SERC Talks "Oceans and Human Health: What We Have Learned About COVID From Cholera"

December 7, 2022 | 1:00 PM ET

Rita R. Colwell, Ph.D., D.Sc., Distinguished University Professor, University of Maryland at College Park and Johns Hopkins Bloomberg School of Public Health; President, CosmosID, Inc.

INNOVATING STEM READINESS

- Today's session will be recorded.
- An archive of today's talk will be available at: www.sercuarc.org/serc-talks/ as well as on the SERC YouTube channel.
- Use the Q&A box to queue up questions, reserving the chat box for comments, and questions will be answered during the last 5-10 minutes of the session.
- If you are connected via the dial-in information only, please email questions or comments to SERCtalks@stevens.edu.
- Any issues? Use the chat feature for any technical difficulties or other comments, or email SERCtalks@stevens.edu.

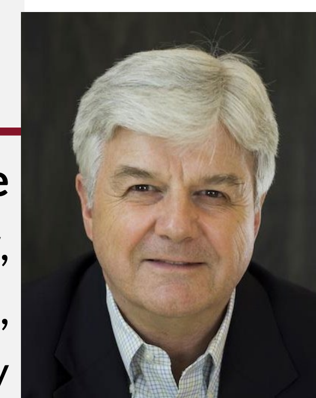
SYSTEMS ENGINEERING RESEARCH CENTER

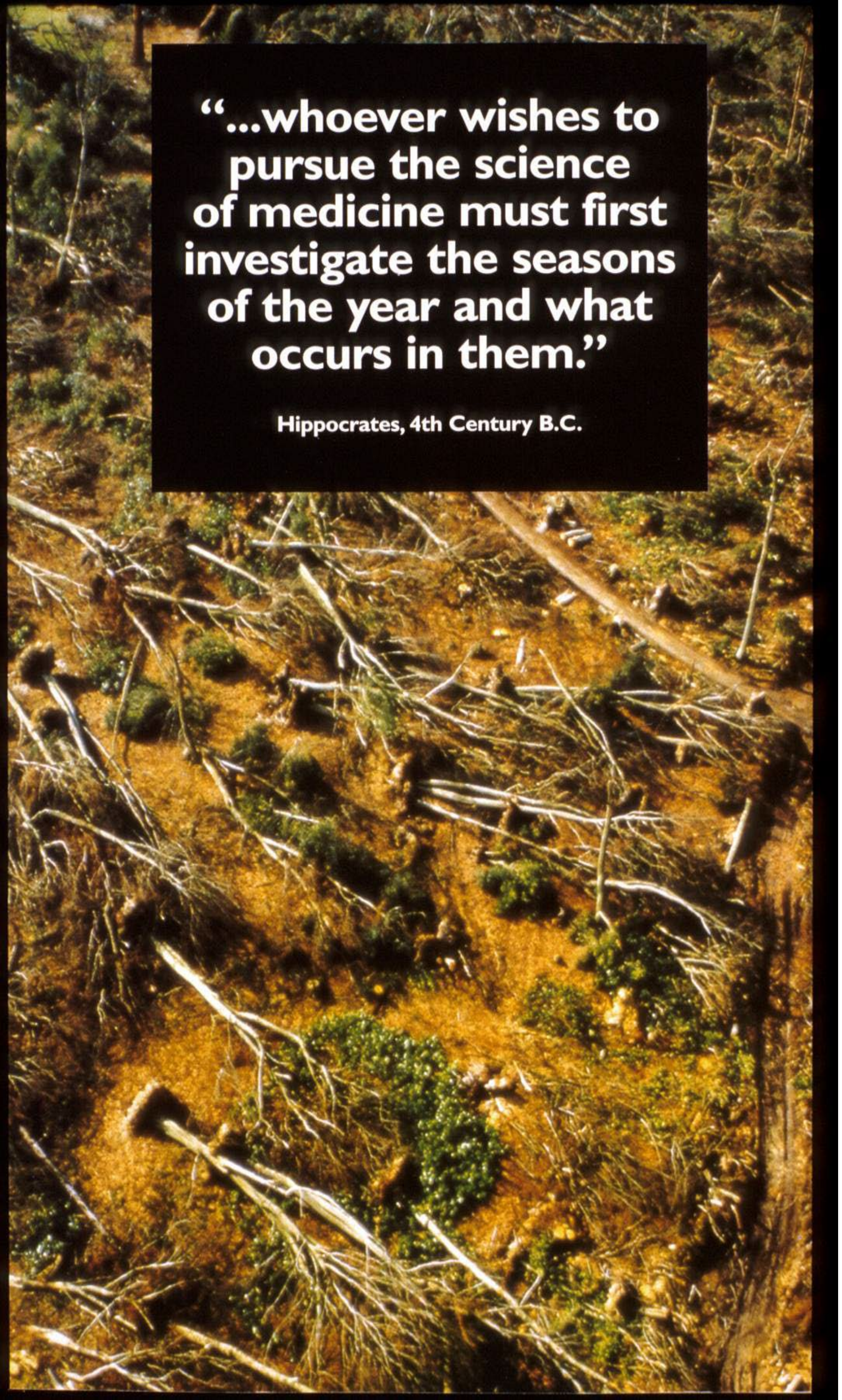
SERC TALKS

"Oceans and Human Health: What We Have Learned About COVID From Cholera"

Rita R. Colwell, Ph.D., D.Sc.
Distinguished University Professor,
University of Maryland at College Park and
Johns Hopkins Bloomberg School of Public Health;
President, CosmosID, Inc.

Moderator: Dr. William Rouse
SERC Research Council Member; Senior Fellow,
Office of the Senior Vice President for Research,
McCourt School of Public Policy, Georgetown University





Oceans and Human Health: What we have learned about COVID from Cholera

SERC TALKS

December 7, 2022

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

Pandemics of the modern world

Impacted Region

Year	Broad Pathogen	Years lasted	Mortality	Possible Origin	Pandemics
Pre-mobilized world		Unknown	Decimated civilizations	Worldwide	Plague Cholera Influenza
1347	Bacterium	22	75-200M	Central/ East Asia	Bubonic Plague
1521	Virus	7	56M	Europe	Smallpox
1817	Bacterium	7	Unknown	India	First Cholera
1829	Bacterium	8	300K	India	Second Cholera
1837	Bacterium	26	1.5M	India	Third Cholera
1855	Bacterium	12	17-50M	China	Plague
1863	Bacterium	15	150K	India	Fourth Cholera
1881	Bacterium	15	600K	India	Fifth Cholera
1889	Virus	6	1.0M	Uzbekistan	Russian Flu*
1899	Bacterium	24	1.0M	India	Sixth Cholera
1918	Virus	3	25-50M	Debated	Spanish Flu*
1957	Virus	1	2M	Singapore	Asian Flu
1961	Bacterium	Ongoing	Ongoing	Indonesia	Seventh Cholera
1968	Virus	1	1M	Hong Kong	Hongkong Flu*
2002	Virus	2	774	China	SARS#
2009	Virus	1	600K	Mexico	Swine Flu
2013	Virus	3	11K	Africa	Ebola
2019	Virus	Ongoing	Ongoing	China	COVID19$
?					

Cholera

COVID-19

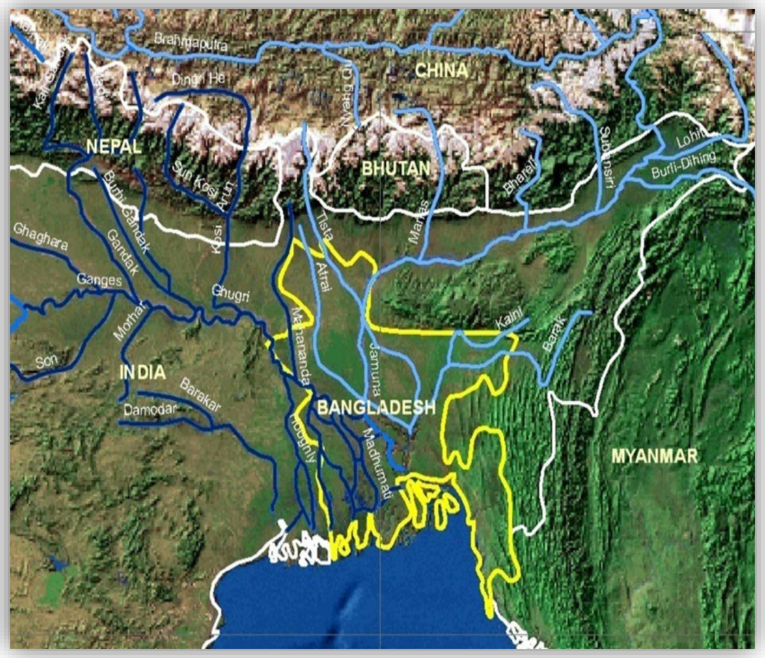
Data collected and summarized from
Sherman., I. 2007 Twelve Disease that Changed Our World, American Society for Microbiology, USA
Zimmerman, B.E. and Zimmerman., D.J 2003 Killer Germs, McGraw Hill, USA
*Source of virus debated, hence used prevalent name of disease, #SARS-CoV-1, $SARS-CoV-2

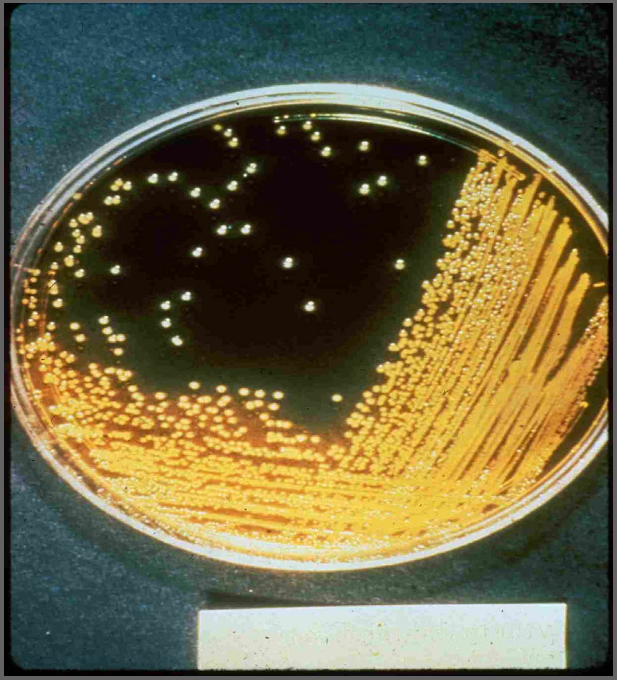
Water-related diseases

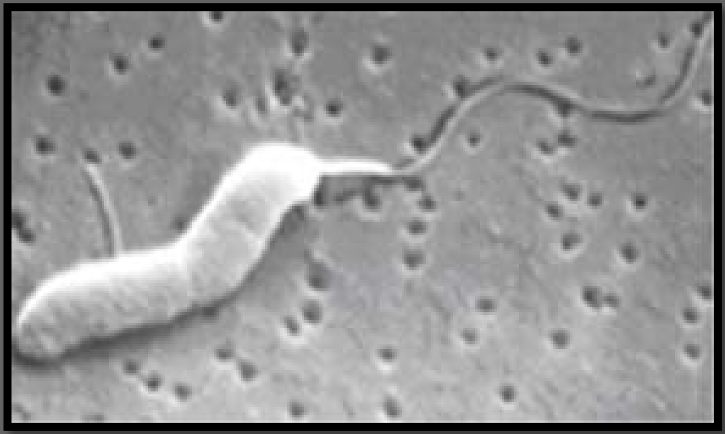
	Cases per year	Deaths per year
Amoebiasis	48,000,000	110,000
Arsenic	28-35m exposed to drinking water with elevated levels	
Diarrhoeal disease, Including cholera	1.5 billion	1,800,000
Dracunuliasis (guinea worm)	> 5000	-
Fluorosis	26 million (China)	-
Giardiasis	500,000	Low
Hepatitis A	1,500,00	-
Intestinal 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

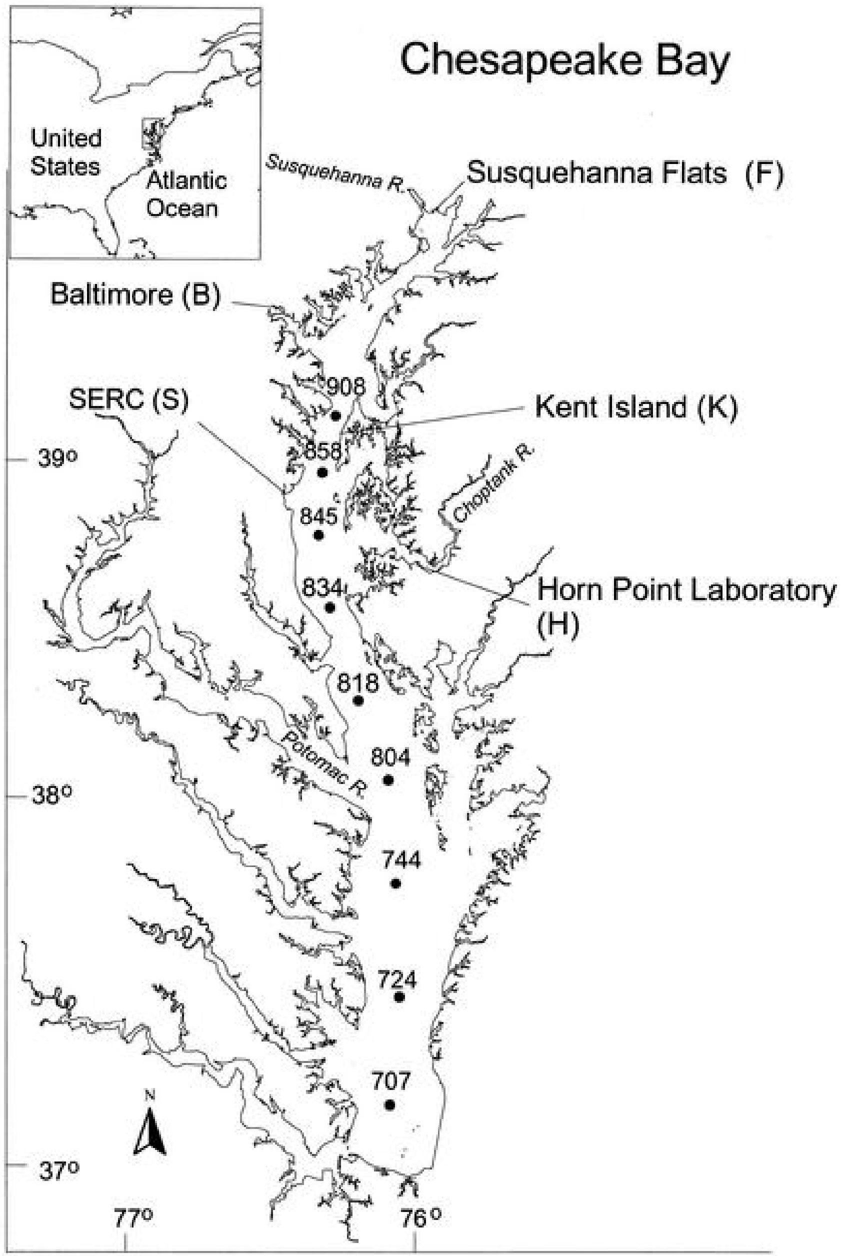
Cholera: A Global Disease

- 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, *it is highly unlikely that cholera will be eradicated but clearly can be controlled by provision of safe drinking water.*



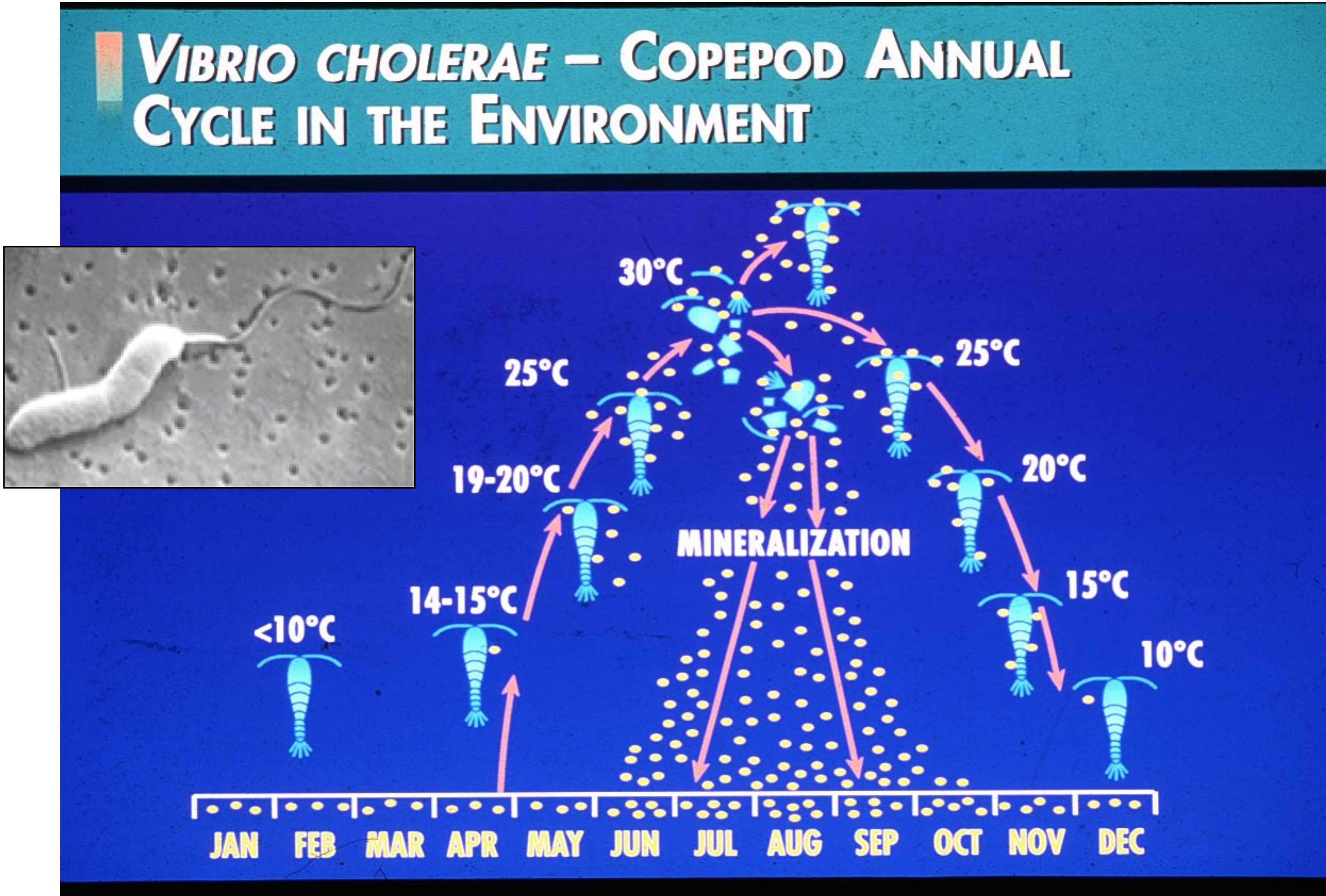




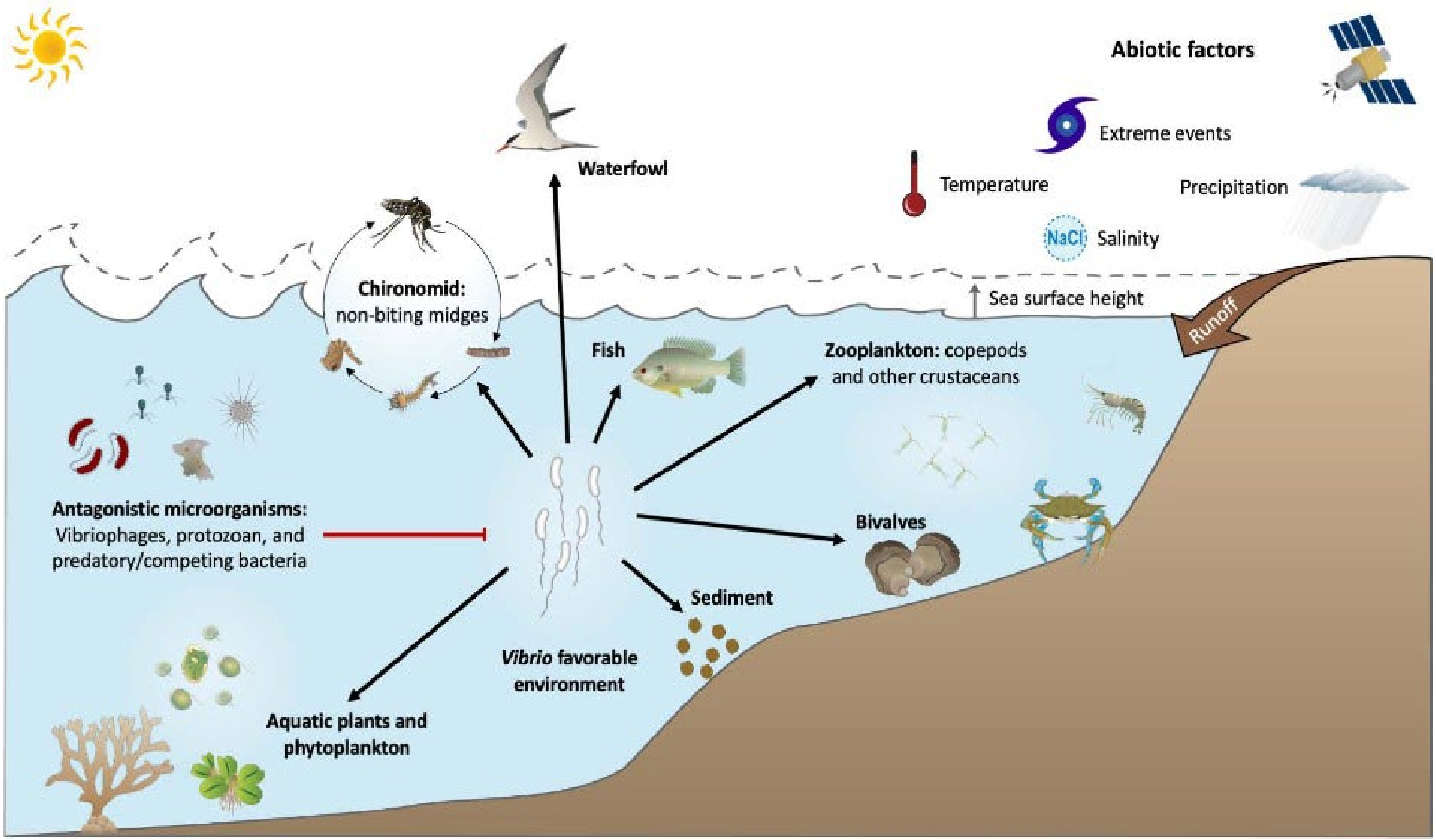


Map of Chesapeake Bay – beginning of the cholera chronicle

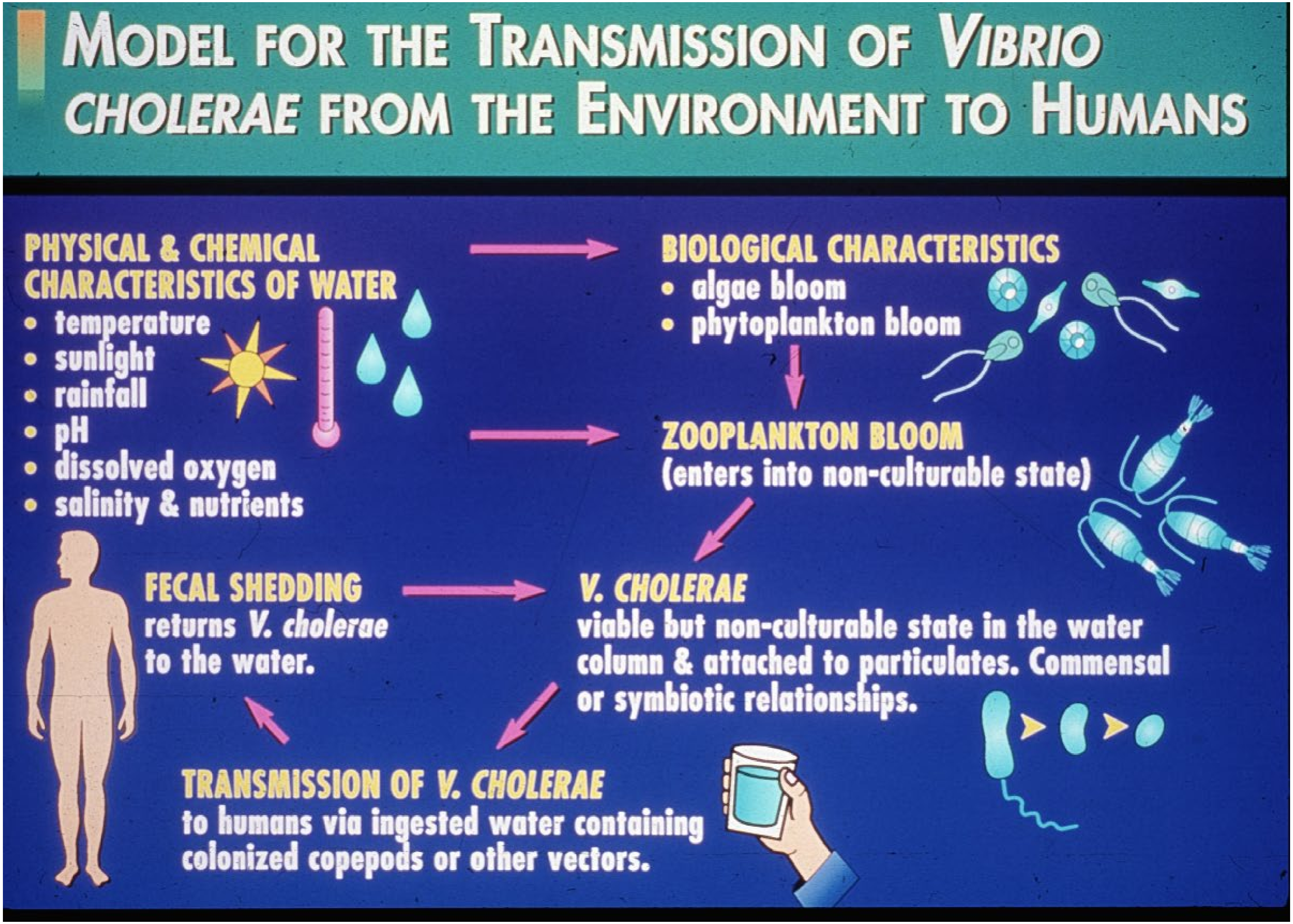
1965-1975 An early contribution of marine microbiology to human health: Determination of the *Vibrio cholerae* life cycle



Vibrio and their natural environment

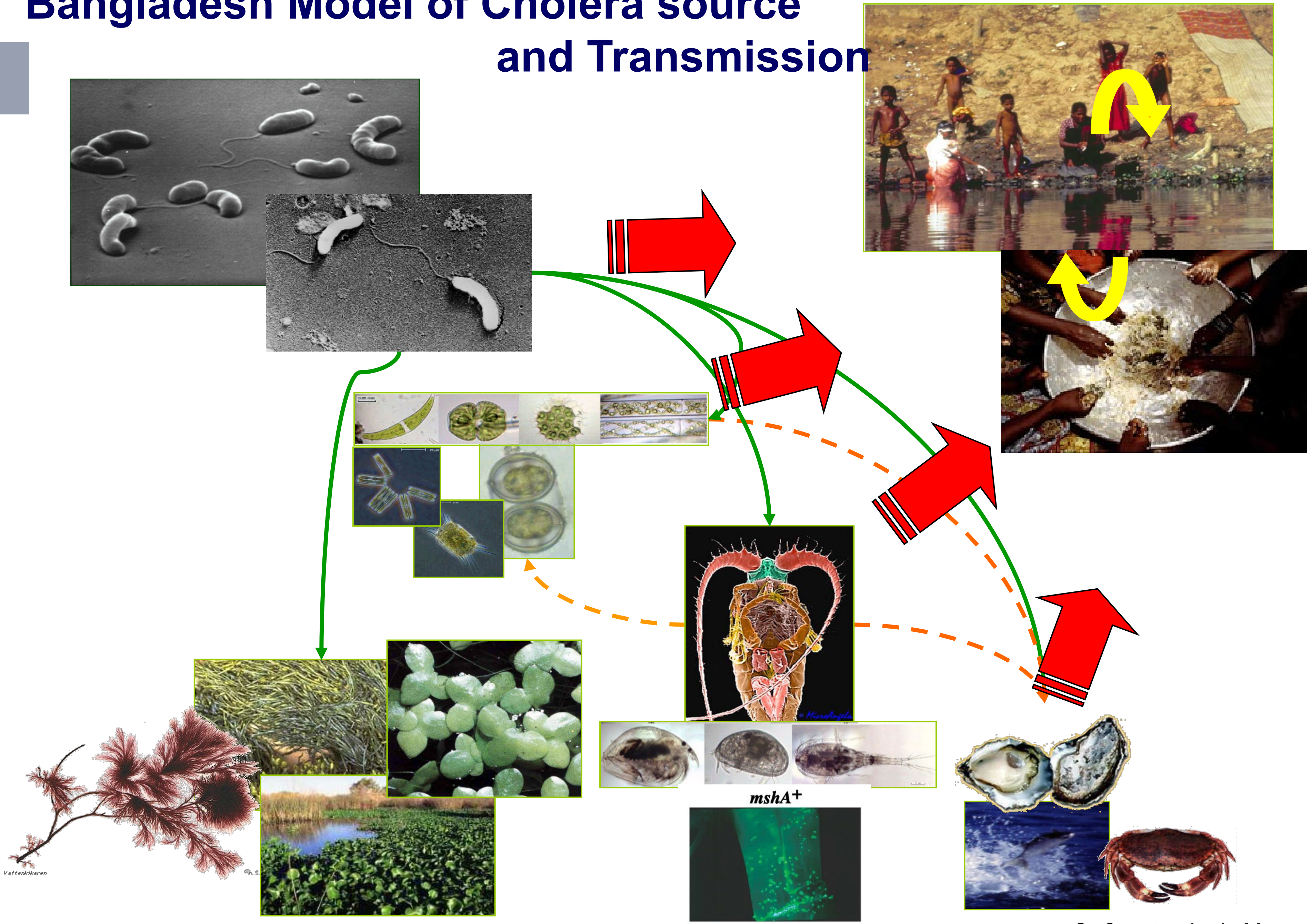


Brumfield et al. 2021, Env Micro



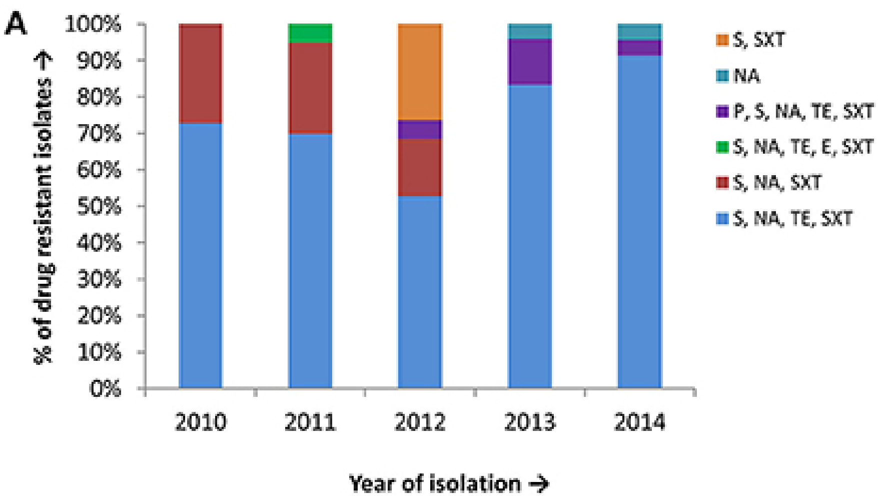
MODEL FOR THE TRANSMISSION OF VIBRIO CHOLERAE FROM THE ENVIRONMENT TO HUMANS
PHYSICAL & CHEMICAL CHARACTERISTICS OF WATER
• temperature
• sunlight
• rainfall
• pH
• dissolved oxygen
• salinity & nutrients
BIOLOGICAL CHARACTERISTICS
• algae bloom
• phytoplankton bloom
ZOOPLANKTON BLOOM
(enters into non-culturable state)
FECAL SHEDDING
returns V. cholerae to the water.
V. CHOLERAE
viable but non-culturable state in the water column & attached to particulates. Commensal or symbiotic relationships.
TRANSMISSION OF V. CHOLERAE
to humans via ingested water containing colonized copepods or other vectors.

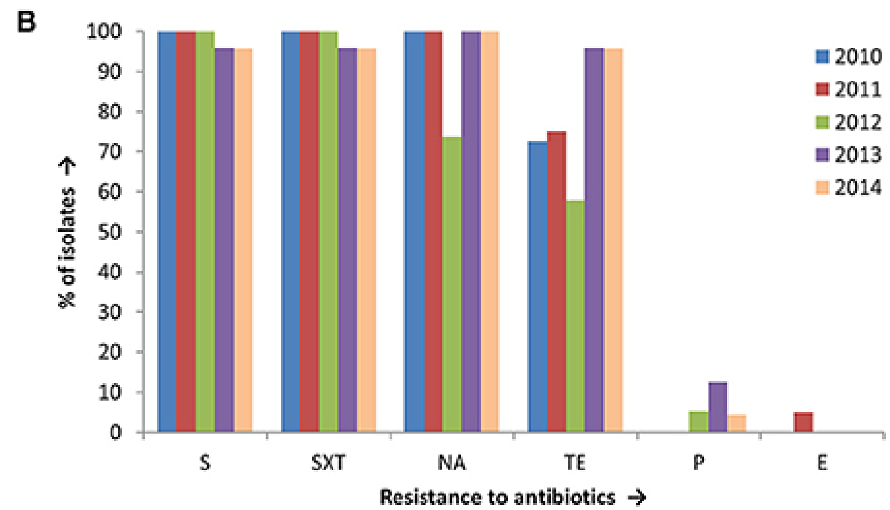
Bangladesh Model of Cholera source and Transmission



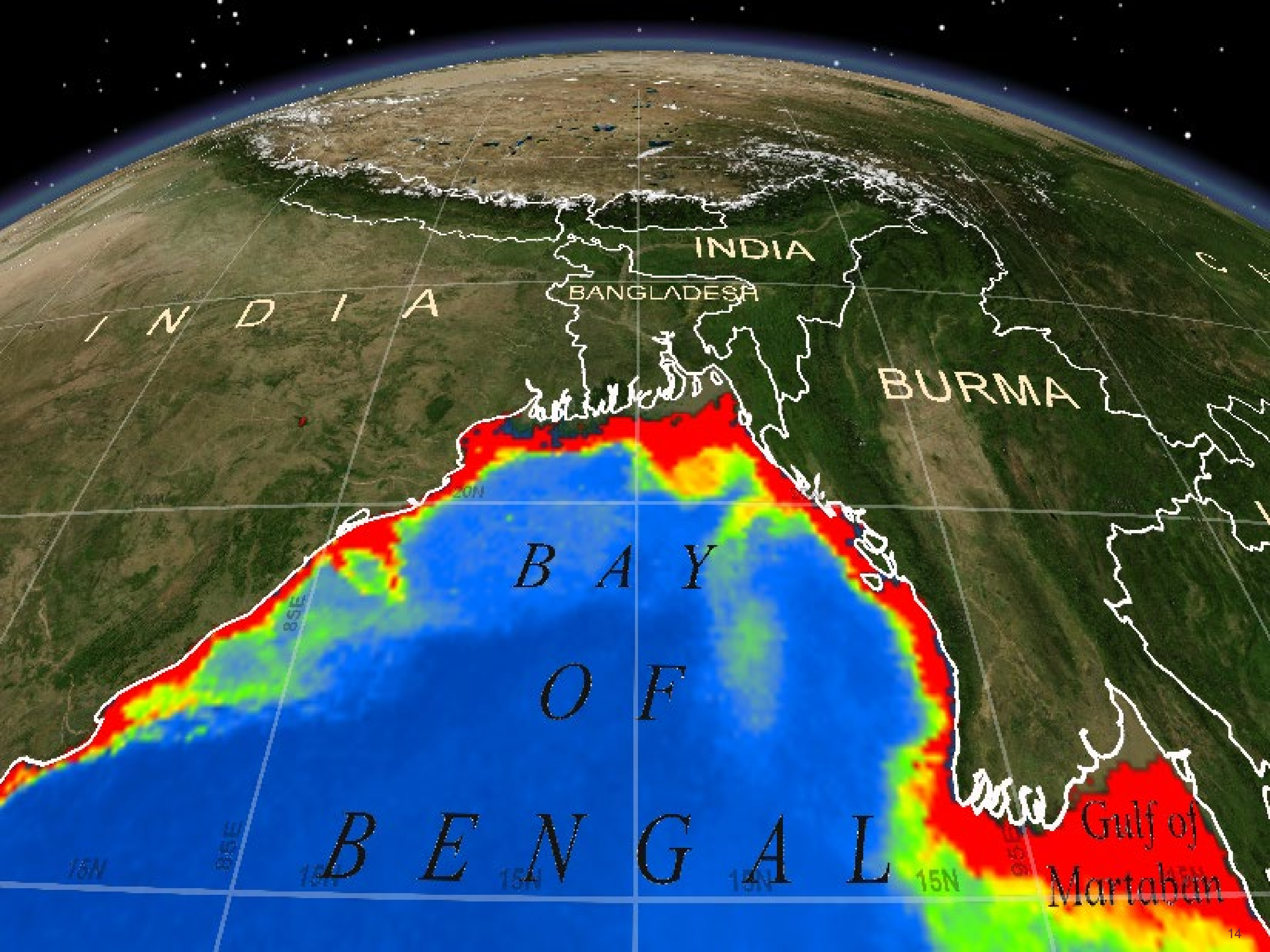
G. Constantin de Magny

Drug resistance profile of *V. cholerae* O1 from environmental sources (Mathbaria 2010-2014)



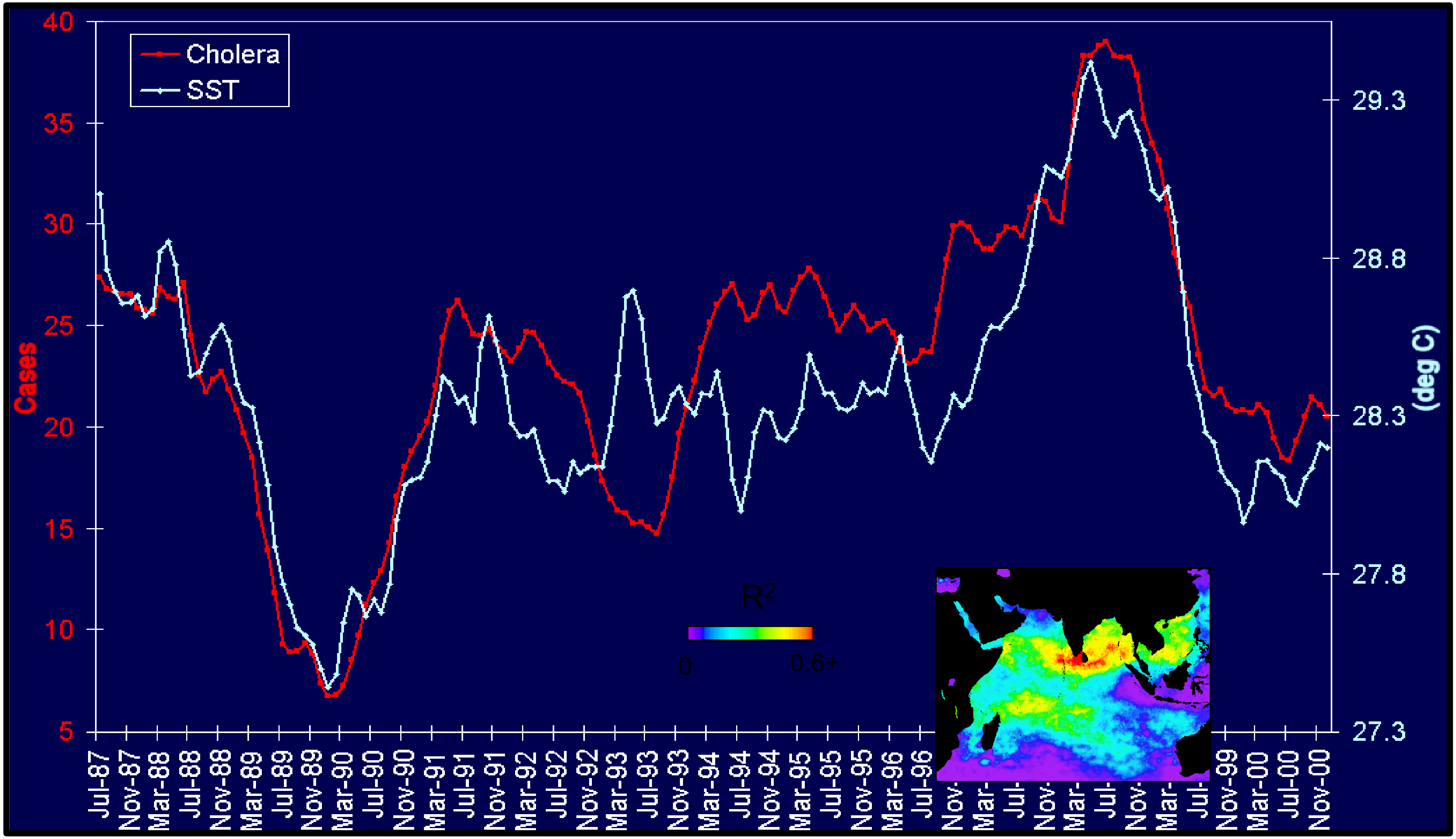


Rashed et al. 2017, Front Microbiol

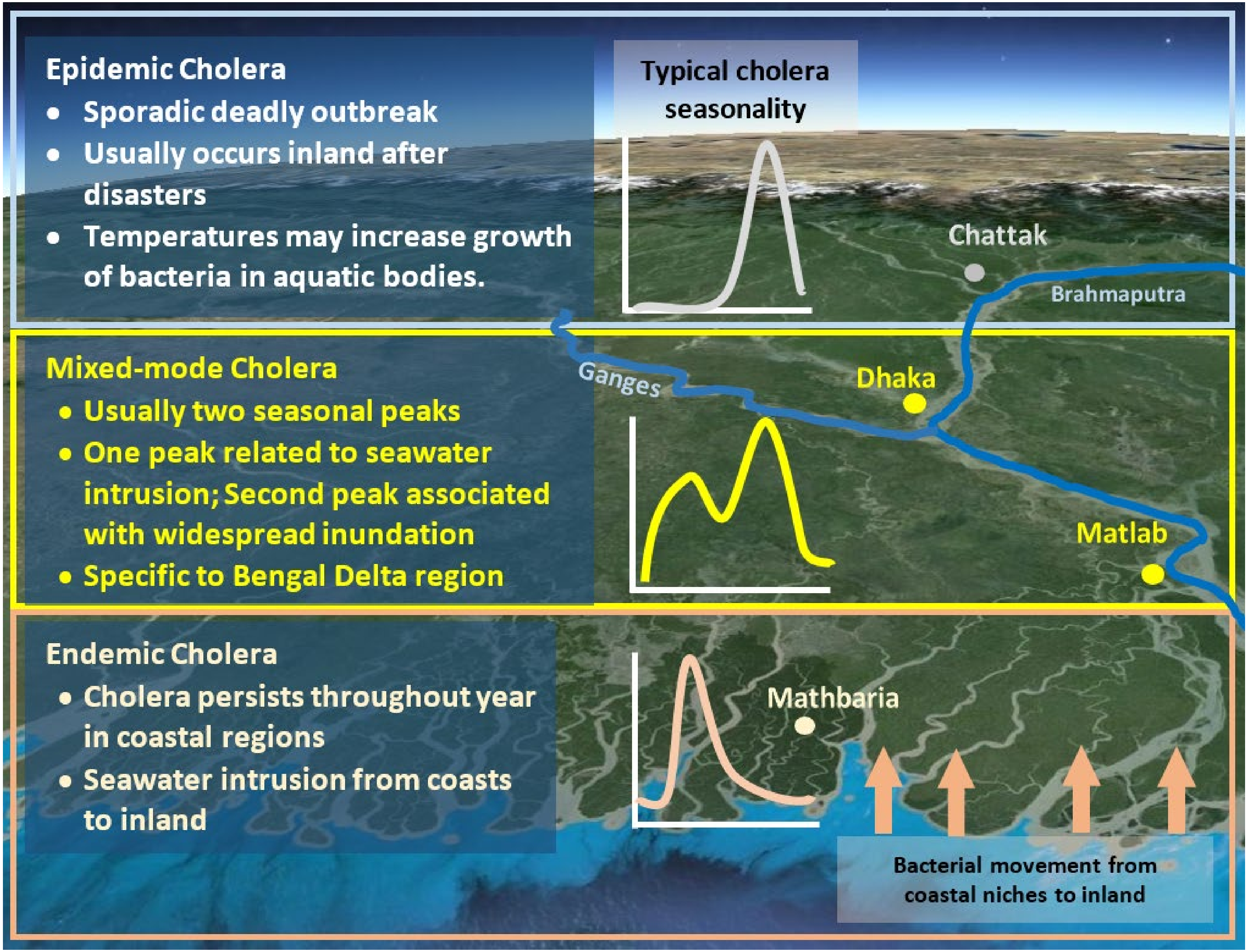

INDIA
BANGLADESH
I N D I A
BURMA
B A Y
O F
B E N G A L
Gulf of
Martaban
20N
85E
15N

Cholera and SST in the Indian Ocean 1985 - 2000

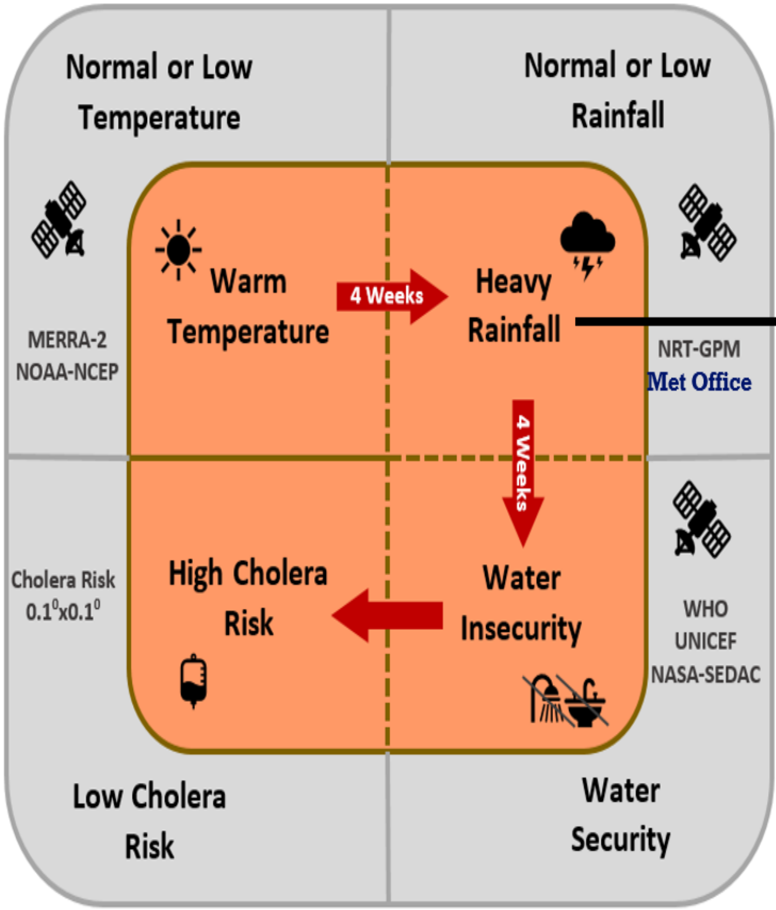
Six-month SST lead: R^2 = 0.72



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


Epidemic Cholera
• Sporadic deadly outbreak
• Usually occurs inland after disasters
• Temperatures may increase growth of bacteria in aquatic bodies.
Typical cholera seasonality
Chattak
Brahmaputra
Mixed-mode Cholera
• Usually two seasonal peaks
• One peak related to seawater intrusion; Second peak associated with widespread inundation
• Specific to Bengal Delta region
Ganges
Dhaka
Matlab
Endemic Cholera
• Cholera persists throughout year in coastal regions
• Seawater intrusion from coasts to inland
Mathbaria
Bacterial movement from coastal niches to inland

Epidemic Mode of Cholera



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%

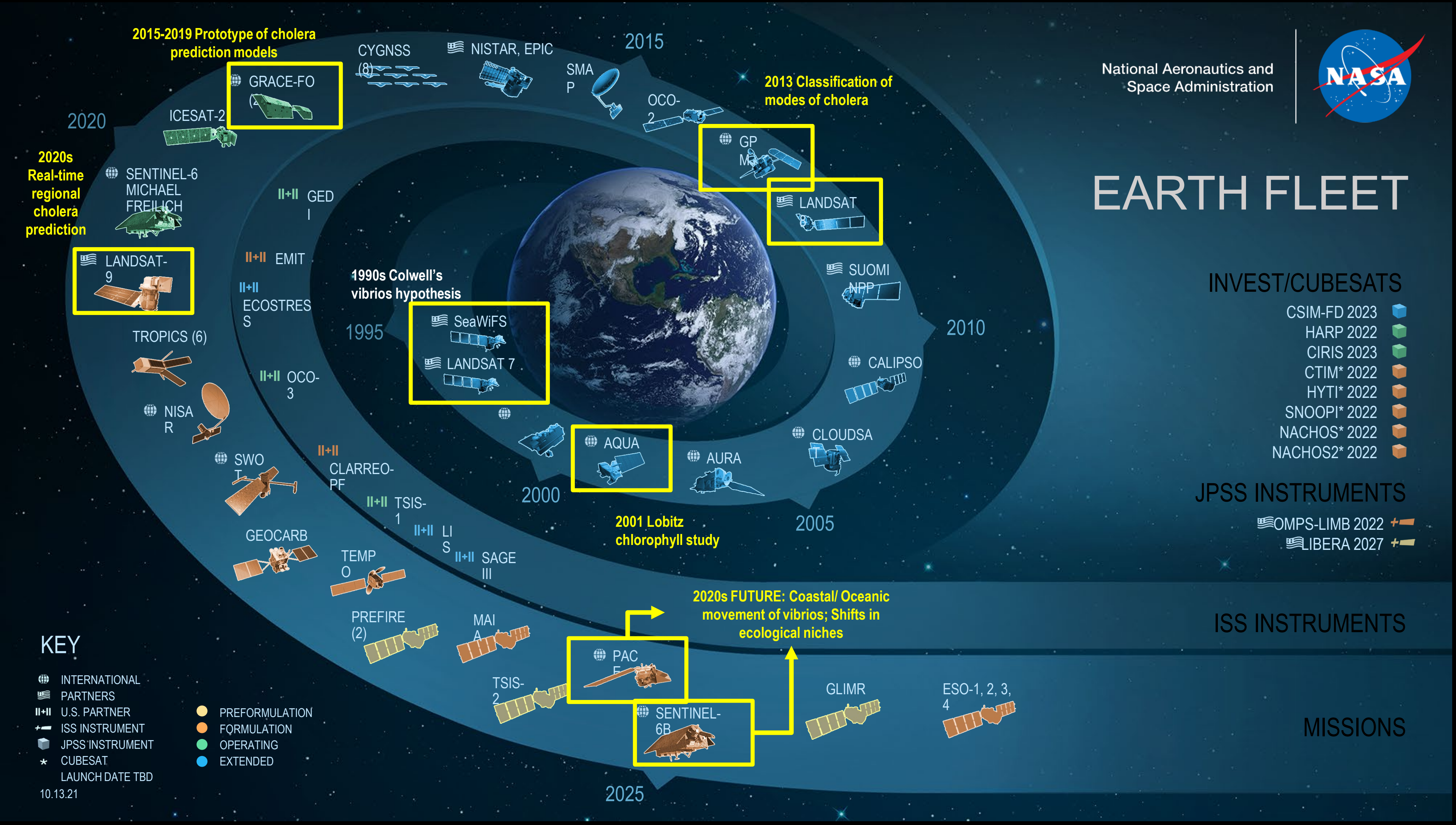
- Sporadic outbreak
- Usually occurs following floods or inundation of large landscapes
- Warm temperatures may increase growth of bacteria in aquatic bodies.

Accumulated rainfall above threshold

Challenge

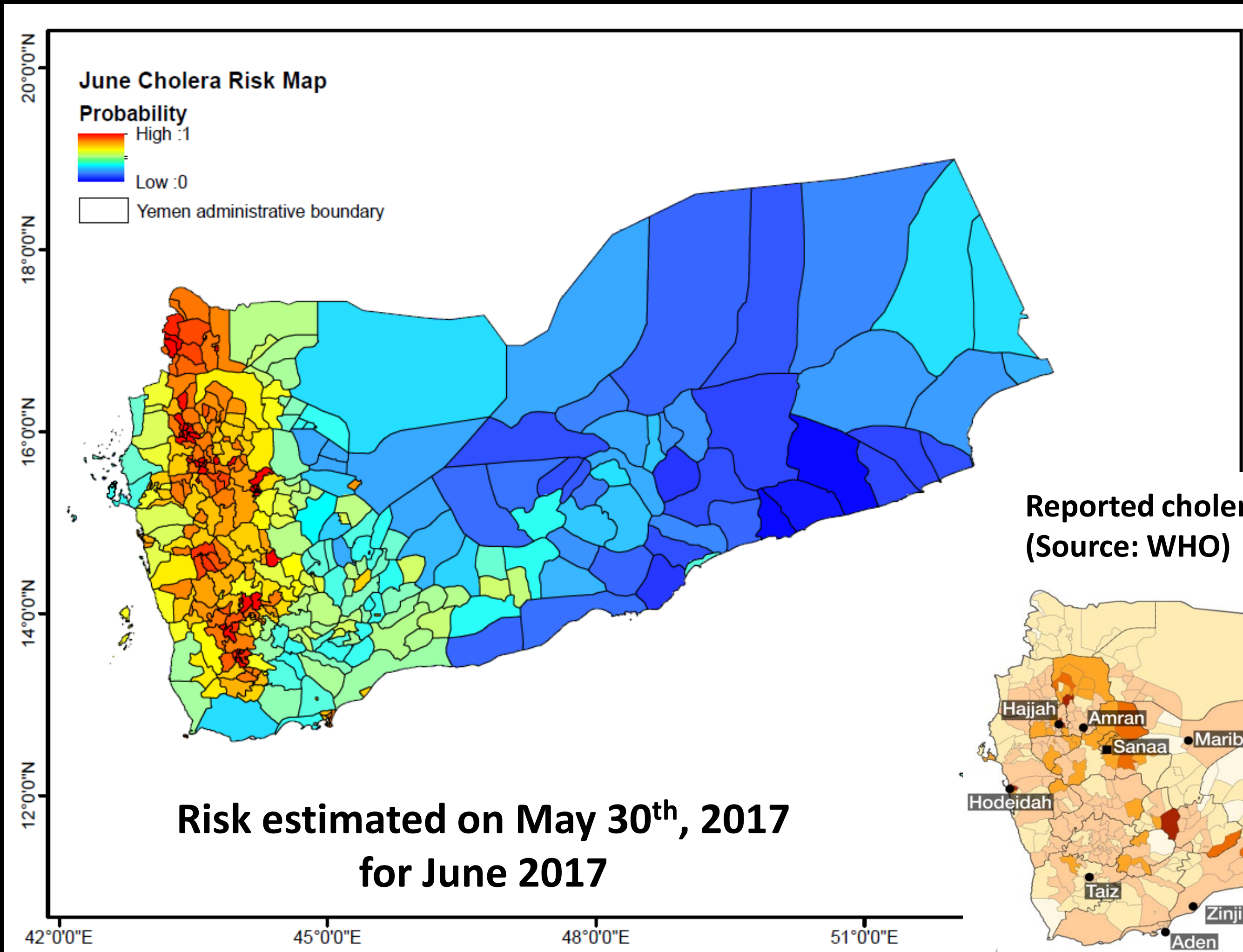
- Disease (prevalence) data
- Time invariant algorithm
- Search for self-adaptive algorithm

Jutla et al., 2017, ASCE JWRPM



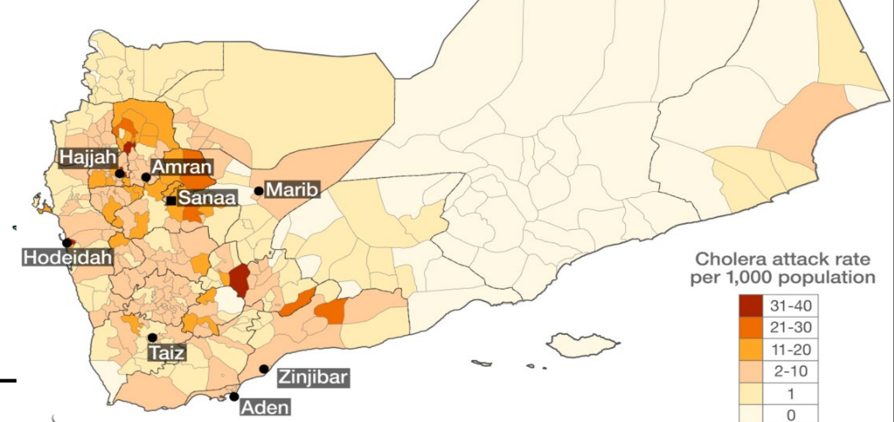
National Aeronautics and Space Administration
NASA
EARTH FLEET
2015-2019 Prototype of cholera prediction models
2013 Classification of modes of cholera
2020s Real-time regional cholera prediction
1990s Colwell's vibrios hypothesis
2001 Lobitz chlorophyll study
2020s FUTURE: Coastal/ Oceanic movement of vibrios; Shifts in ecological niches
1995
2000
2005
2010
2015
2020
2025
GRACE-FO
CYGNSS (8)
NISTAR, EPIC
SMAP
OCO-2
GPM
LANDSAT 8
SUOMI NPP
CALIPSO
CLOUDSAT
AURA
AQUA
SeaWiFS
LANDSAT 7
ICESAT-2
SENTINEL-6 MICHAEL FREILICH
LANDSAT-9
TROPICS (6)
NISAR
SWOT
GEOCARB
TEMPO
PREFIRE (2)
MAIA
TSIS-2
PACE
SENTINEL-6B
GLIMR
ESO-1, 2, 3, 4
GEDI
EMIT
ECOSTRESS
OCO-3
CLARREO-PF
TSIS-1
LIS
SAGE III
INVEST/CUBESATS
CSIM-FD 2023
HARP 2022
CIRIS 2023
CTIM* 2022
HYTI* 2022
SNOOPI* 2022
NACHOS* 2022
NACHOS2* 2022
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
ISS INSTRUMENTS
MISSIONS
KEY
INTERNATIONAL PARTNERS
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
PREFORMULATION
FORMULATION
OPERATING
EXTENDED
10.13.21

Real-time cholera prediction for Yemen

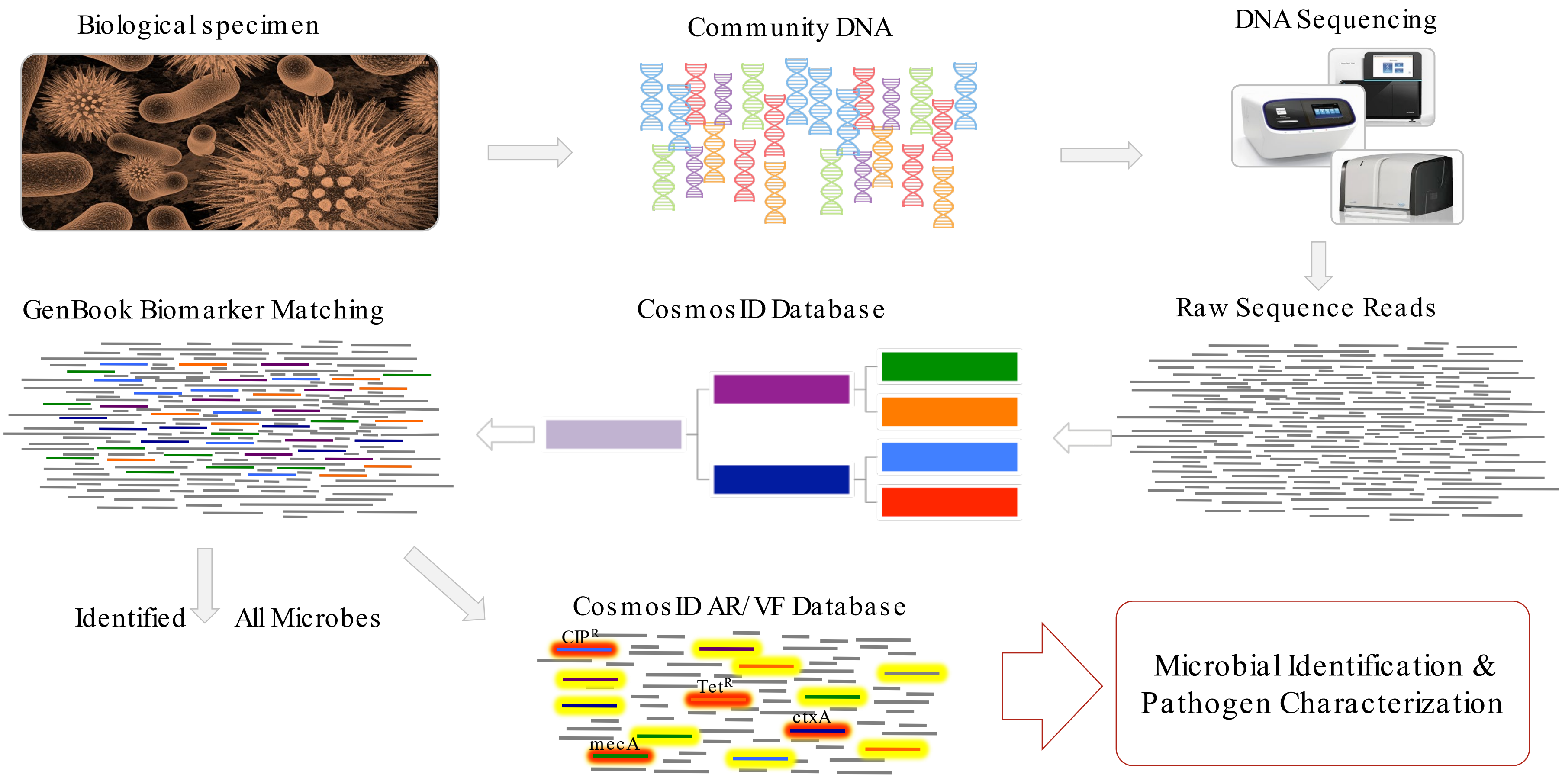


Risk estimated on May 30th, 2017 for June 2017

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



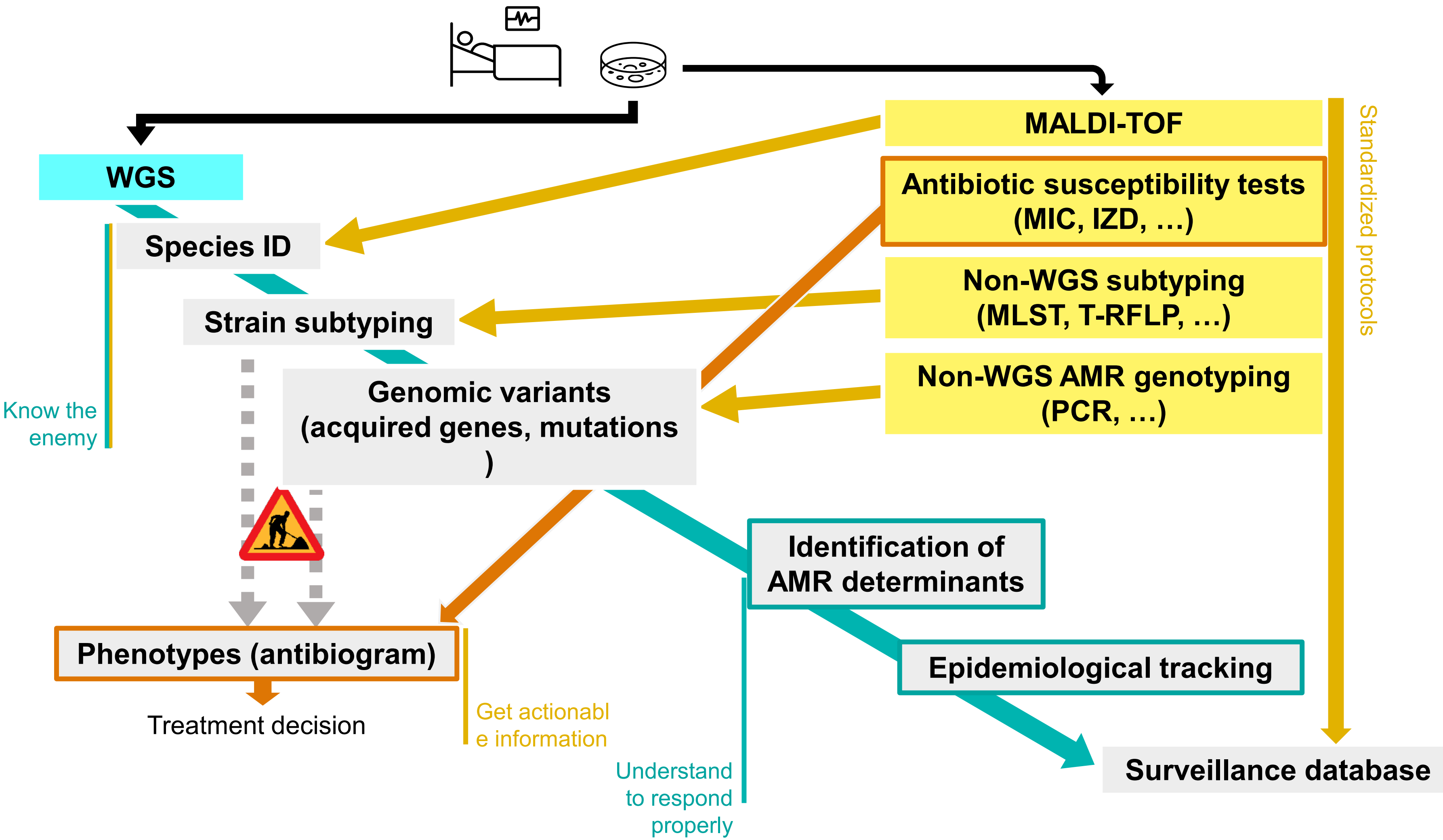
Shotgun whole (meta)genome sequencing



COSMOSID®
Unlocking The Microbiome

UNIVERSITY OF MARYLAND

What WGS provides



Microbiome Analysis of Acute Diarrheal Patients Compared with Healthy Individuals

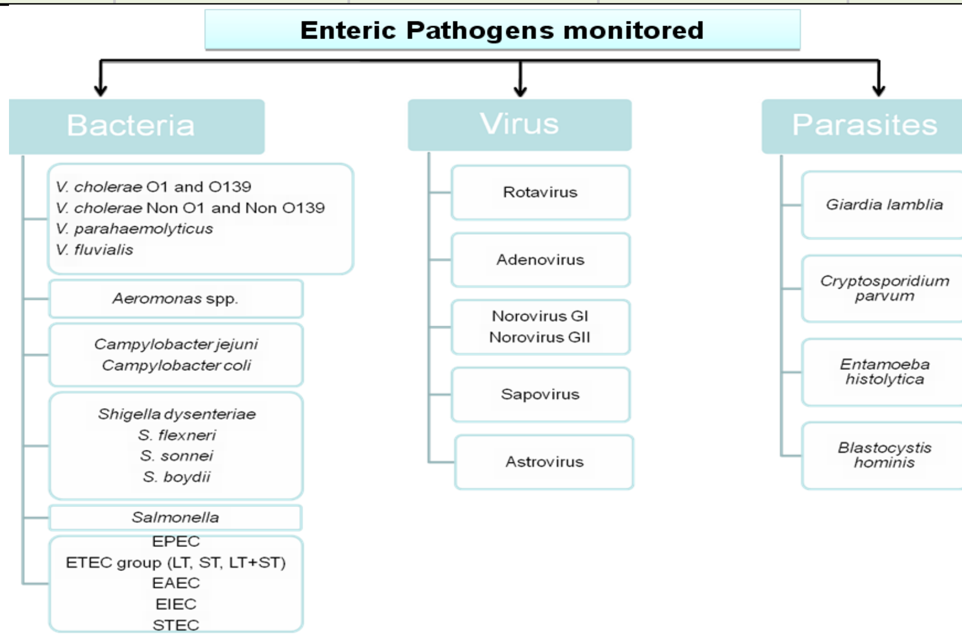
pre-publication results

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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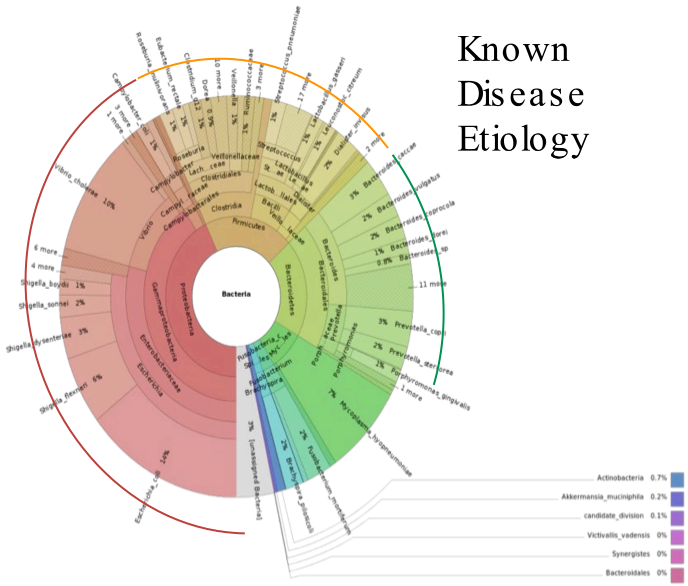
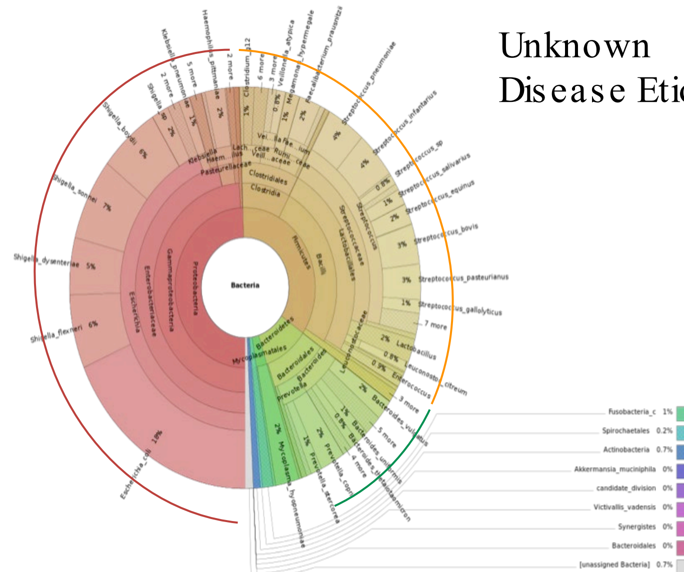
Microbial Community in Healthy vs Diarrheal Patients

DIARRHEAL PATIENTS

Known Disease Etiology



Unknown Disease Etiology



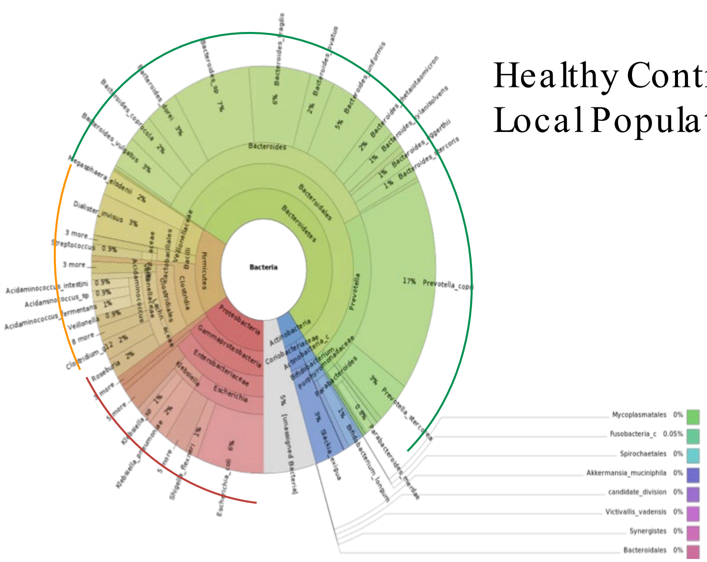
γ-Proteobacteria

Firmicutes

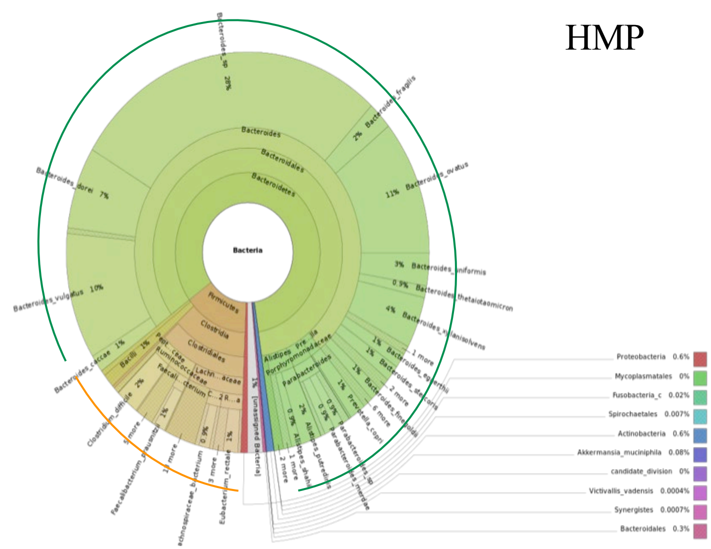
Bacteroidetes

HEALTHY INDIVIDUALS

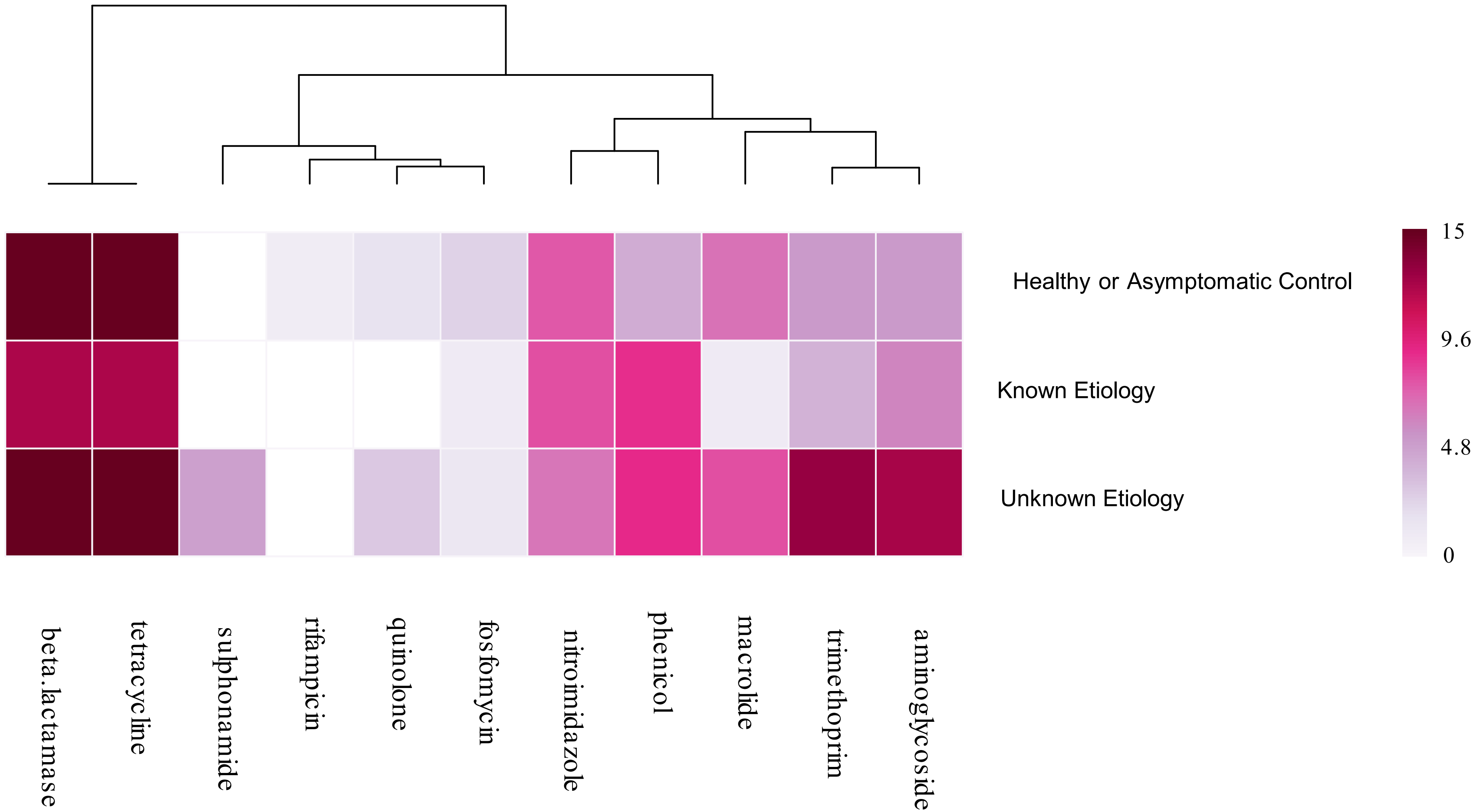
Healthy Control Local Population



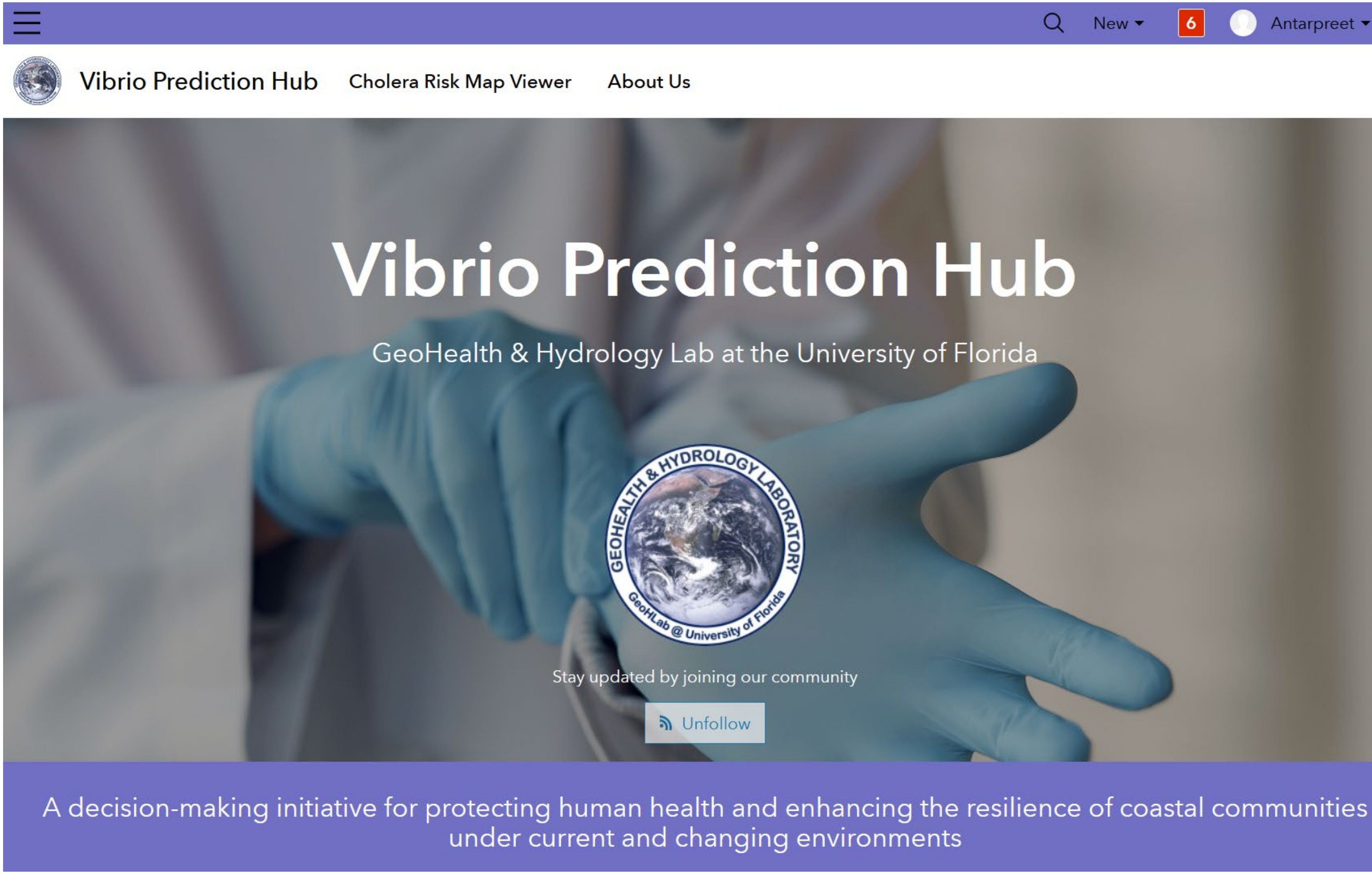
HMP



Antimicrobial resistance prevalent in Indian population



- Genes which match at > 50% coverage
- HMP samples had no genes present which matched at this level of coverage



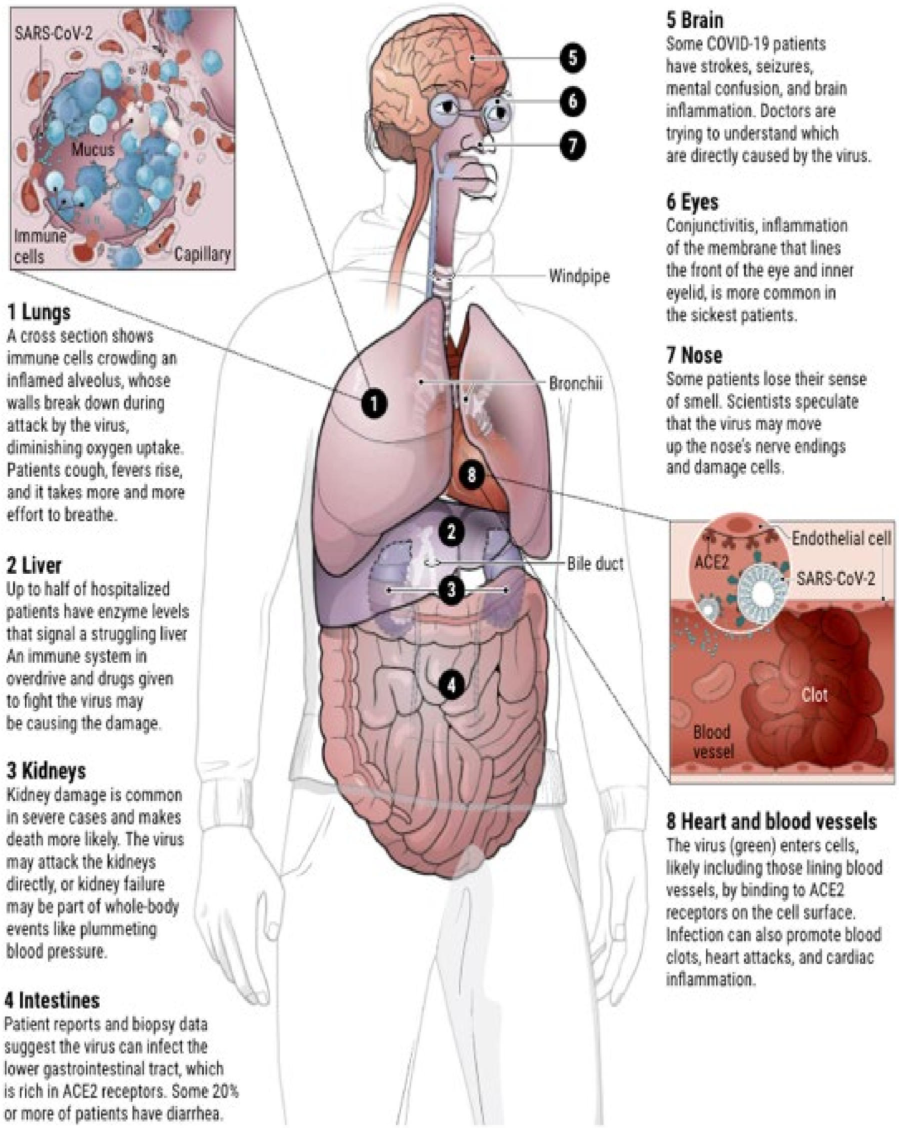
https://vibrio-prediction-ufl.hub.arcgis.com/

Is COVID-19 polymicrobial and systemic?

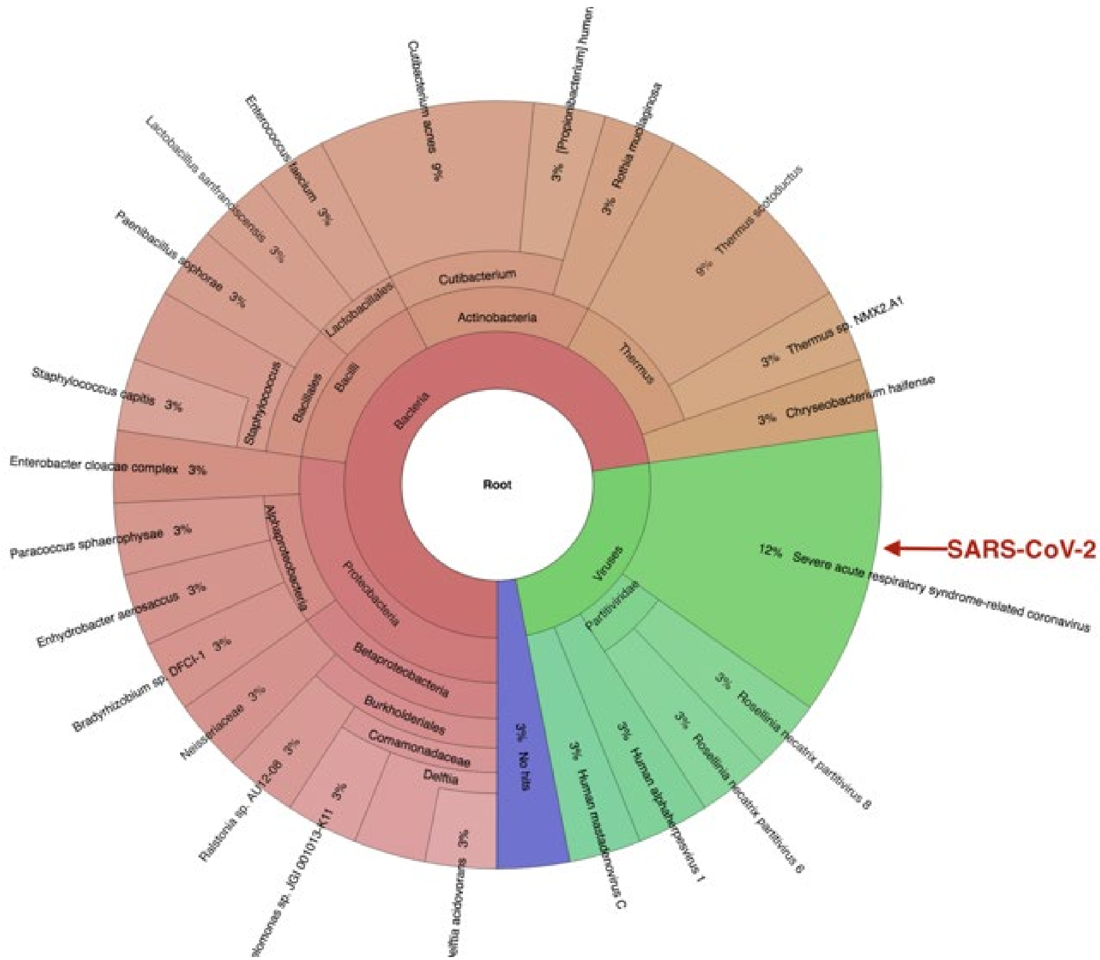
How does coronavirus kill? Clinicians trace a ferocious rampage through the body, from brain to toes

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

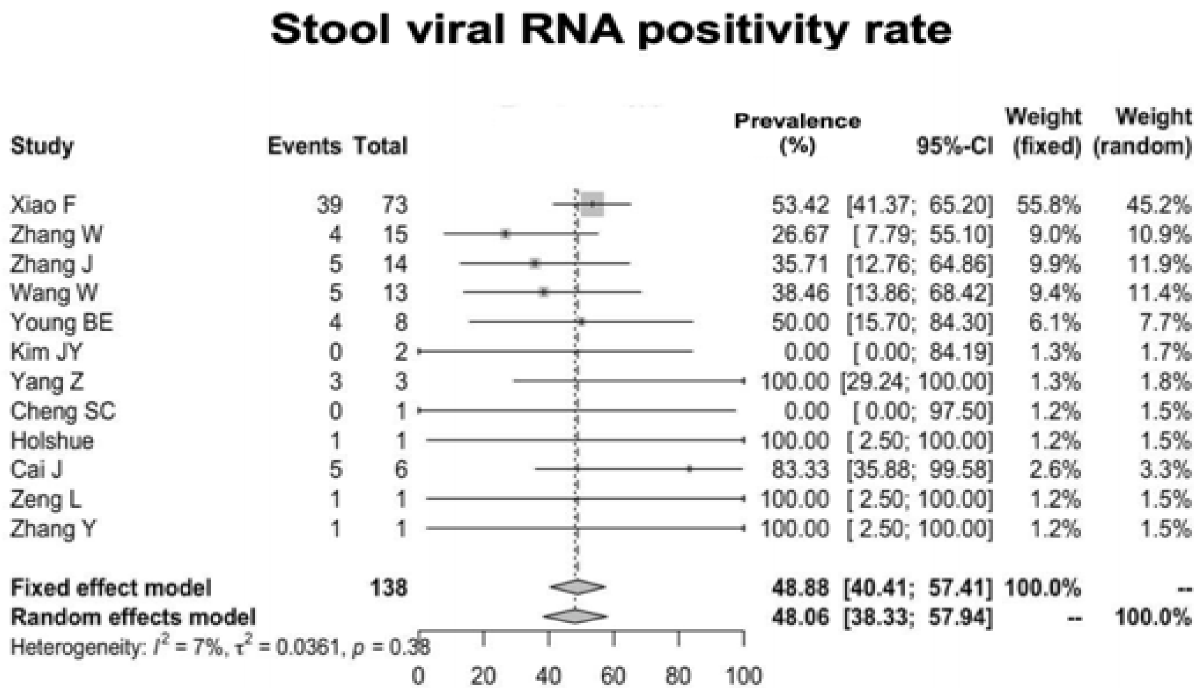
https://www.sciencemag.org/news/2020/04/how-does-coronavirus-kill-clinicians-trace-ferocious-rampage-through-body-brain-toes



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



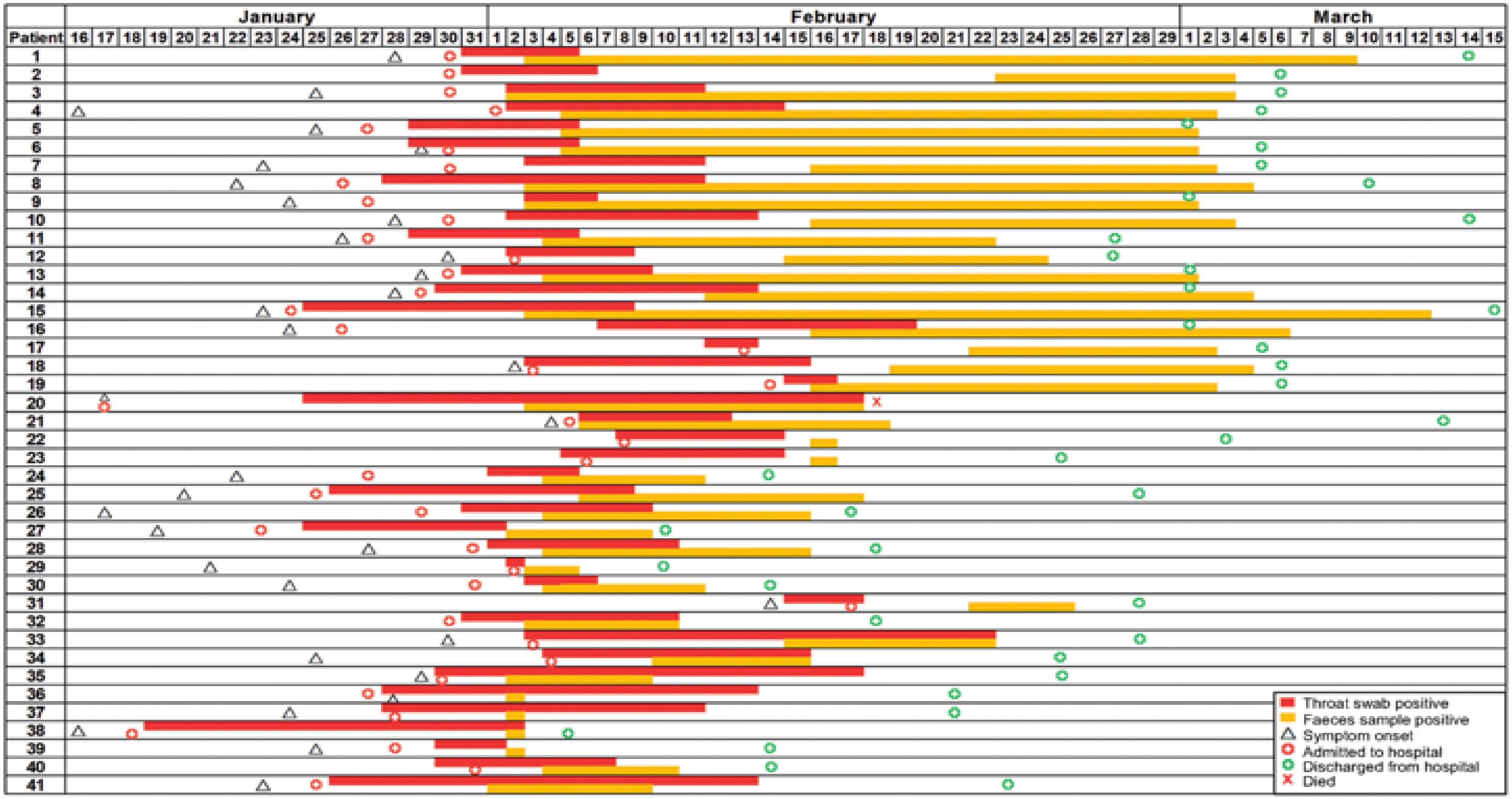
SARS Cov-2 viral RNA has been detected in 48.1% of stool samples



Gastroenterology

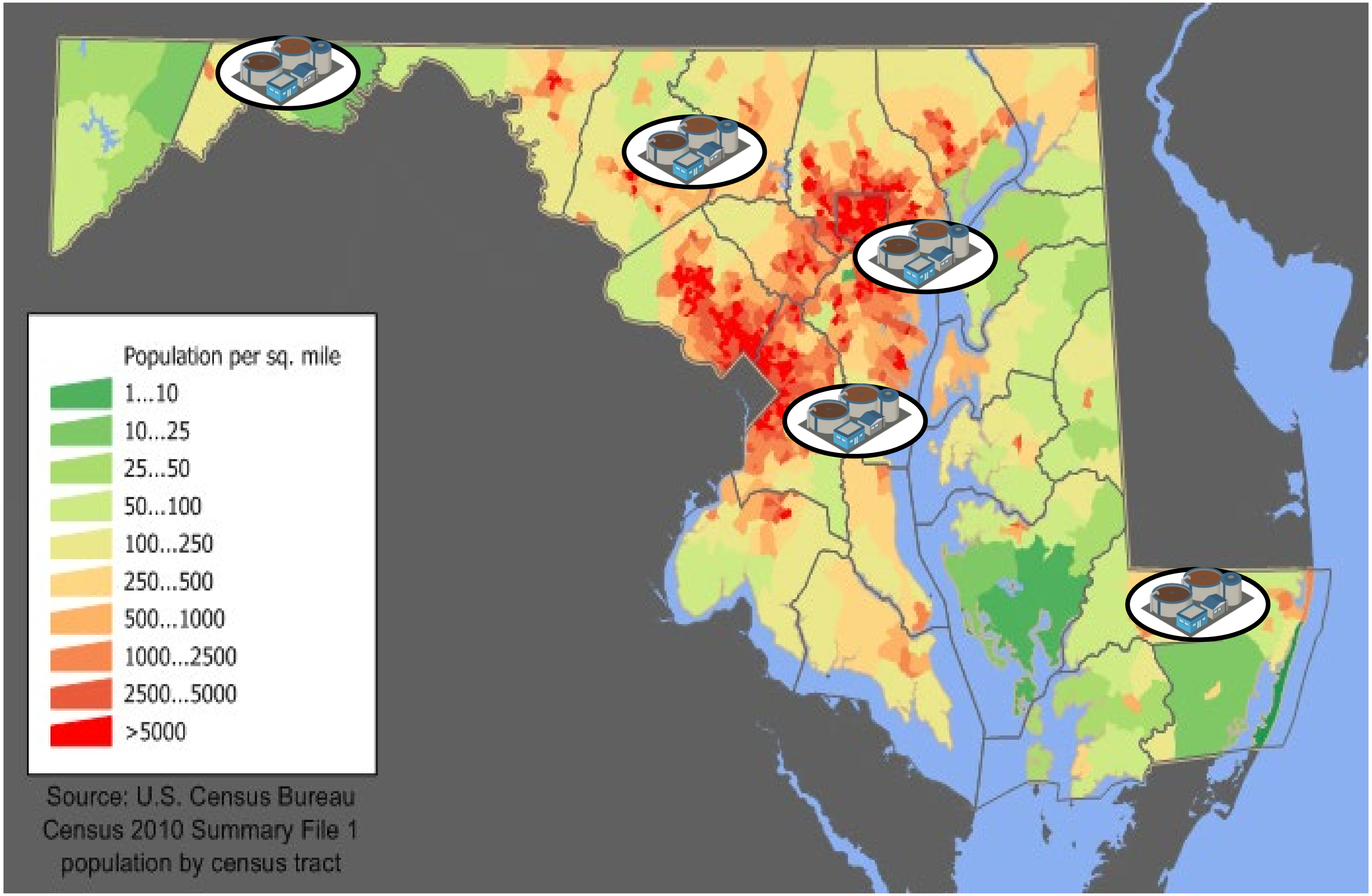
Cheung et al., (2020). Gastrointestinal Manifestations of SARS-CoV-2 Infection and Virus Load in Fecal Samples from the Hong Kong Cohort and Systematic Review and Meta-analysis. Gastroenterology. Pre-Proof

Positive Stool Samples Detected After Respiratory Sample Tested Negative During Recovery

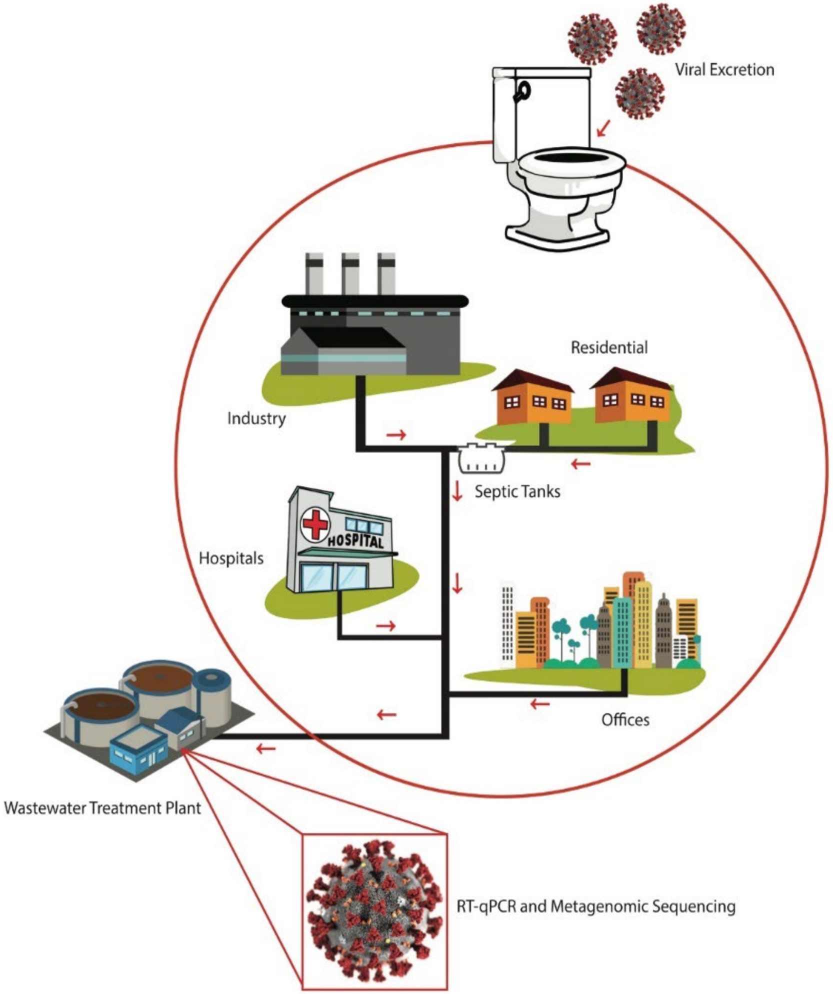


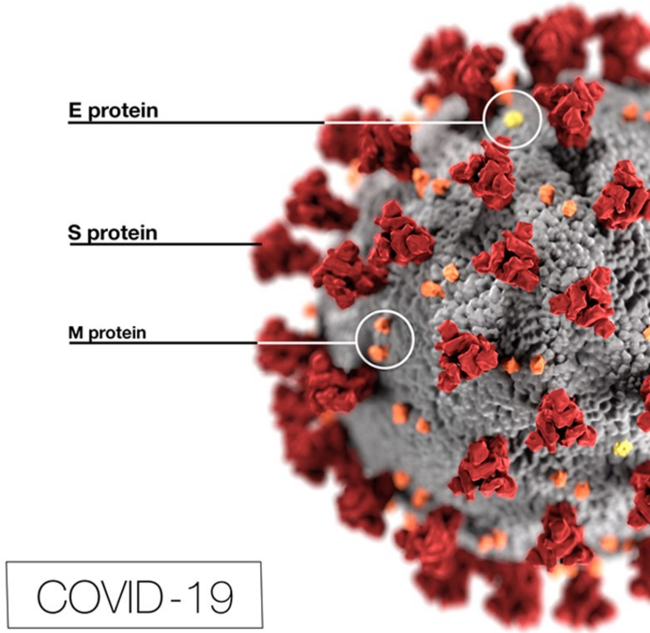
Wu Y, Guo C, Tang L, et al. Prolonged presence of SARS-CoV-2 viral RNA in faecal samples. 2020 The lancet Gastroenterology – hepatology. Volume 5, Issue 5, 434 - 435

COVID-19 tracking in wastewater in Maryland, USA, 2020-2022

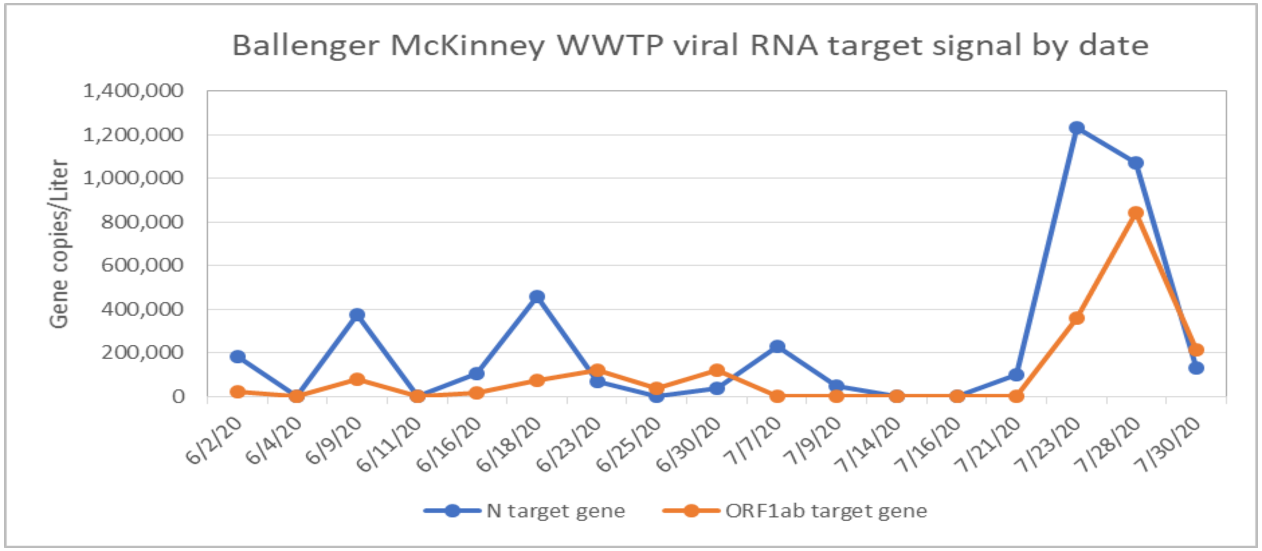


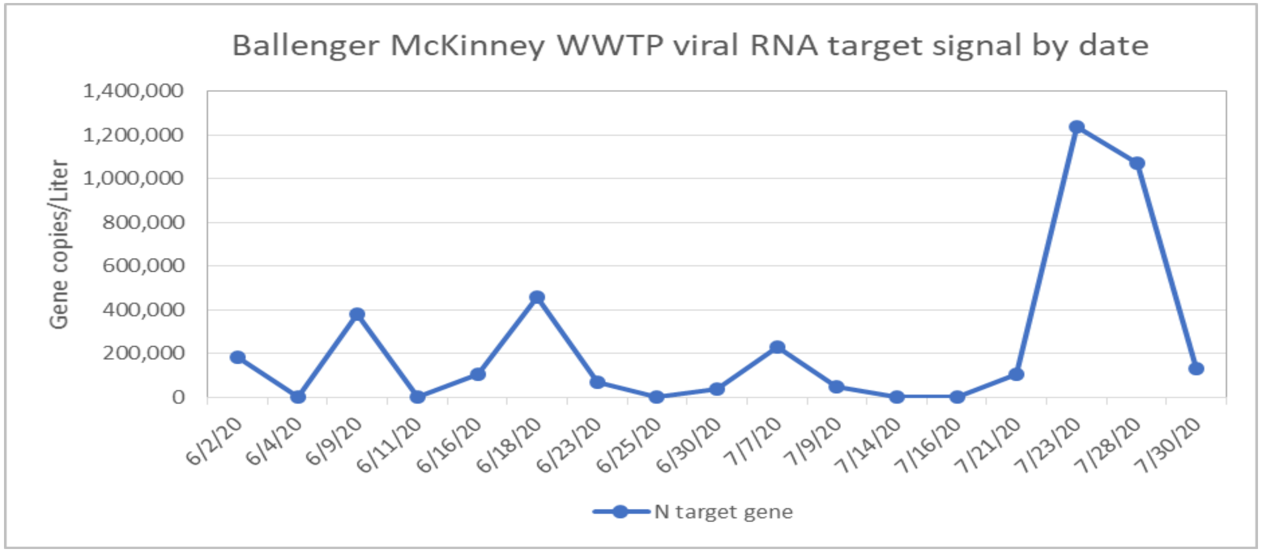
Wastewater surveillance





Results from Frederick, Maryland sites, 2020





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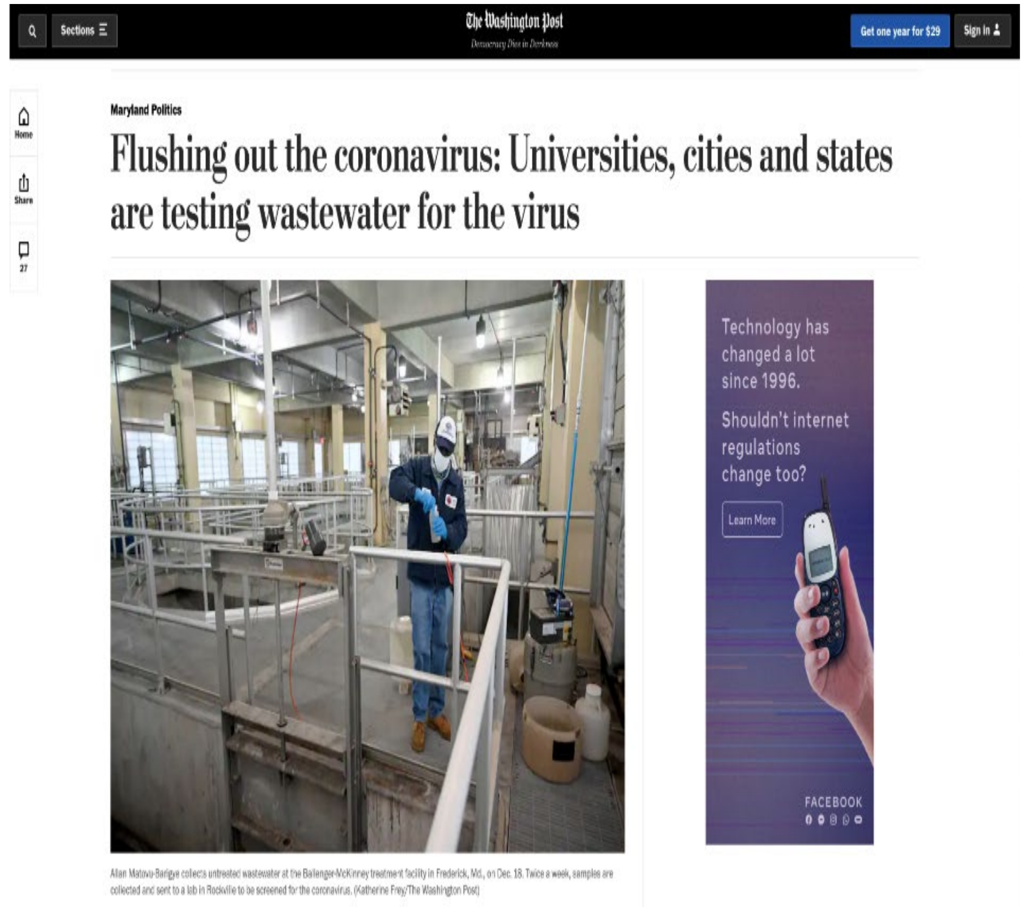
JOHNS HOPKINS UNIVERSITY
UNIVERSITY OF MARYLAND 1856

Case Study: Mount St. Mary's University

- Twice weekly sampling of dormitory effluent
- Covid spike triggered testing of individual students
- 221 students tested
    - 10 positive
    - 9 asymptomatic
- "It could have become quite a spreading event," said Donna Klinger, a spokeswoman for the university
- Coronavirus positive students isolated and wastewater tests done twice weekly

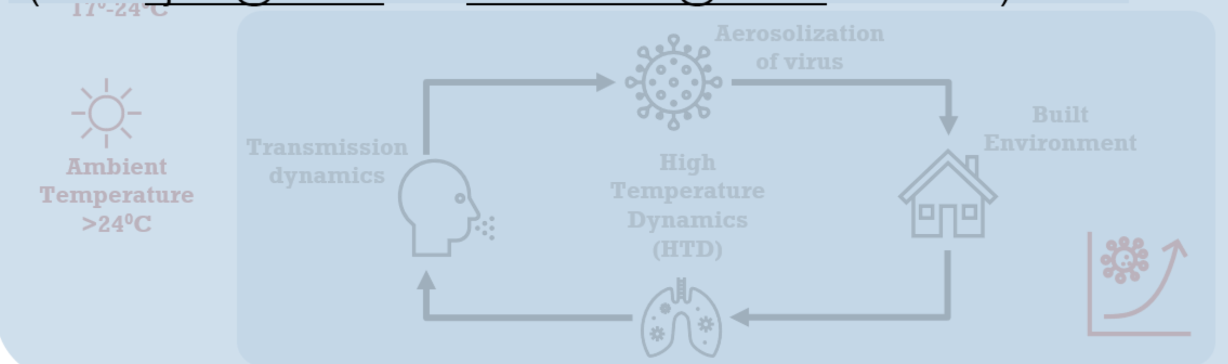


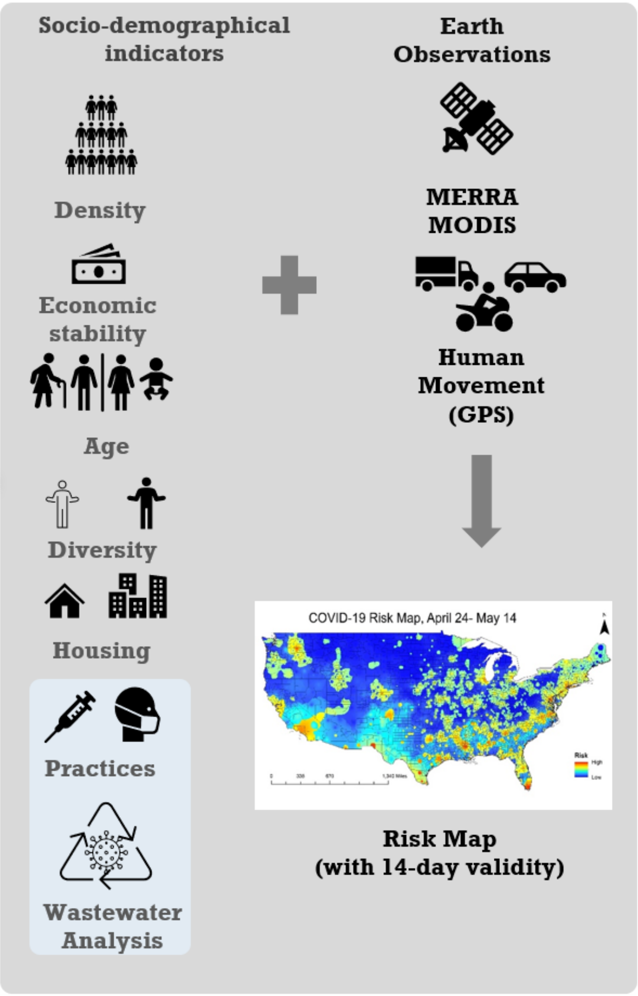
SARS-CoV-2 (COVID-19)

Development of prediction algorithm

In-house cholera prediction algorithm was modified for COVID-19
Algorithm is based on geographically weighted raster probabilistic dose-response assimilation technique

(Email ajutla@ufl.edu and moiz.usmani@ufl.edu for details)

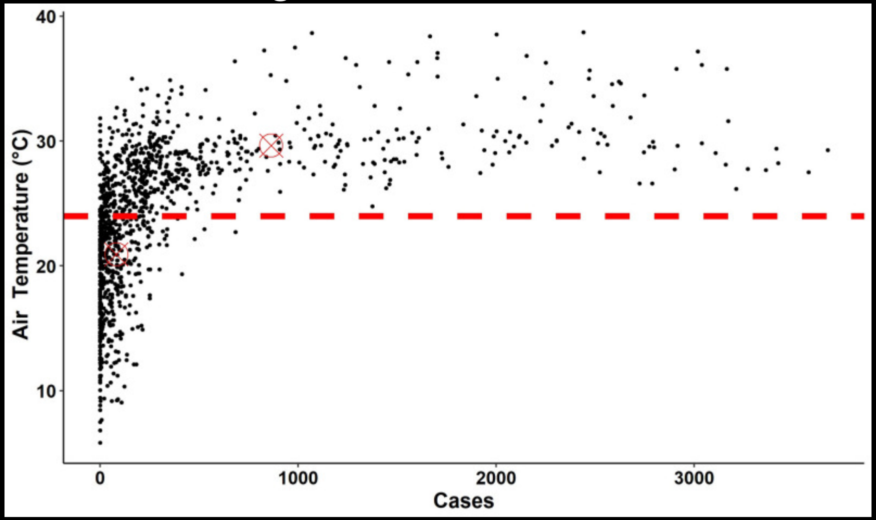




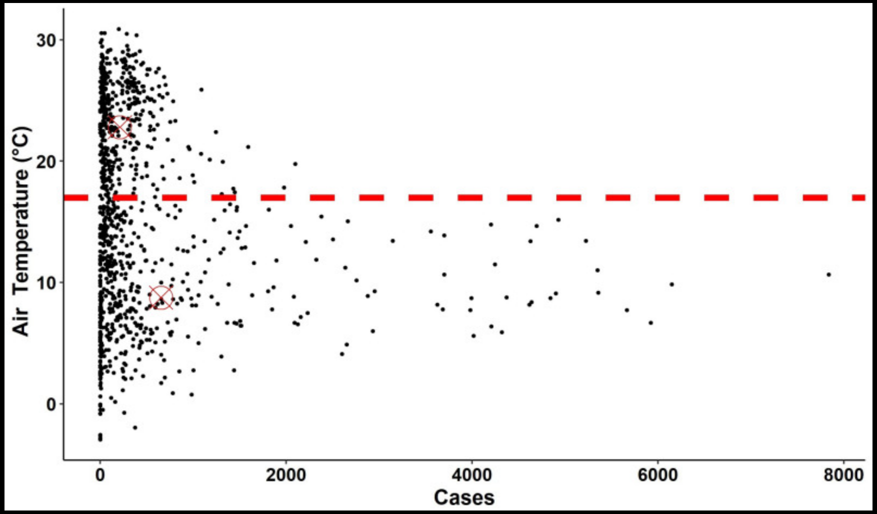
https://covid-ufl.hub.arcgis.com/apps/covid-19-risk-map/explore

Clustering of disease prevalence vs ambient air temperature

Warm regions

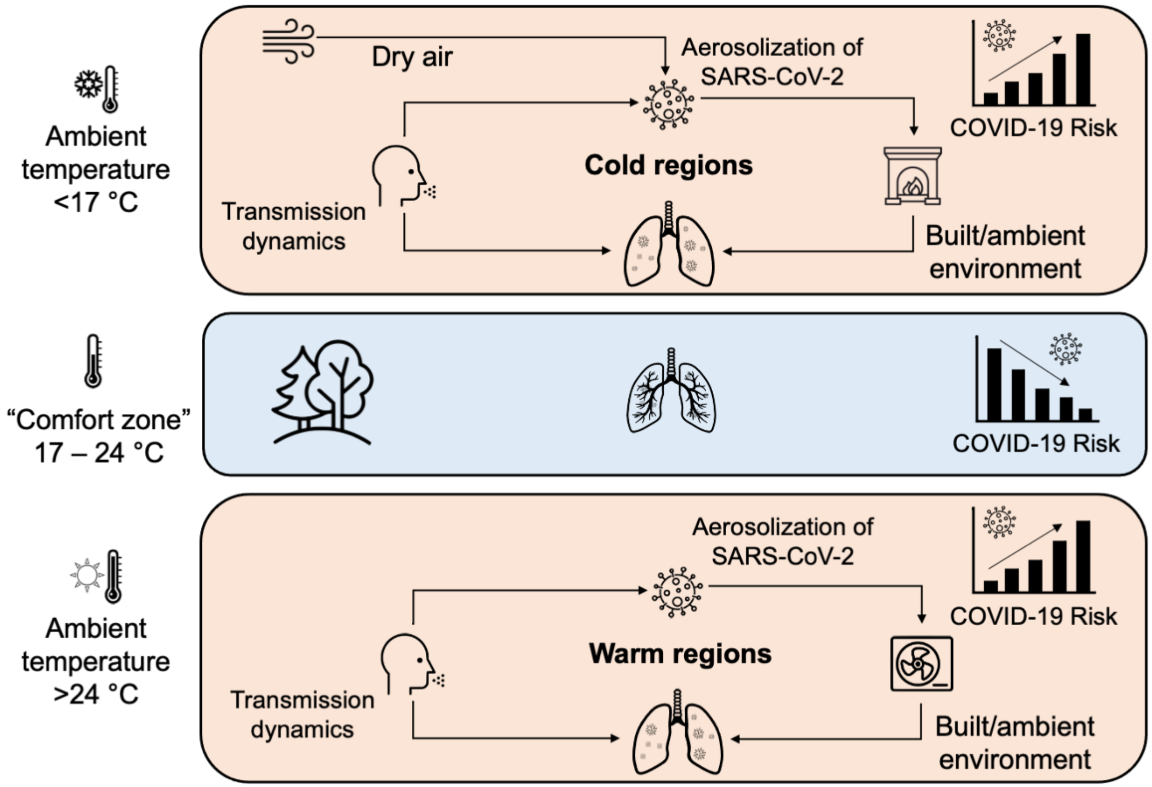


Cold regions



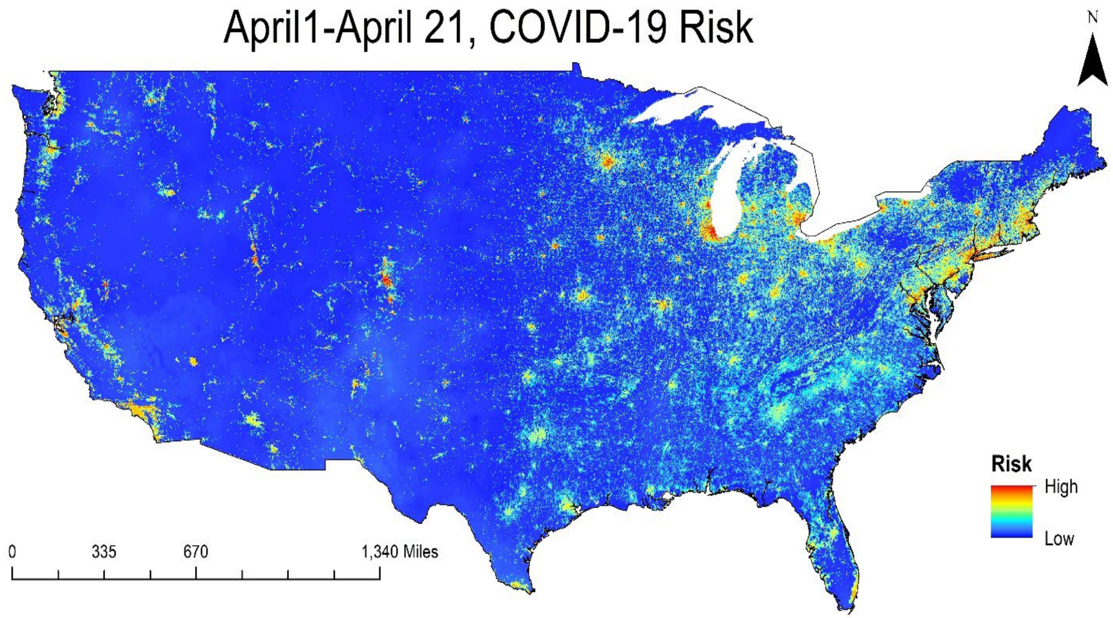
Usmani et al. 2022, AM J Trop Med Hyg

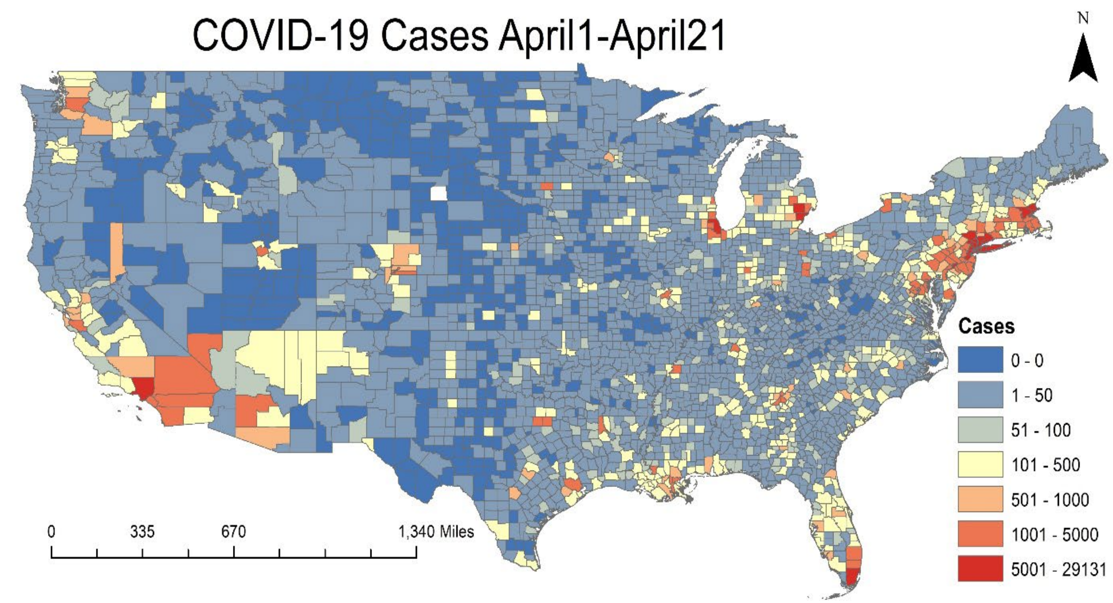
Hypothesis for environmental COVID-19 risk prediction



Usmani et al. 2022, AM J Trop Med Hyg

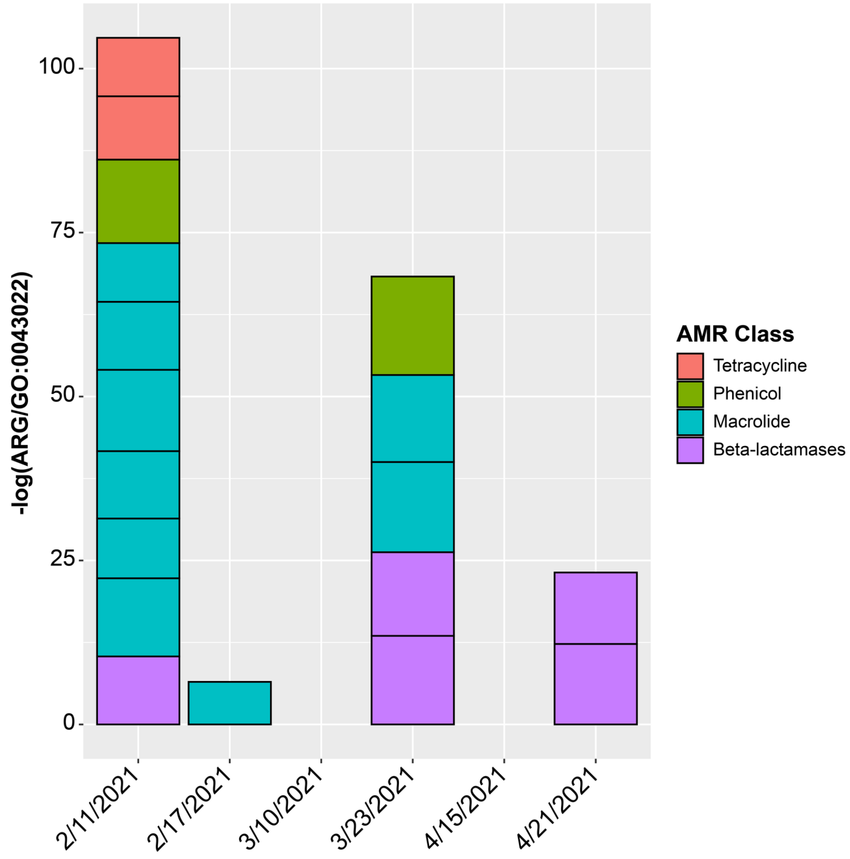
Environmental COVID-19 risk prediction





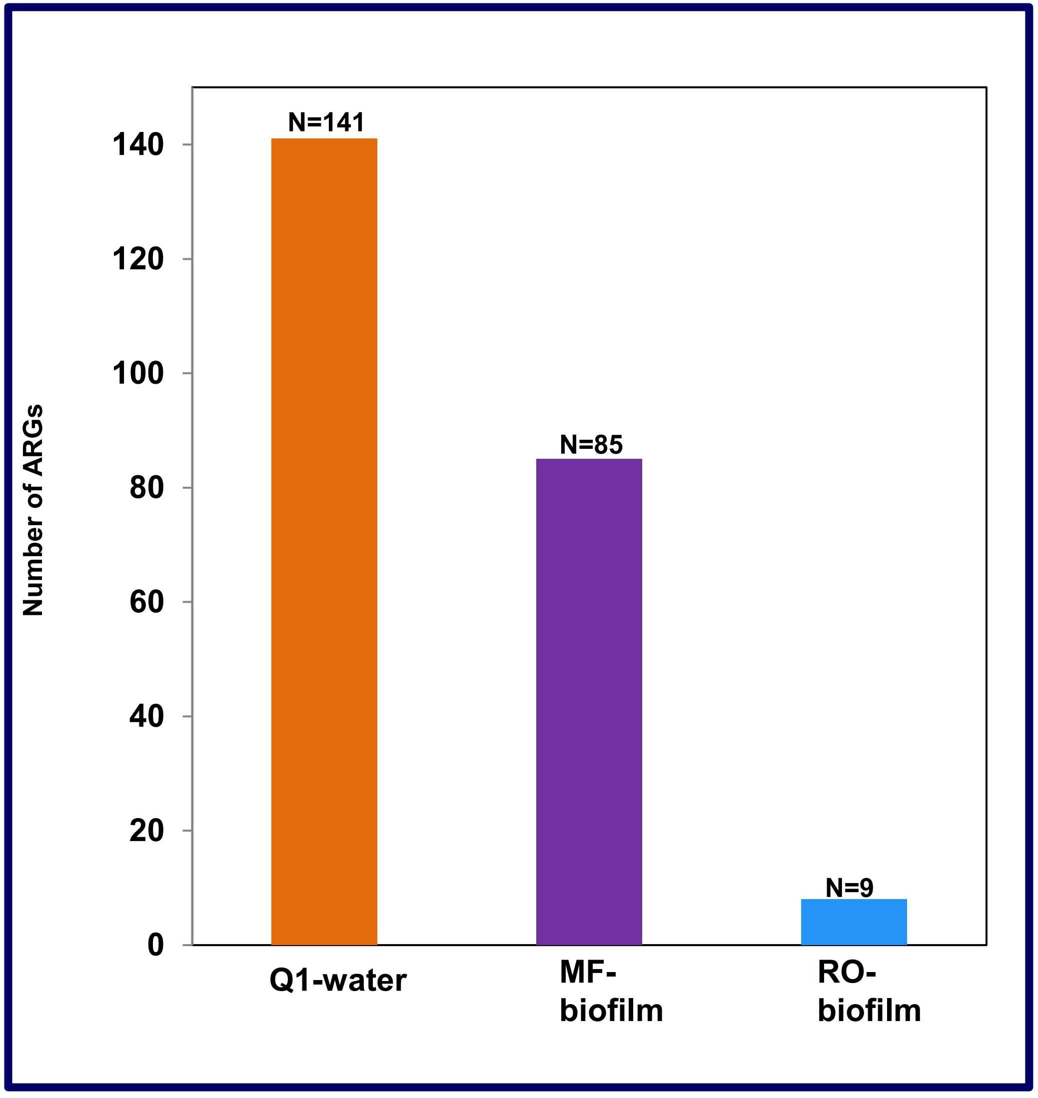
Usmani, Brumfield,
Jutla, & Colwell; *in preparation*

Expression of AMR in wastewater (RNA-seq)

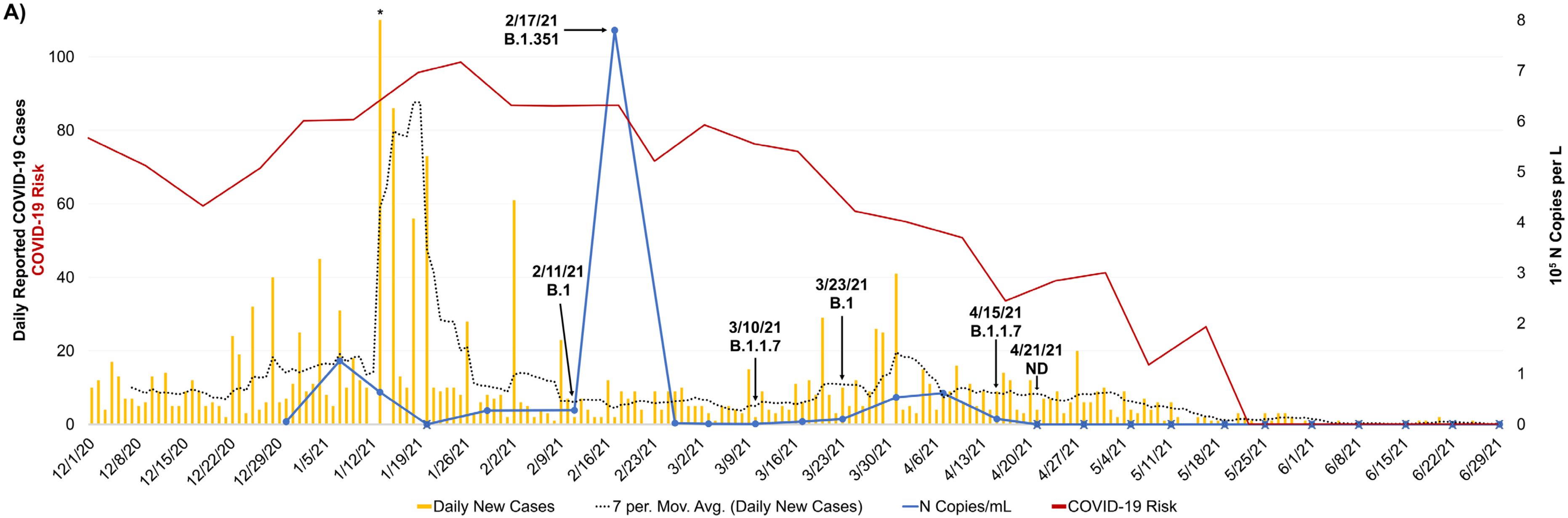


Brumfield et al. 2022, mBio Vol. 13, No. 4, Microbiome Analysis for Wastewater Surveillance during COVID-19

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

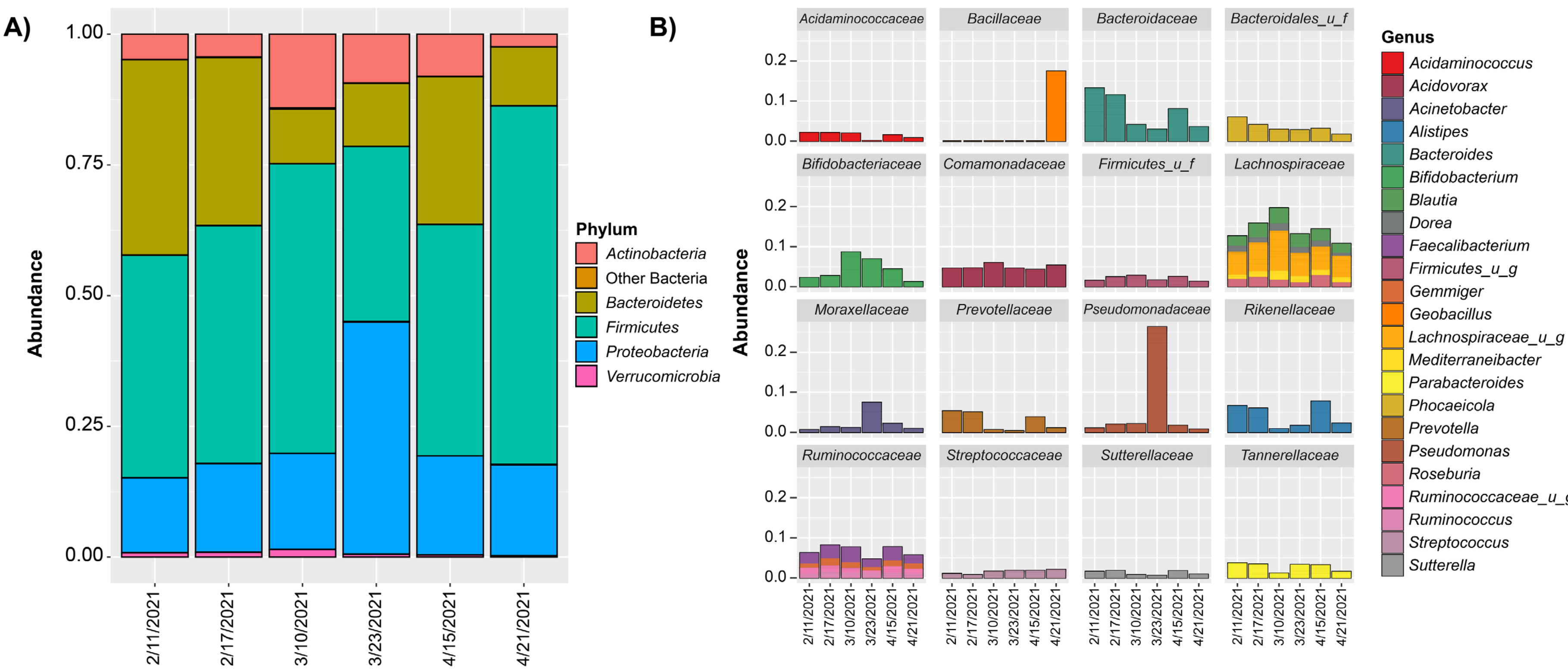


Detection of SARS-CoV-2 in wastewater and predicted risk



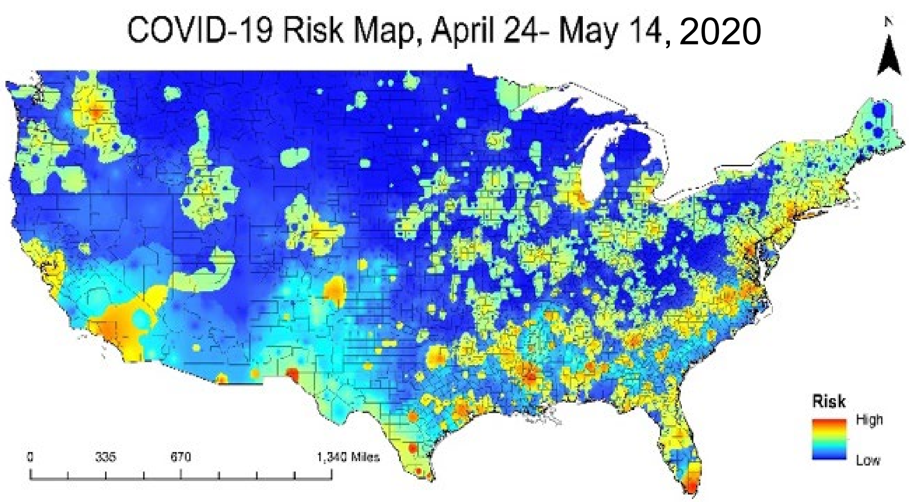
Brumfield et al. 2022, under review

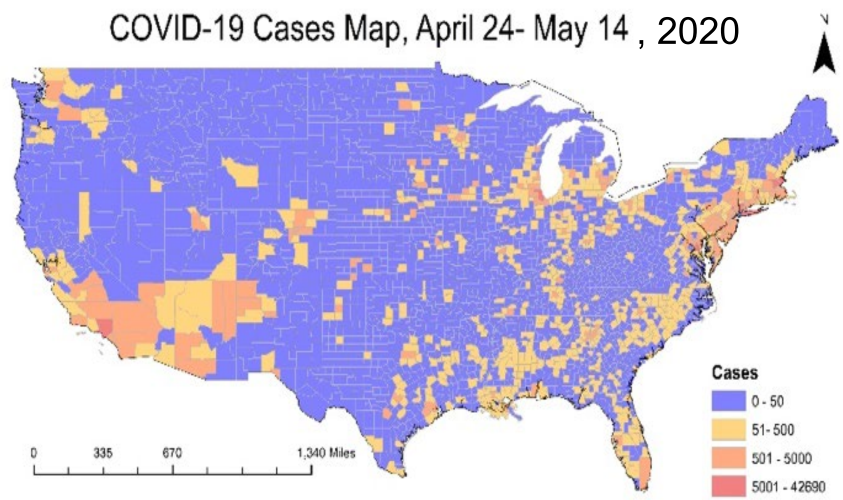
Microbiome profiles of wastewater (DNA metagenomics)



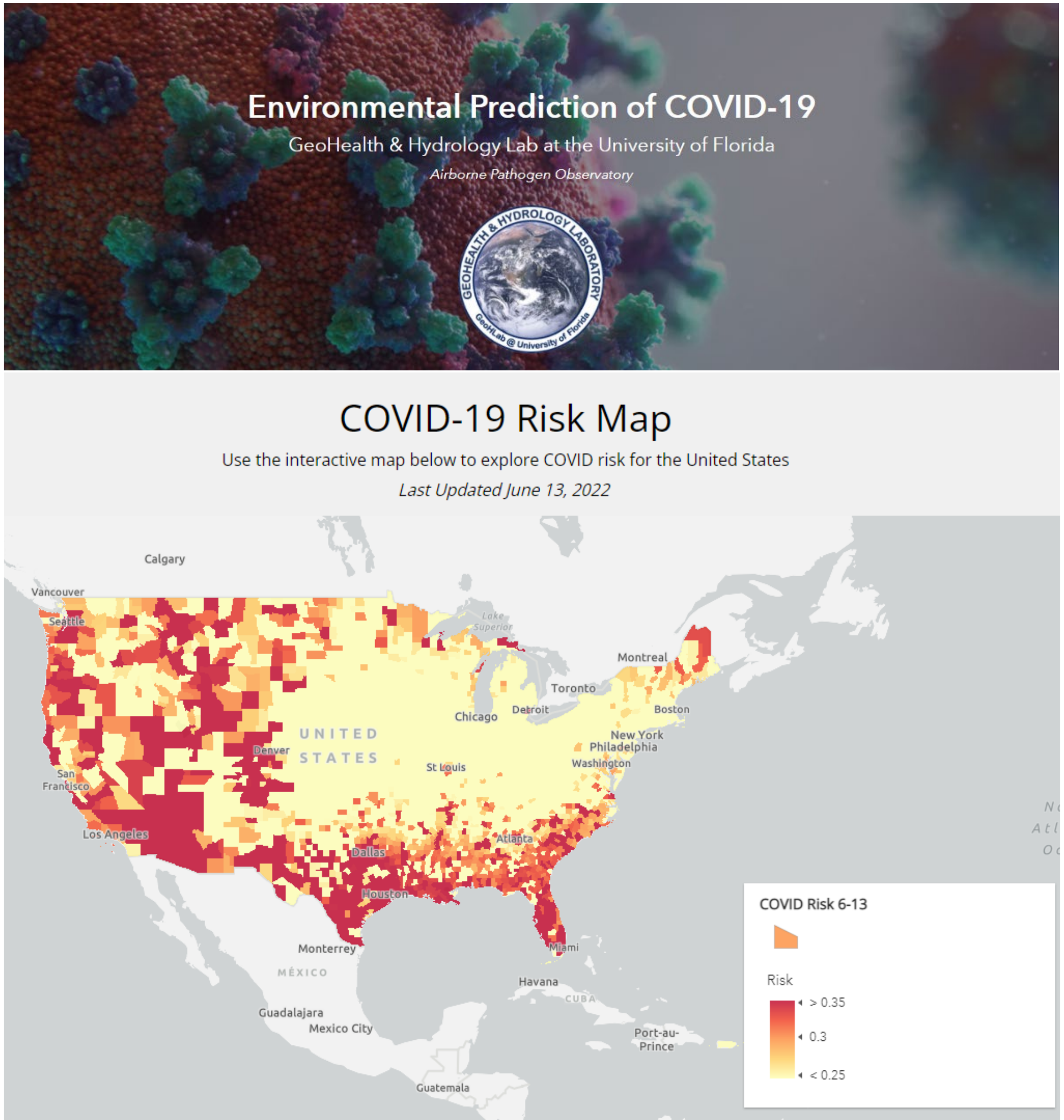
Brumfield et al. 2022, under review

Prediction of coronavirus risk



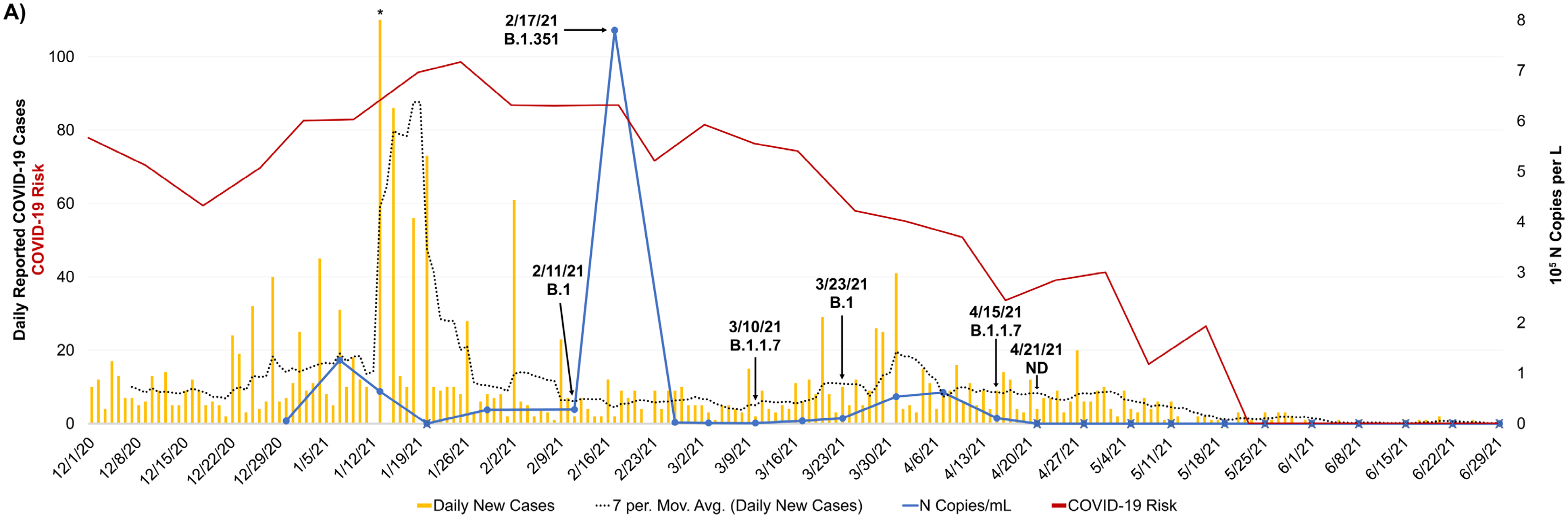


Left panel: **Prediction** made on April 24th 2020 and valid until May 14th, 2020. Right panel: **Actual number** of COVID19 cases during those three weeks: a heuristic prediction model developed in GeoHLab

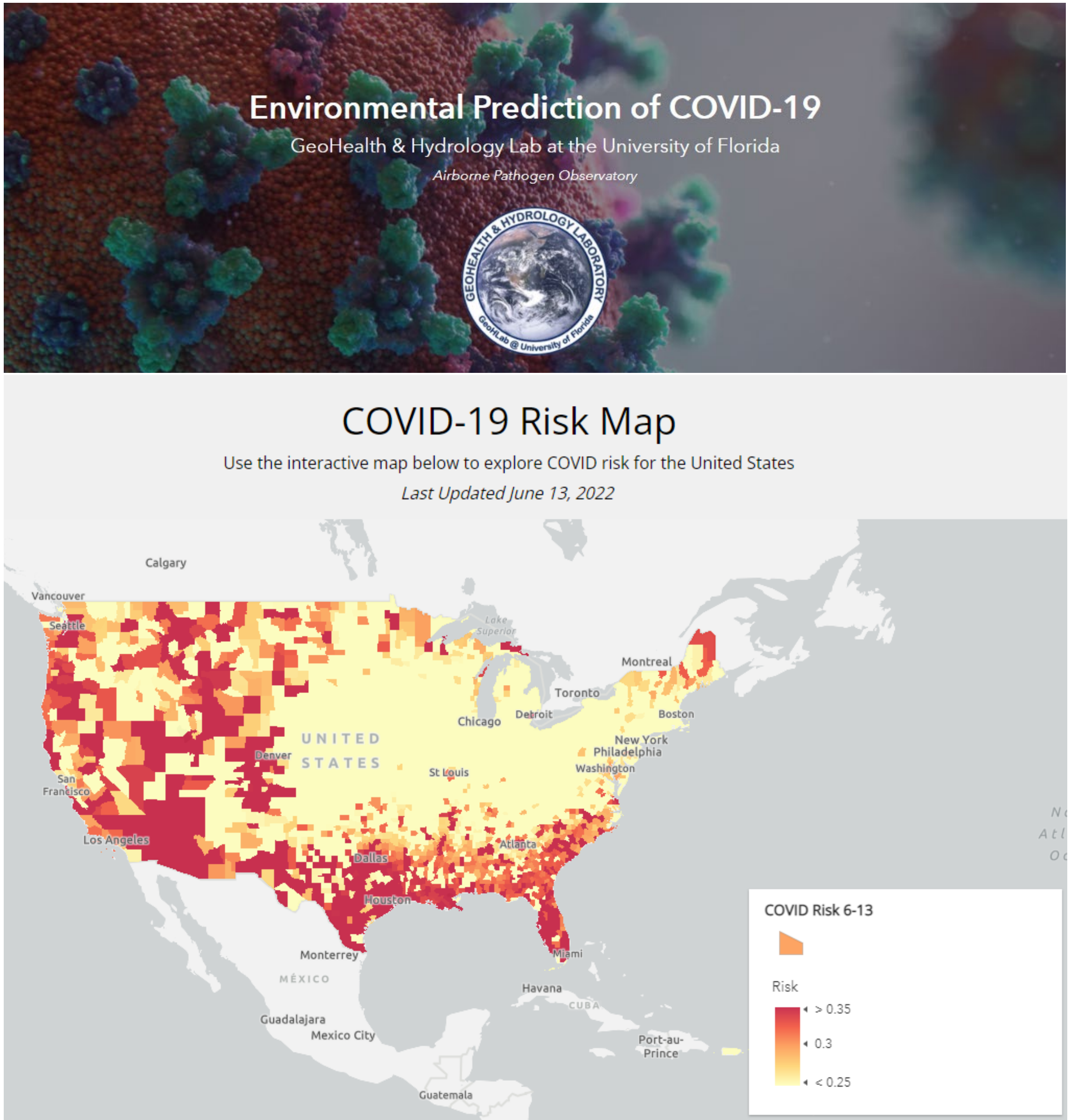


https://covid-ufl.hub.arcgis.com/

Detection of SARS-CoV-2 in wastewater and predicted risk



Brumfield et al. 2022, under review



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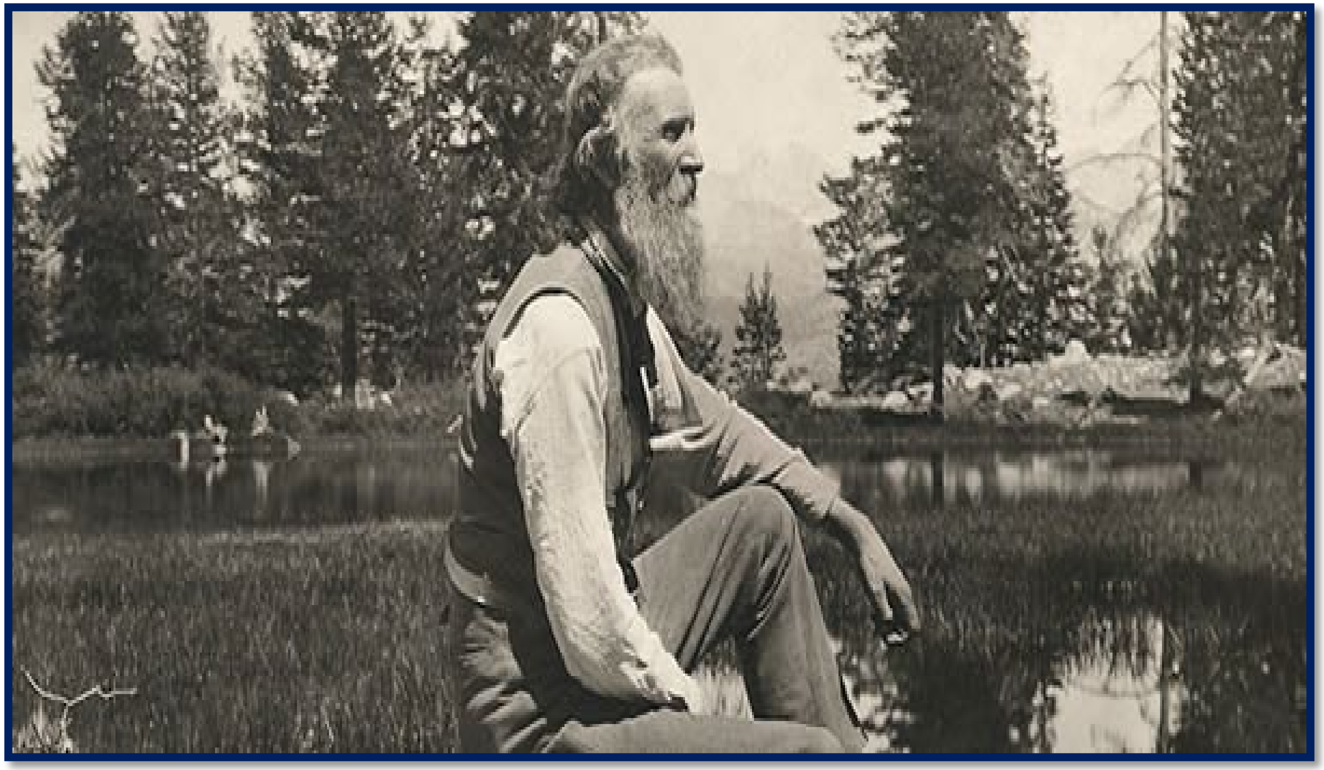

“When one tugs at a single thing in nature, he (and she) find it hitched to the rest of the universe.”

John Muir
(1838-1914)

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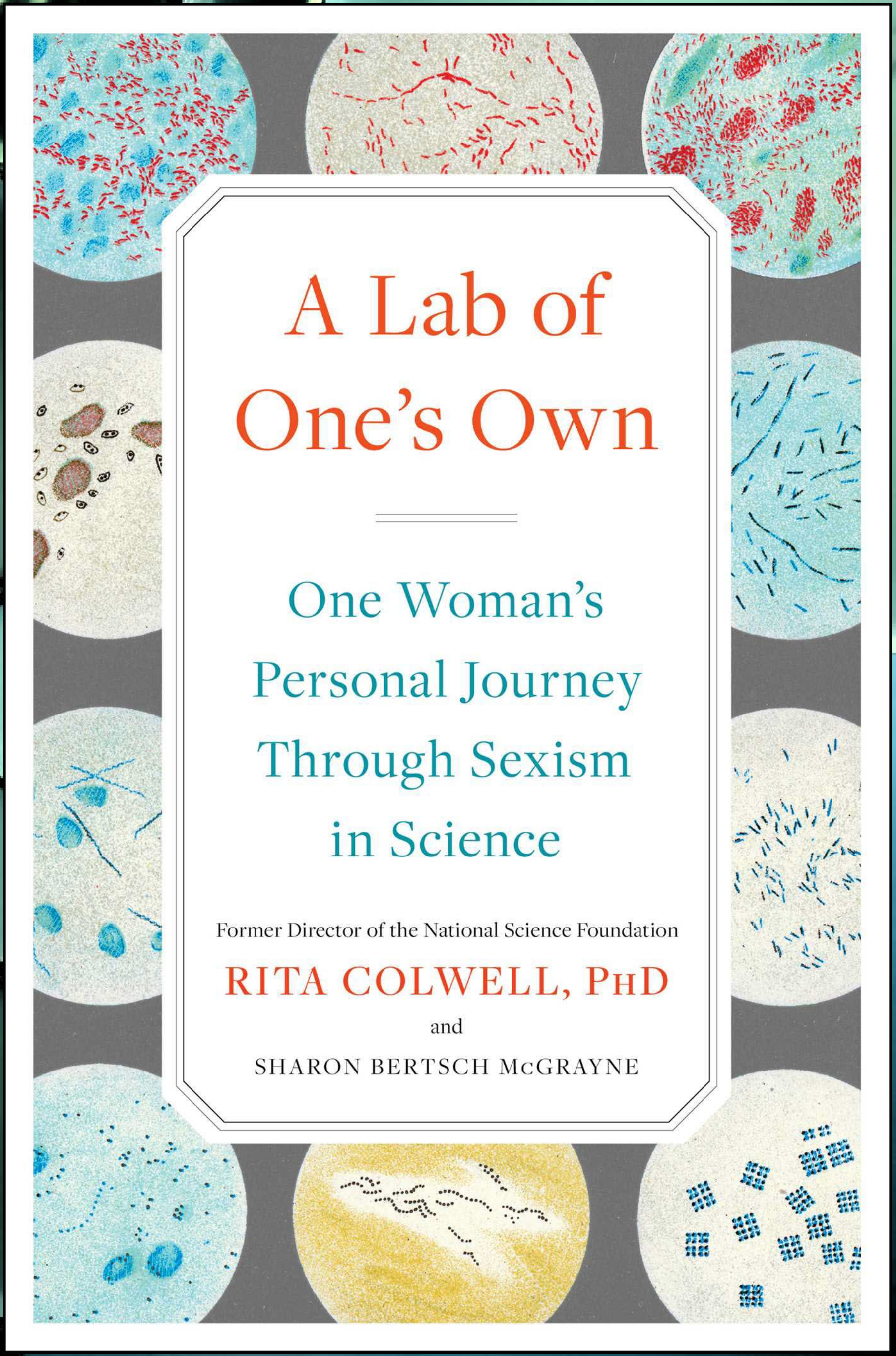
A Lab of One's Own
One Woman's Personal Journey Through Sexism in Science
Former Director of the National Science Foundation
RITA COLWELL, PHD
and
SHARON BERTSCH MCGRAYNE

Questions and Discussion

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