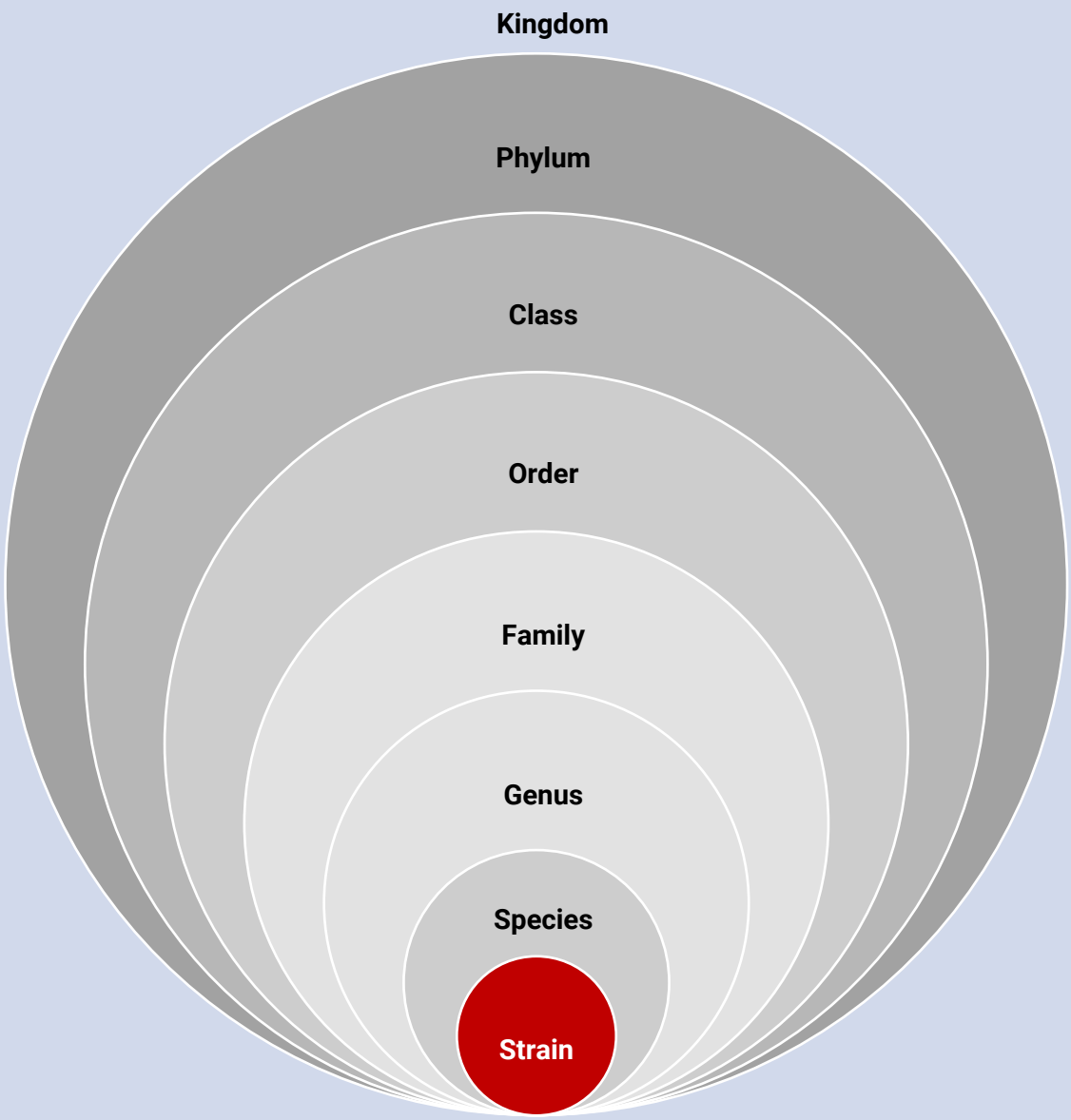
Strain is the Clinically Informative and Actionable Unit



COSMOSID®
Unlocking The Microbiome

Microbiome Analysis of Acute Diarrheal Patients Compared with Healthy Individuals

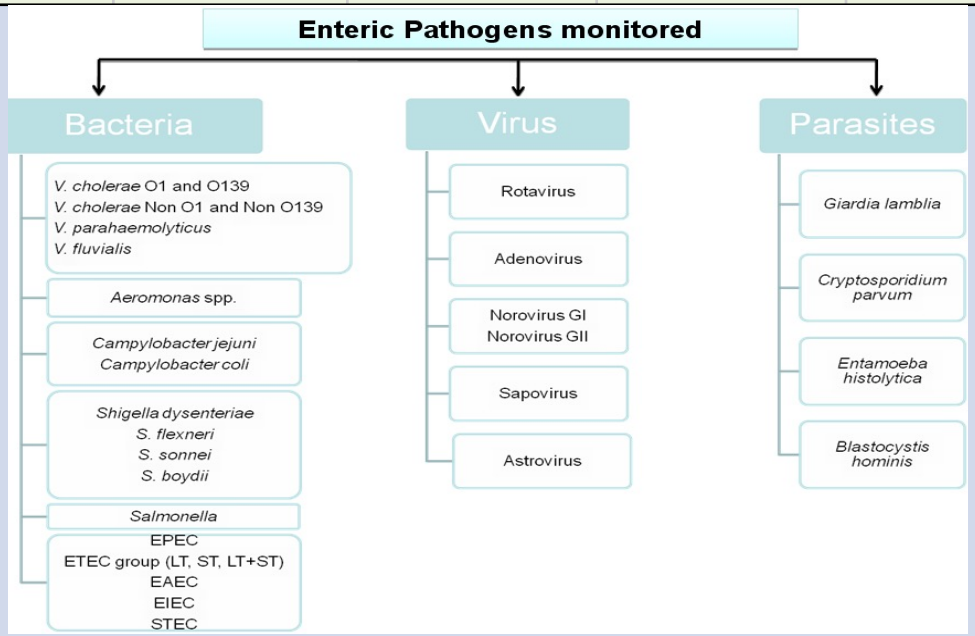
pre-publication results

COSMOSID®
Unlocking The Microbiome

Study Cohort

@ 2% Surveillance (every 50th patient) at the National Institute of Cholera and Enteric Diseases (NICED), Calcutta, India

Study Phases	Total # of Samples	Known Etiology	Unknown Etiology	Healthy Control
PHASE I	9	9	0	0
PHASE II	28	0	18	10
PHASE III	37	17	10	10



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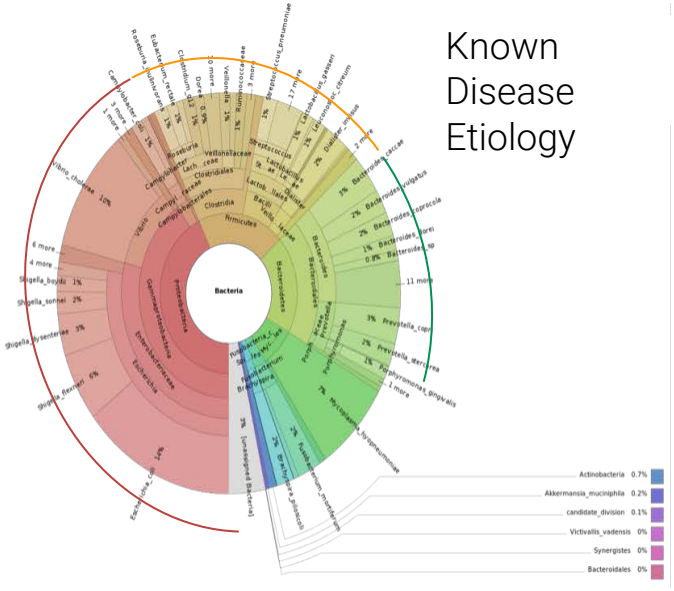
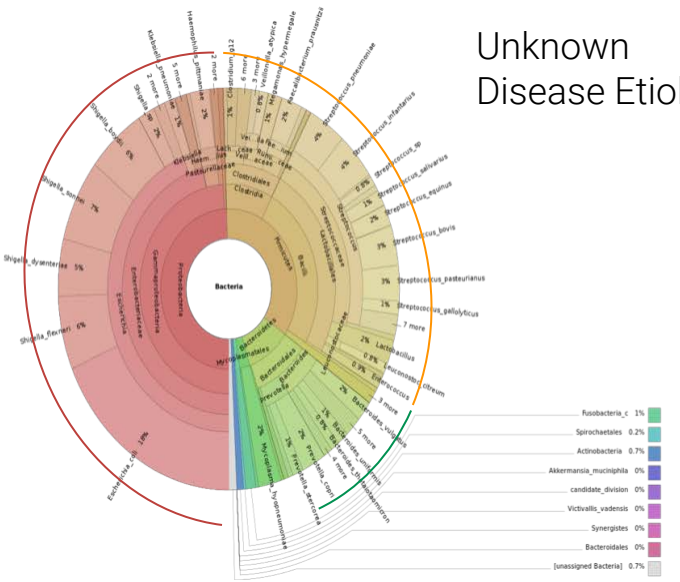
Microbial Community in Healthy vs Diarrheal Patients

DIARRHEAL PATIENTS

HEALTHY INDIVIDUALS



Known Disease Etiology

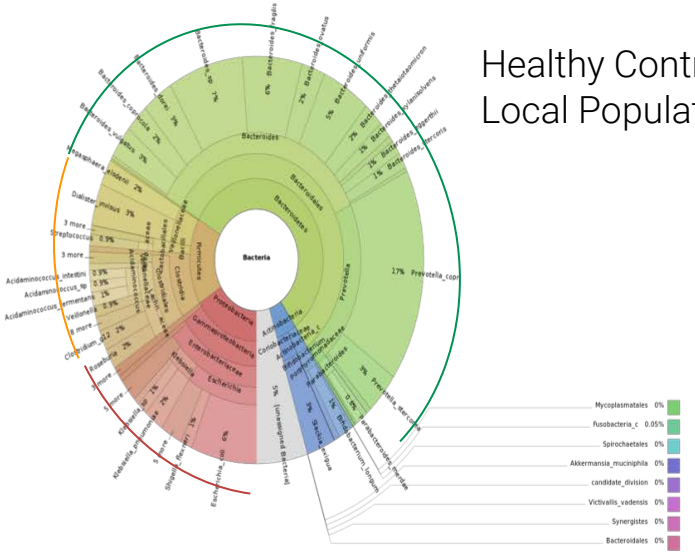


Unknown Disease Etiology

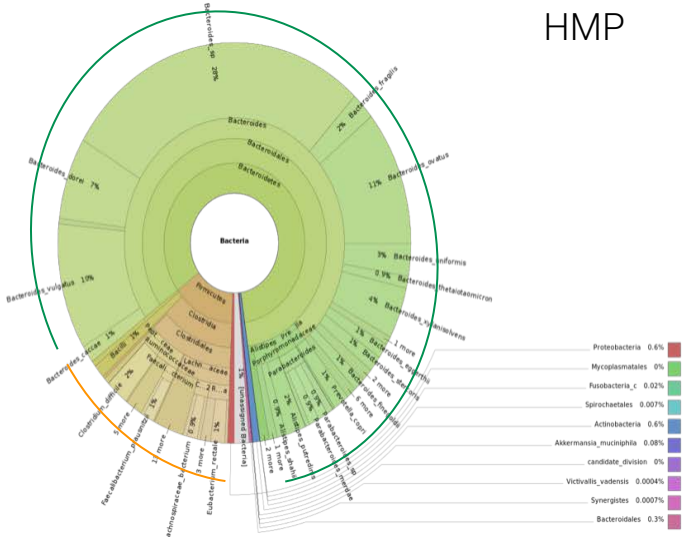
γ- Proteobacteria

Firmicutes

Bacteroidetes

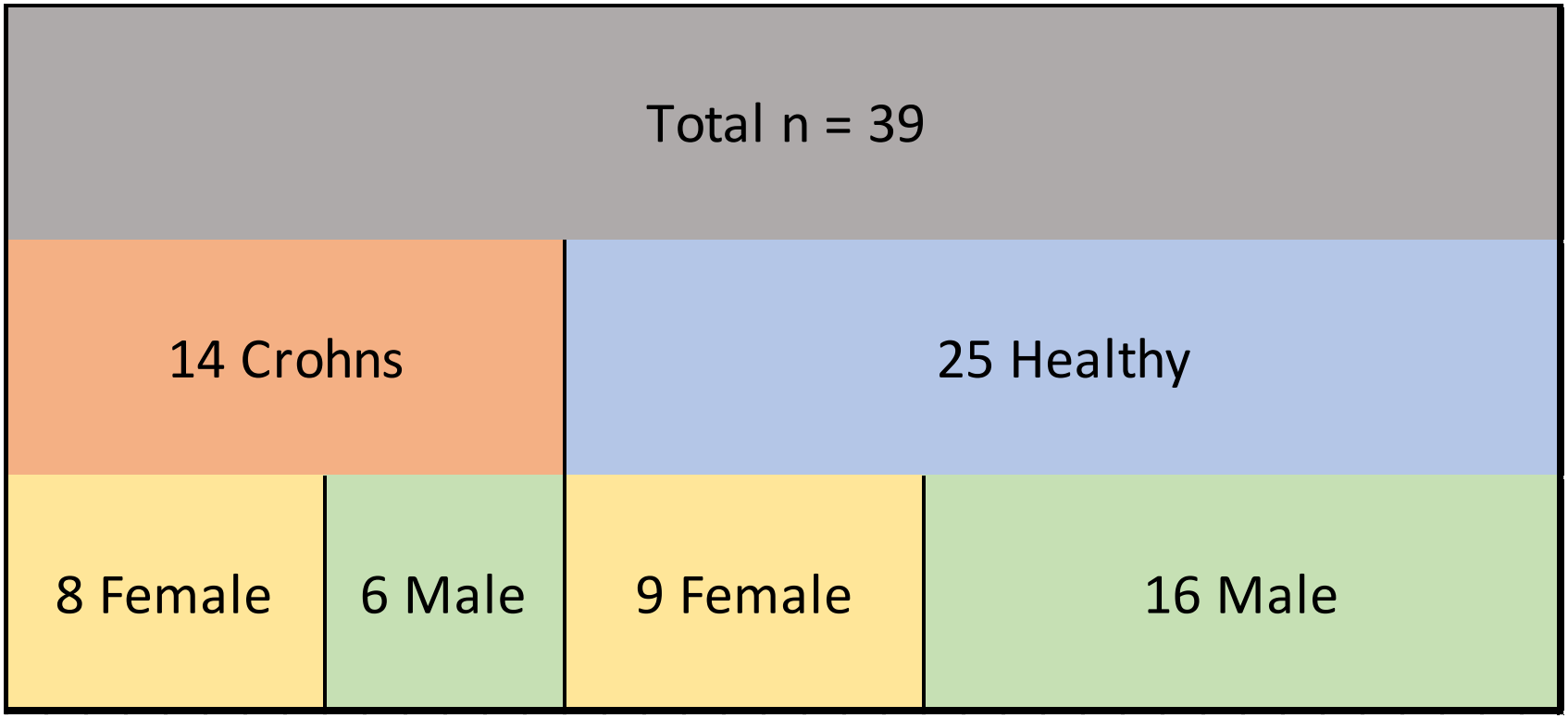


Healthy Control Local Population



HMP

Crohn’s Disease and the Microbiome



- 1: Crohn’s data come from SRA Bioproject PRJNA46321 " Metagenomic Analysis of the Structure and Function of the Human Gut Microbiota in Crohn's Disease”
- 2: Healthy data come from SRA Bioproject PRJNA48479 “Human Microbiome Project (HMP) Metagenomic WGS Projects, deeper sequencing of the human microbiome samples: Production Phase”

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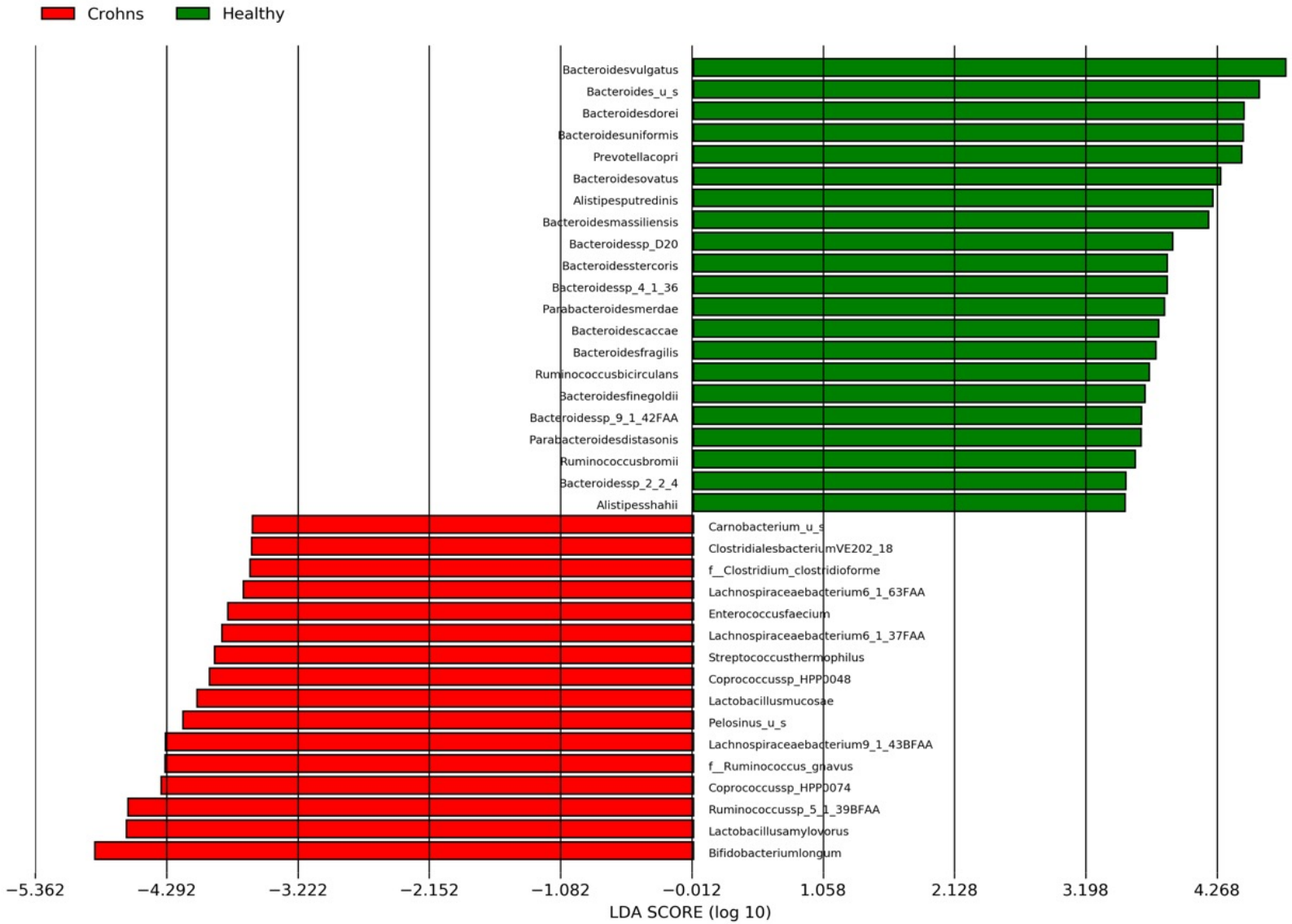
Species Enrichment in Healthy vs Crohn's



Analysis provided by CosmosID

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Water Safety

COSMOSID®
Unlocking The Microbiome

Journal American Water Works Association

Characterization of Microbial Signatures From Advanced Treated Wastewater Biofilms

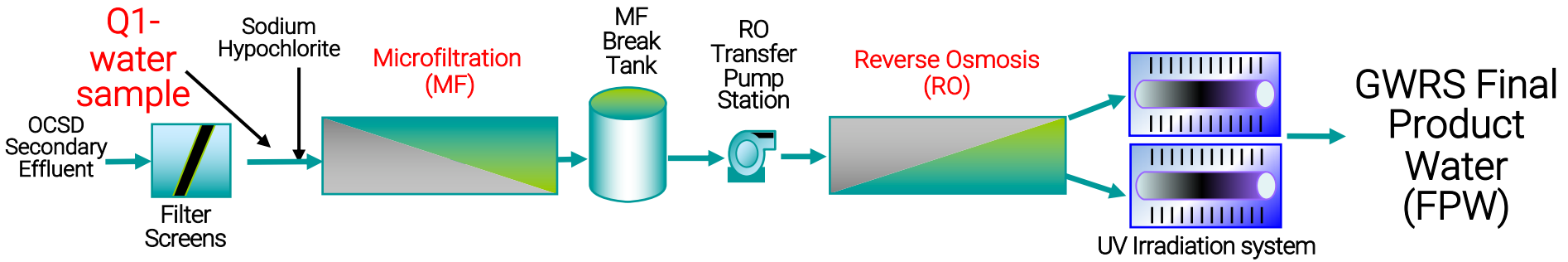
Author(s): Leddy, Menu B.; Hasan, Nur A.; Subramanian, Poorani; Heberling, Colin; Cotruvo, Joseph; Colwell, Rita R.

Publications: Journal - American Water Works Association

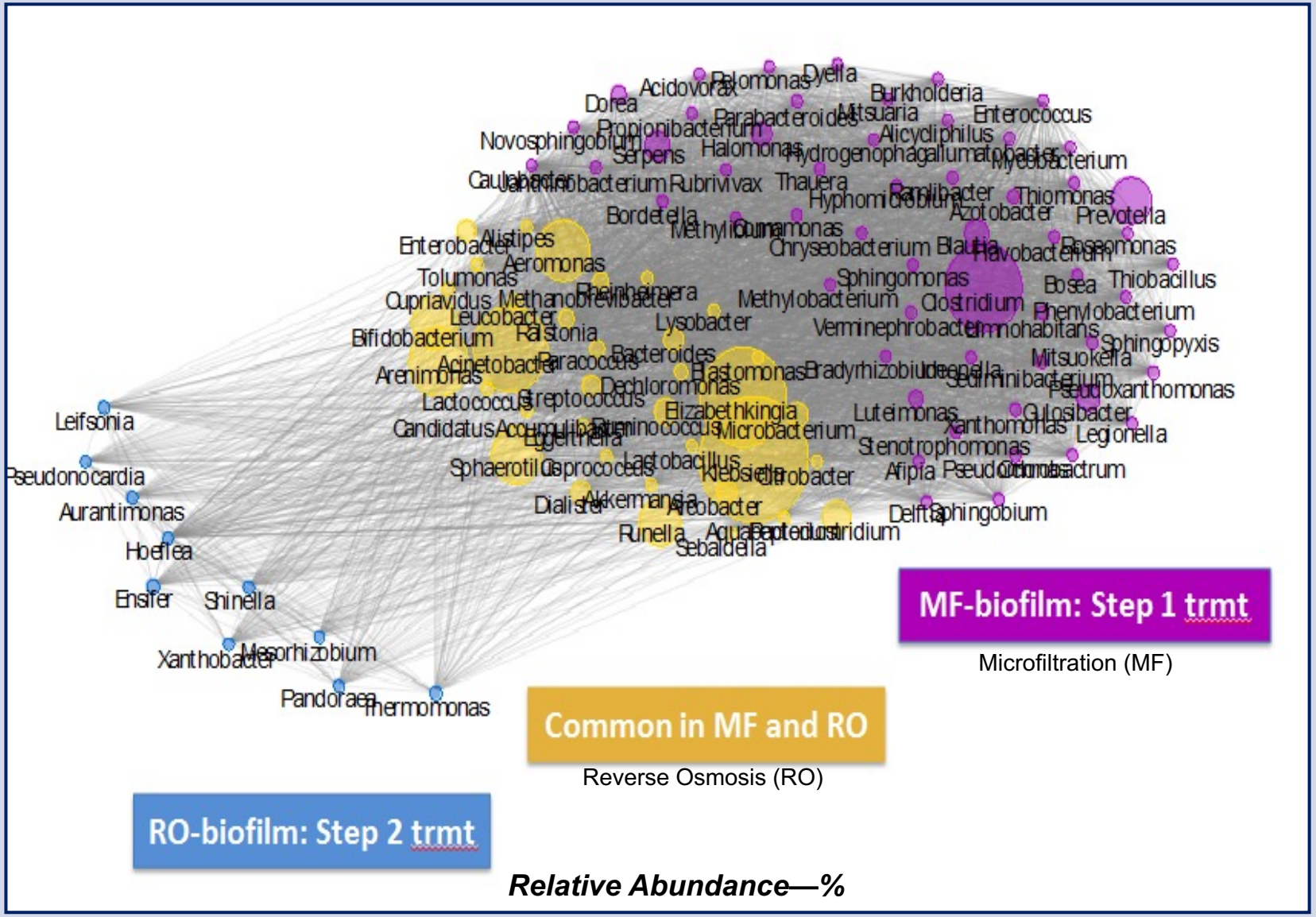
Issue Date: November 2017

Volume / Number: 109, Number 11

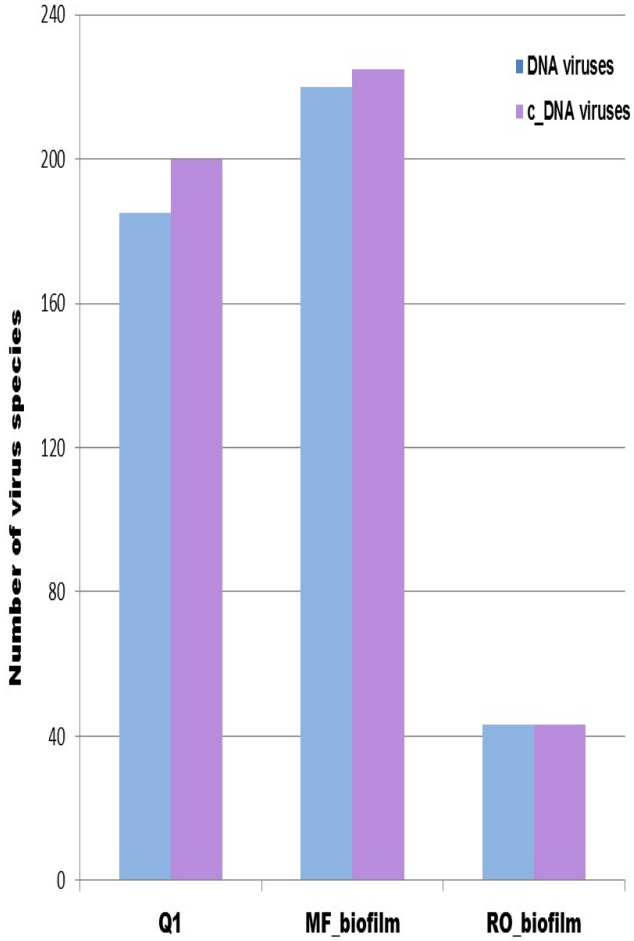
Page(s): E503-E512

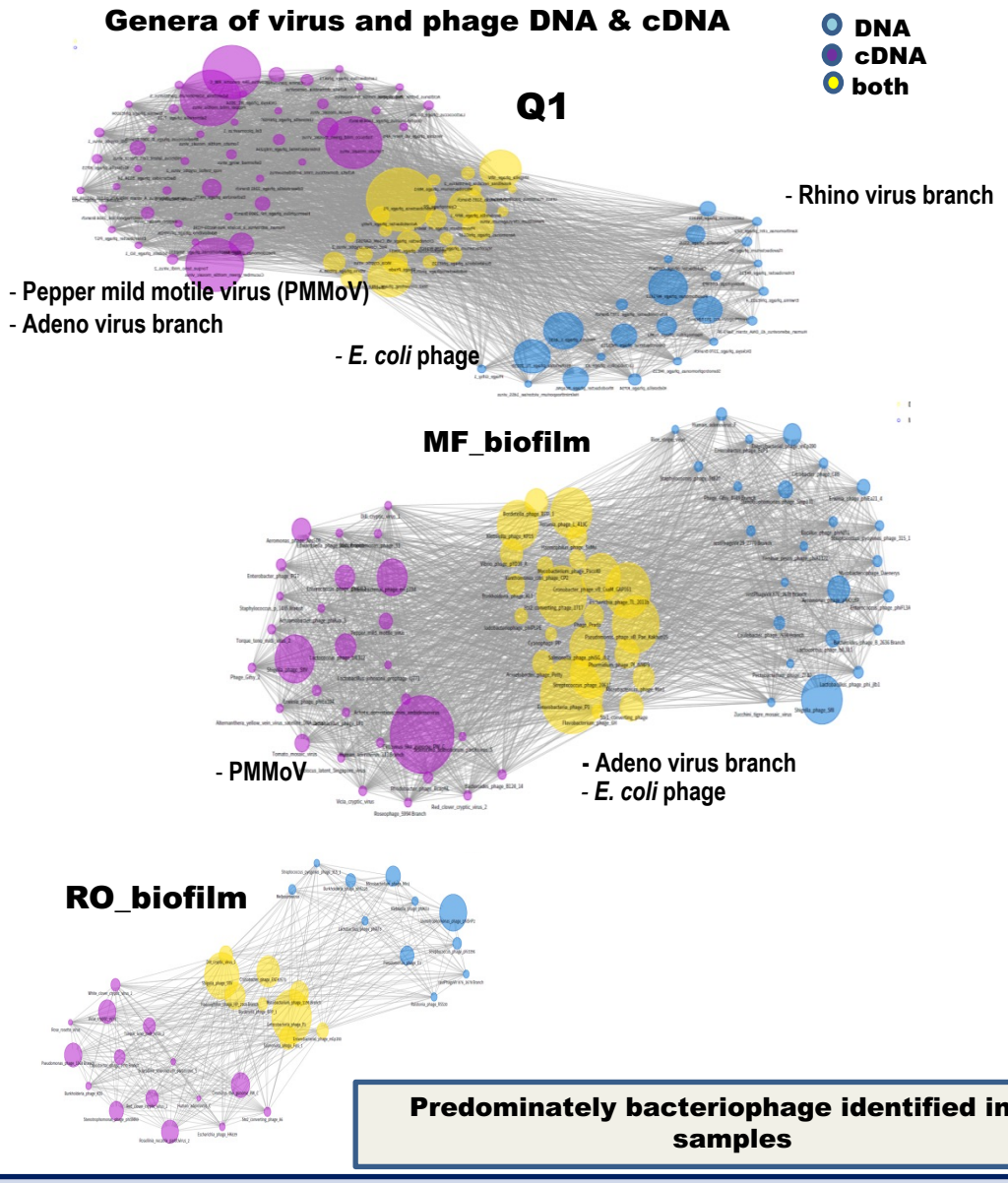


Stepwise reduction of bacterial genera from MF to RO



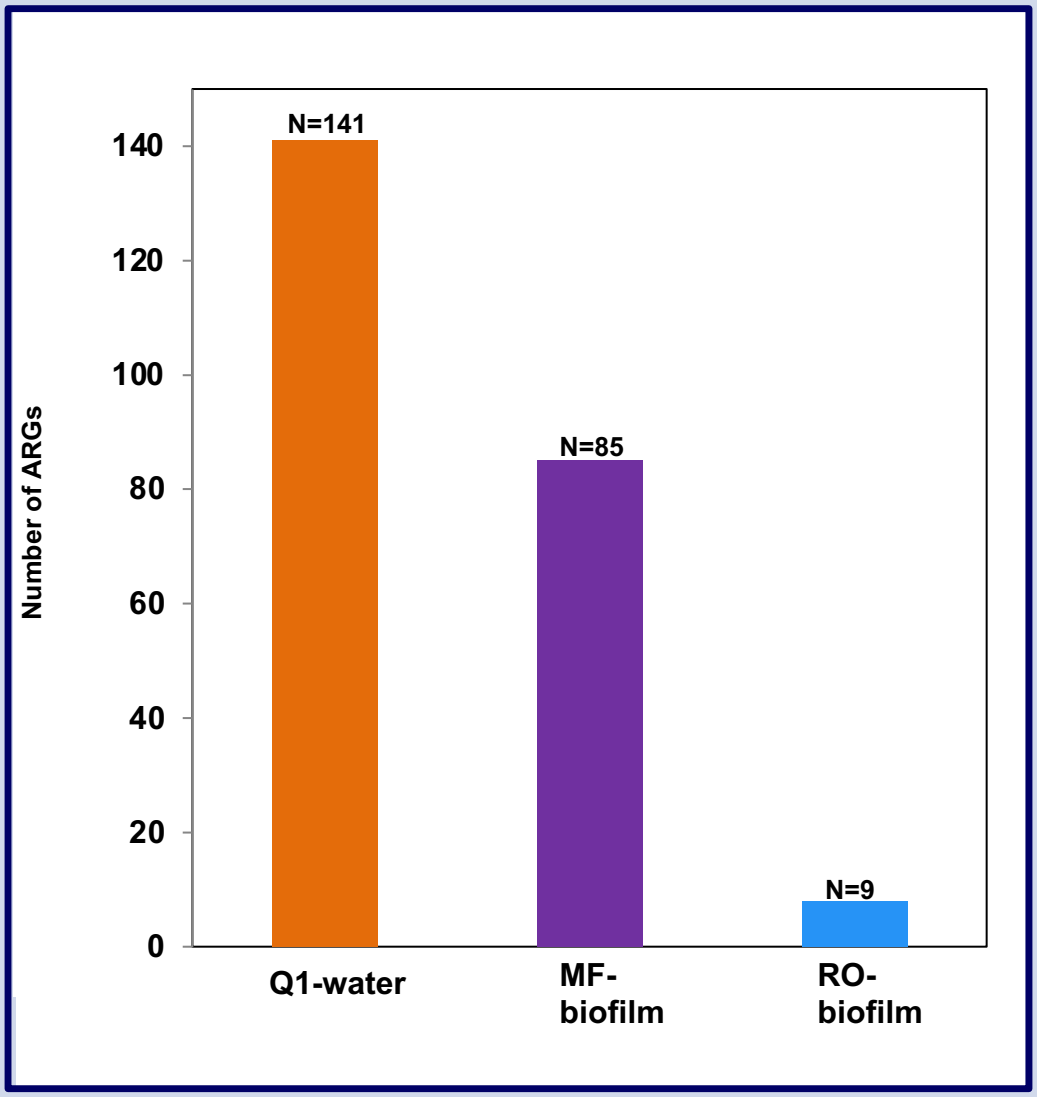
Viral Diversity





Predominately bacteriophage identified in all samples

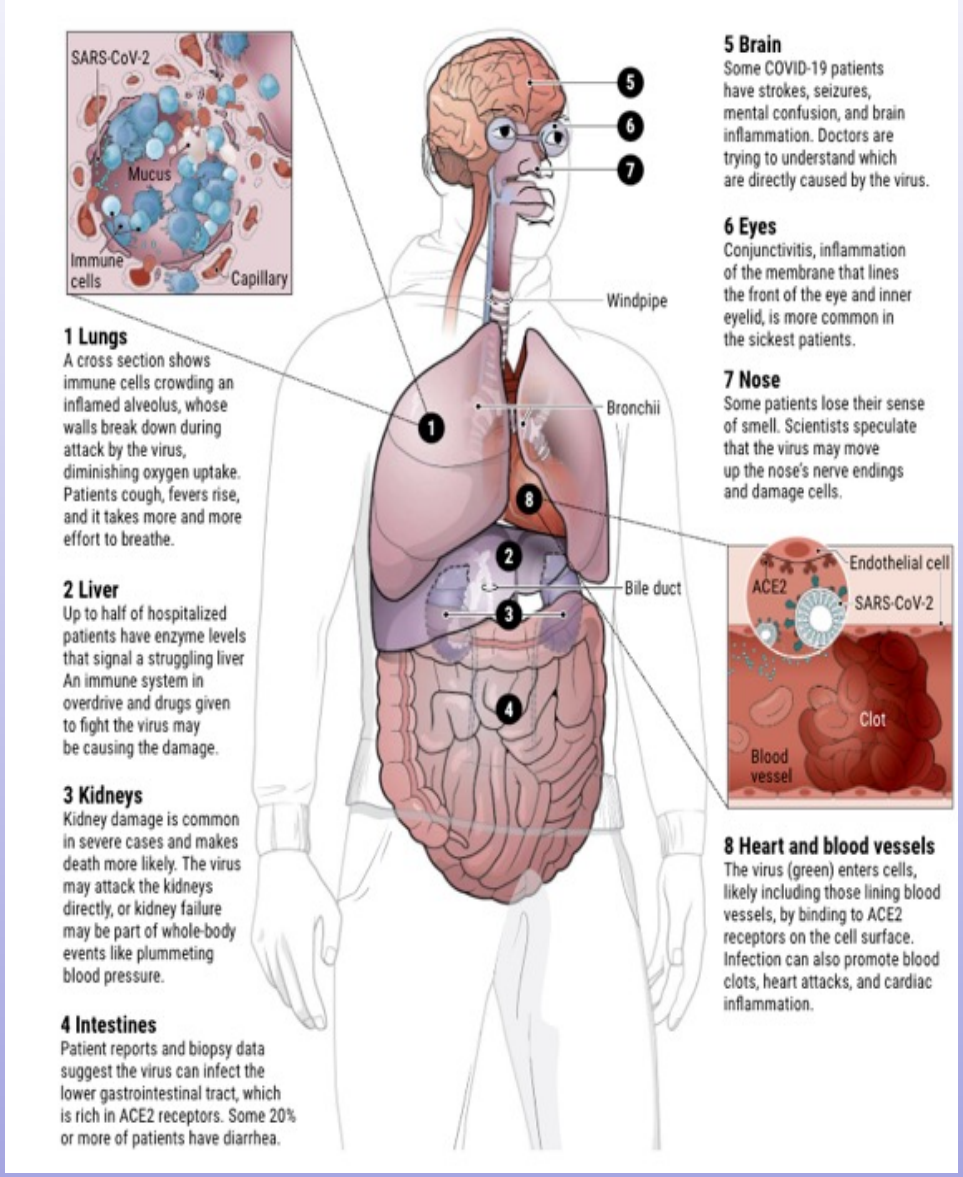
Distribution of antibiotic resistance genes (ARGs) and stepwise reduction of ARG's in MF and RO-biofilms



Is COVID-19 polymicrobial and systemic?

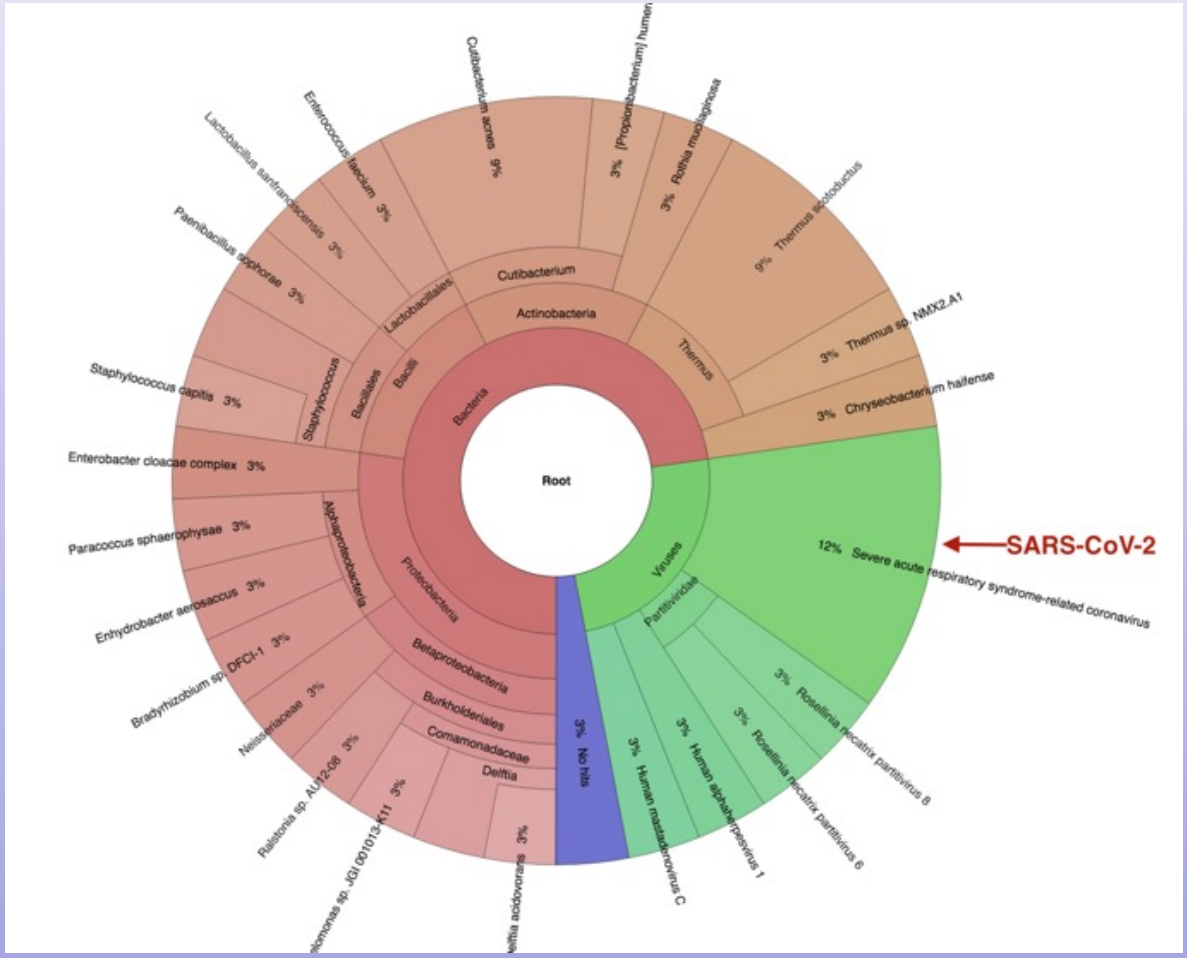
How does coronavirus kill? Clinicians trace a ferocious rampage through the body, from brain to toes

By Meredith Wadman, Jennifer Couzin-Frankel, Jocelyn Kaiser, Catherine Matacic.
Science, Apr. 17, 2020 , 6:45 PM

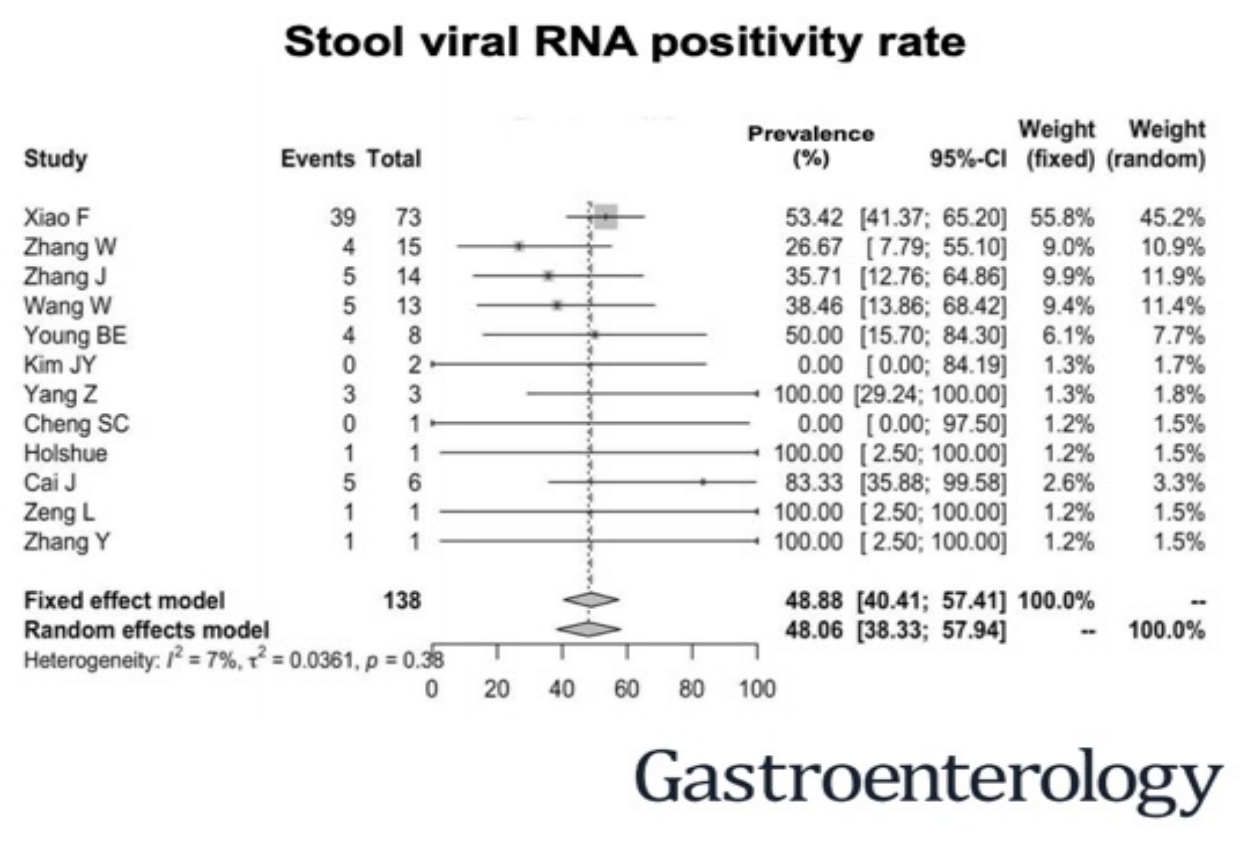


https://www.sciencemag.org/news/2020/04/how-does-coronavirus-kill-clinicians-trace-ferocious-rampage-through-body-brain-toes

Identification of Bacteria and Viruses Present in Respiratory Samples in which SARS-CoV-2 has been Detected

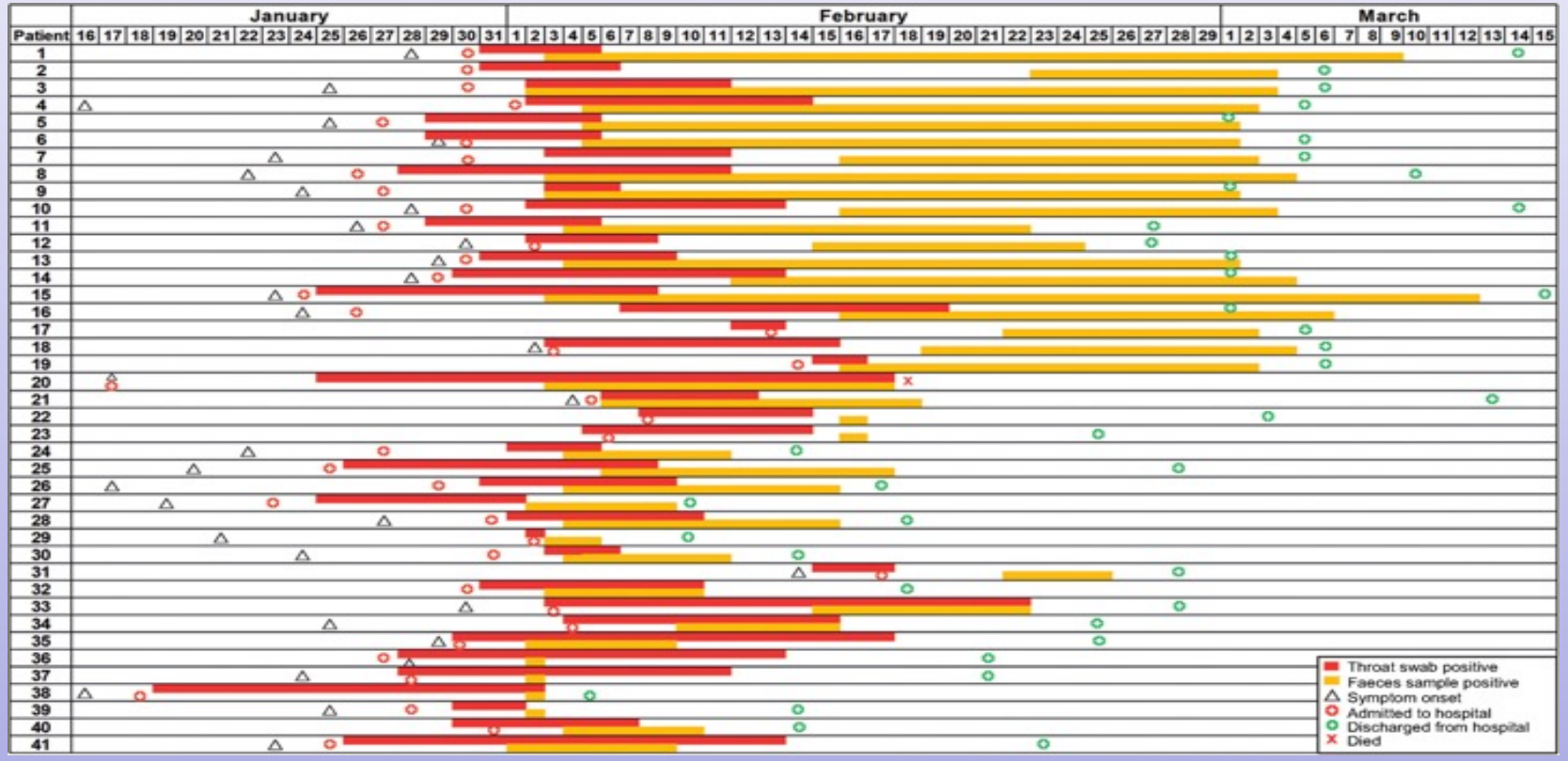


SARS Cov-2 viral RNA has been detected in 48.1% of stool samples



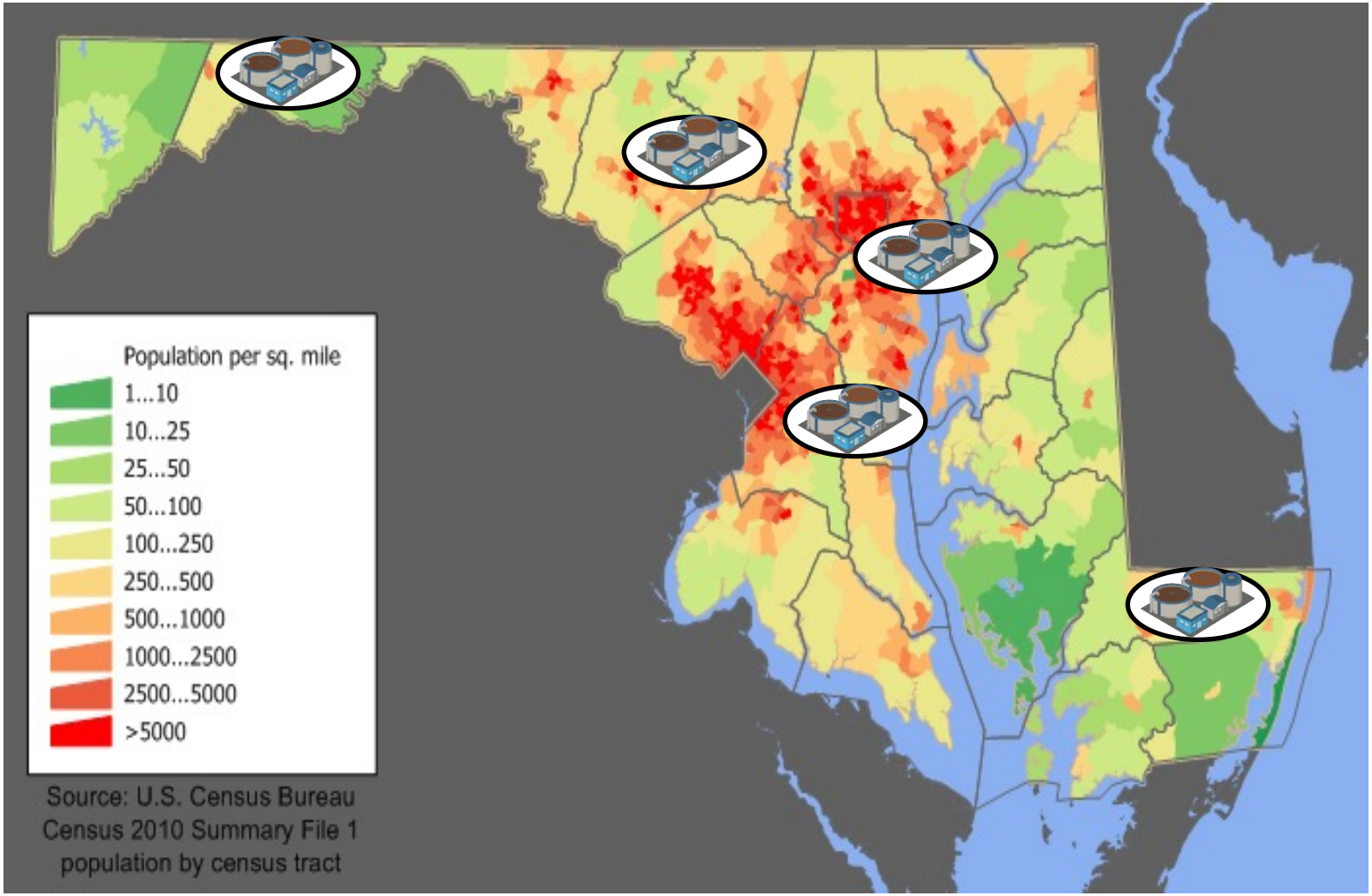
Cheung et al., (2020). Gastrointestinal Manifestations of SARS-CoV-2 Infection and Virus Load in Fecal Samples from the Hong Kong Cohort and Systematic Review and Meta-analysis. Gastroenterology. Pre-Proof

Positive Stool Samples Detected After Respiratory Sample Tested Negative During Recovery

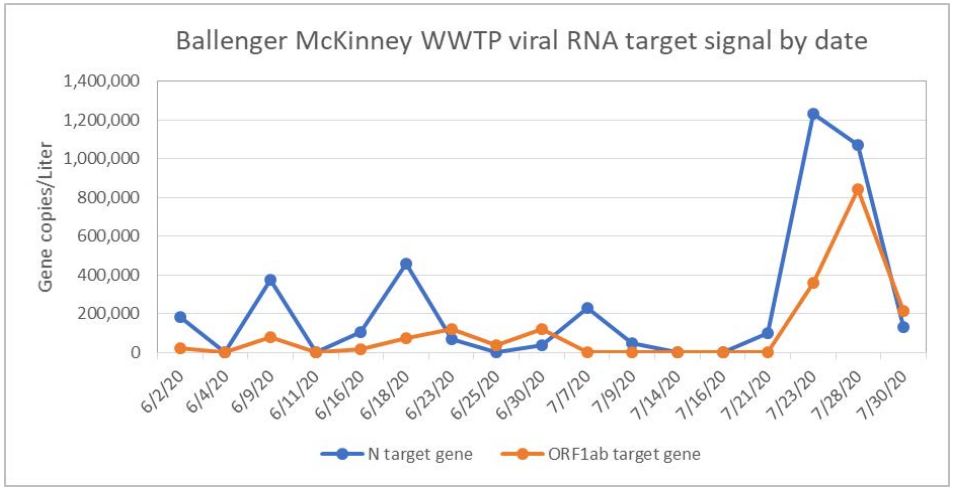


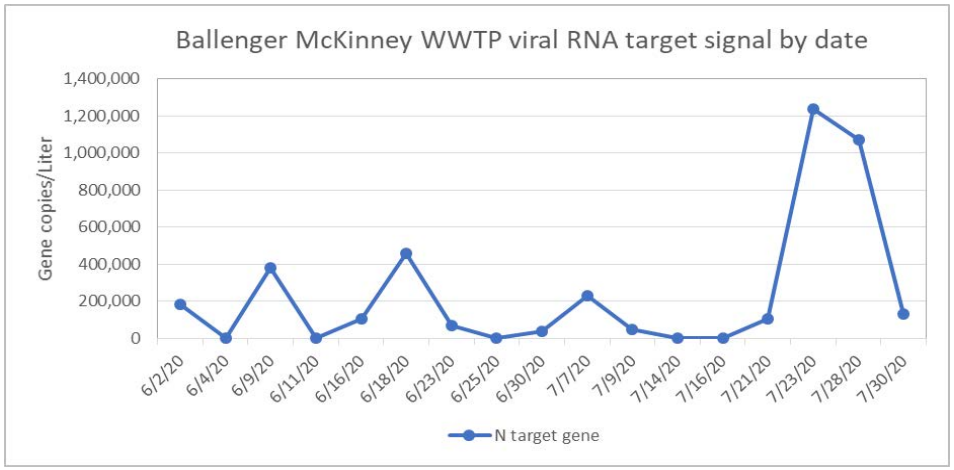
Wu Y, Guo C, Tang L, et al. Prolonged presence of SARS-CoV-2 viral RNA in faecal samples. 2020 *The lancet Gastroenterology – hepatology. Volume 5, Issue 5, 434 - 435*

COVID-19 tracking in wastewater underway



Results from Frederick, Maryland sites





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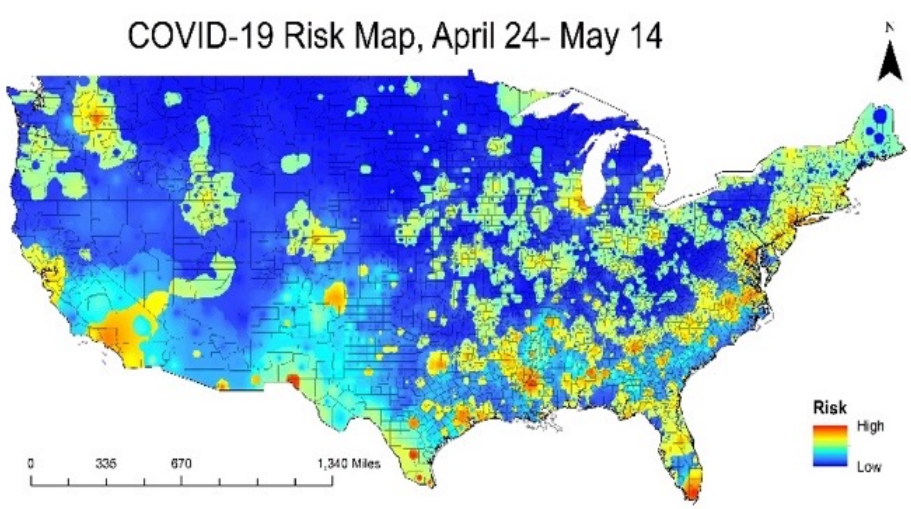
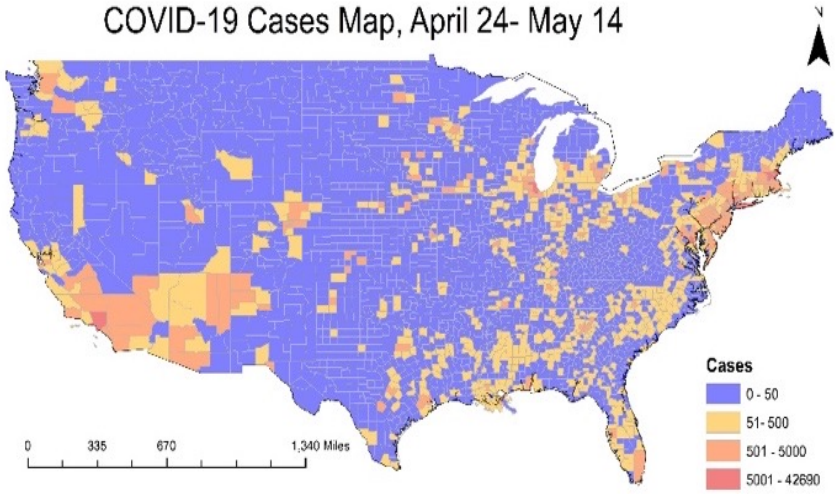
Prediction of coronavirus risk

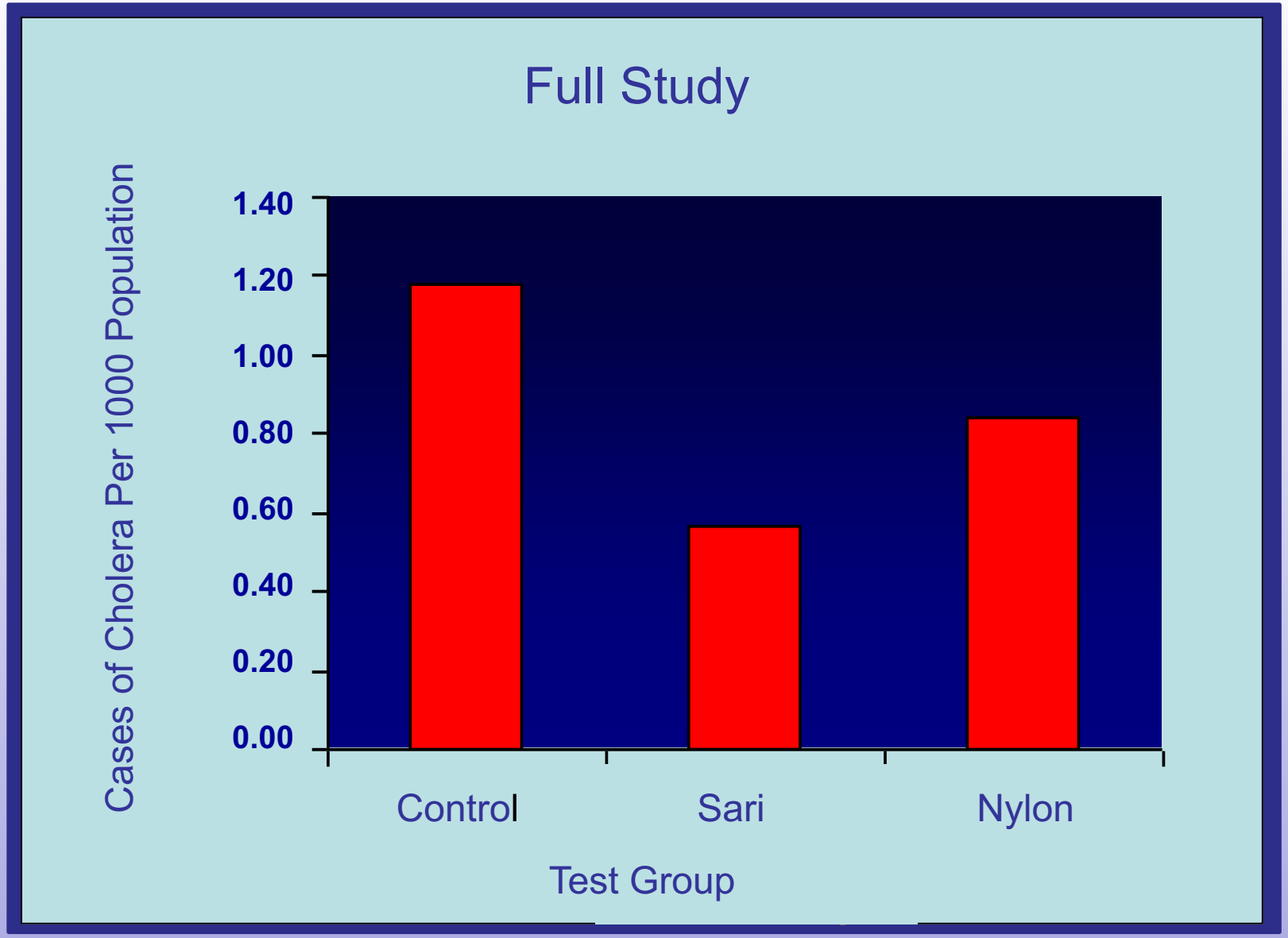




Left panel: **Prediction** made on April 24th 2020 and valid until May 14th, 2020.
Right panel: **Actual number** of COVID19 cases during those three weeks: a heuristic prediction model developed in GeoHLab


A Simple, Sustainable
Method for
Reducing Cholera


Vibrio cholerae


Full Study
Cases of Cholera Per 1000 Population
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Control
Sari
Nylon
Test Group

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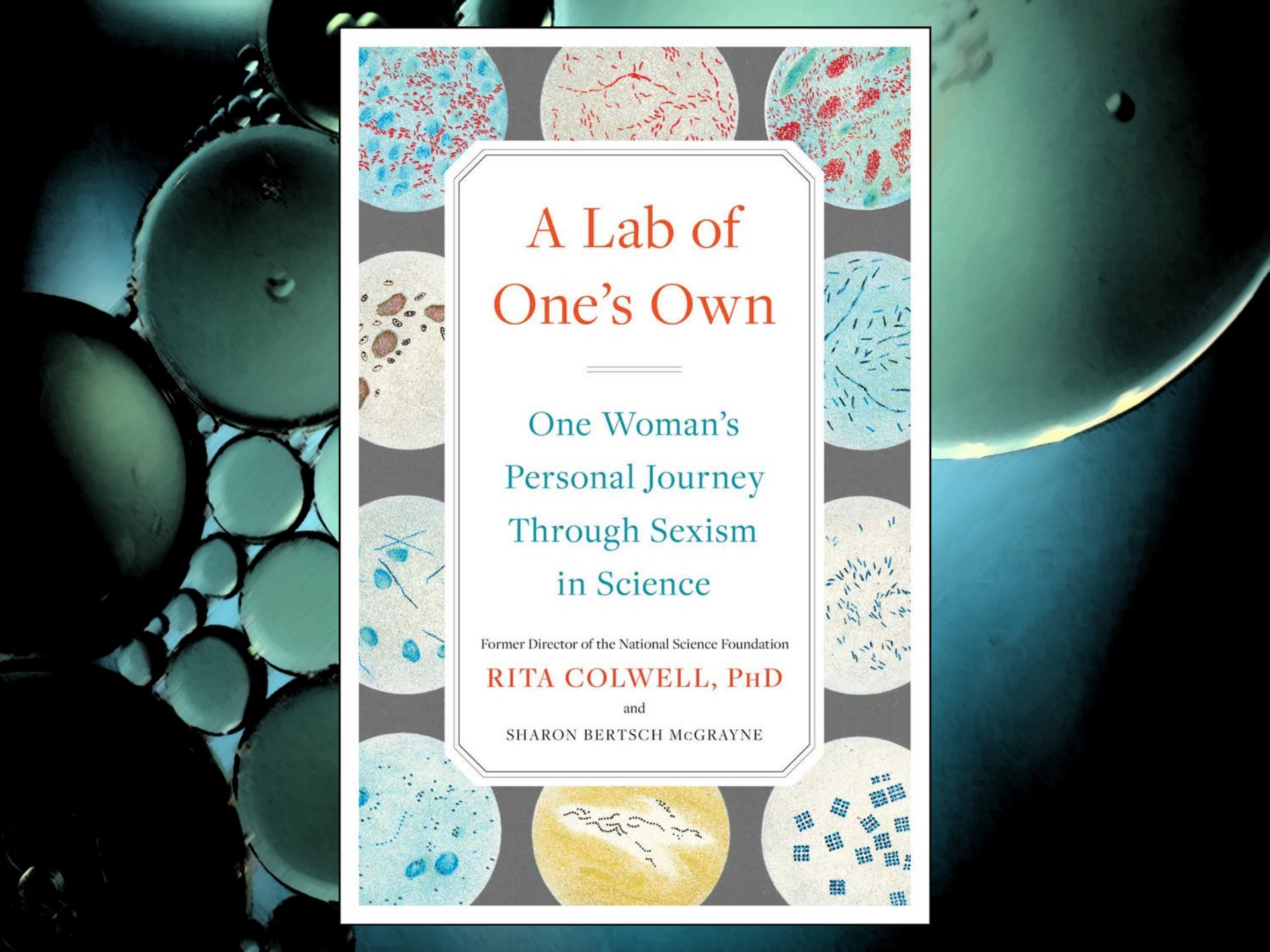
Safe water is a global challenge

Courtesy of GB Nair, NICED, Kolkata, India


A Lab of One's Own
One Woman's Personal Journey Through Sexism in Science
Former Director of the National Science Foundation
RITA COLWELL, PhD
and
SHARON BERTSCH McGRAYNE