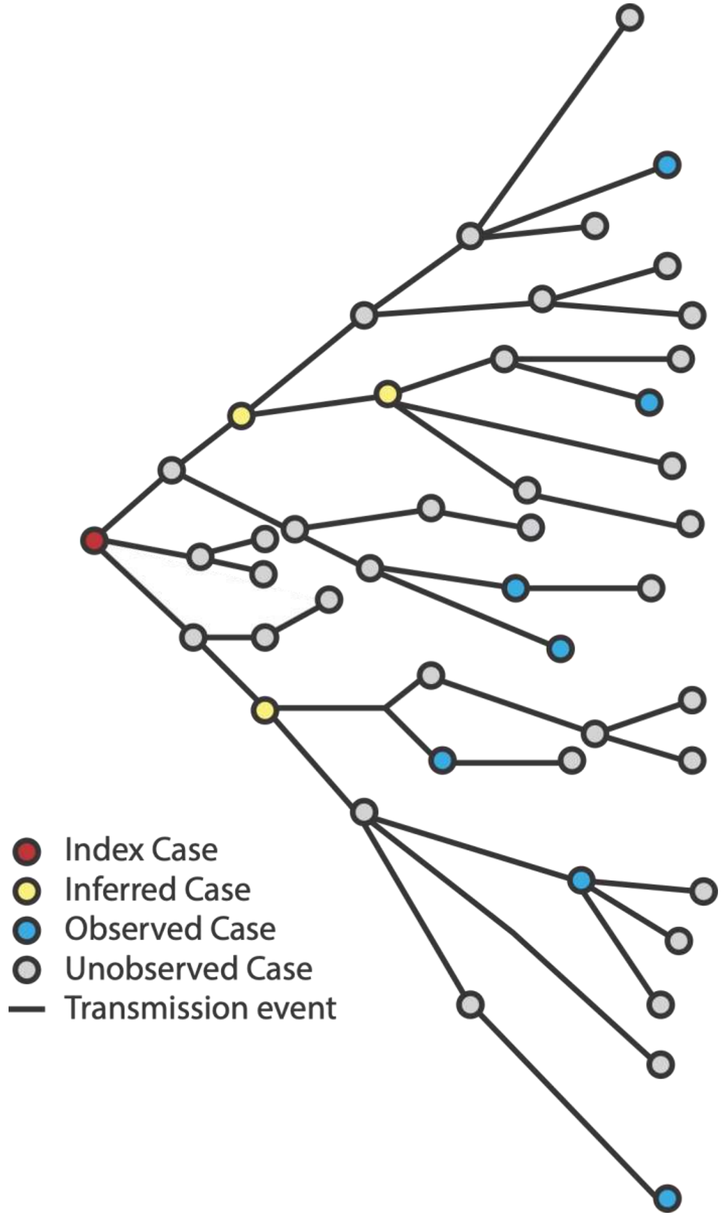
A wastewater-integrated, global virus genomic surveillance framework

IDM Annual Meeting

Joshua Levy, PhD || jolevy@scripps.edu || 2024-10-01

How we track viruses: case-based, clinical surveillance



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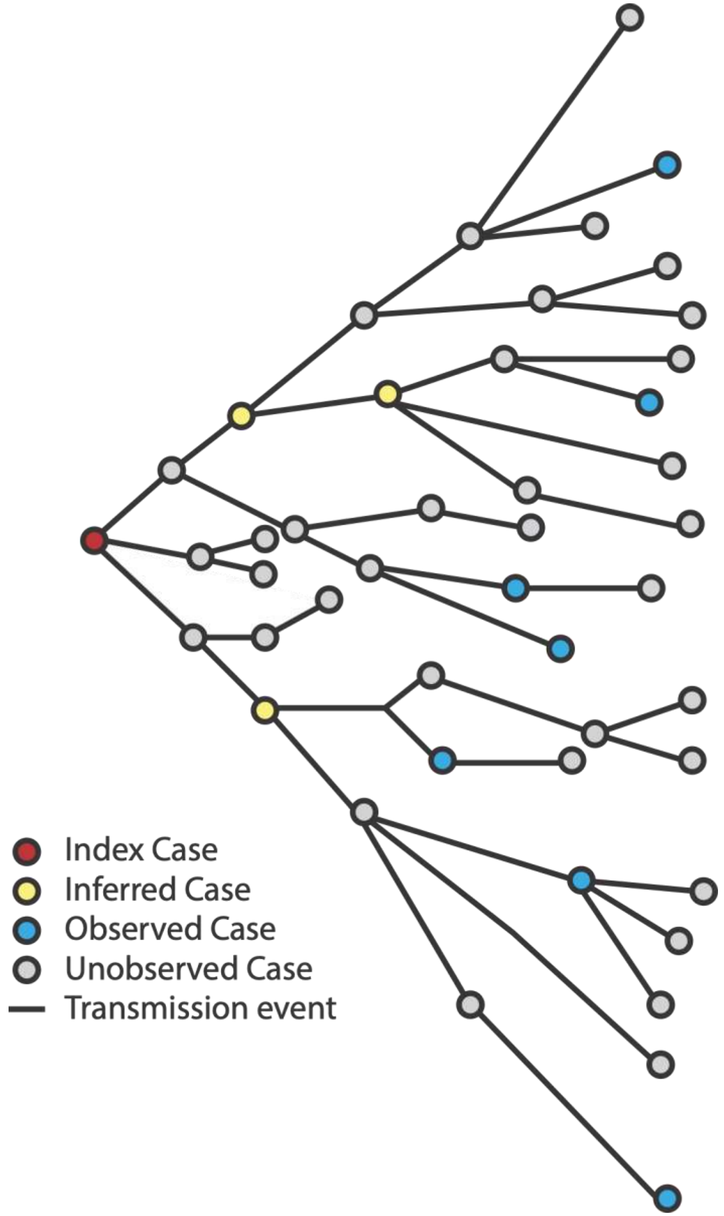

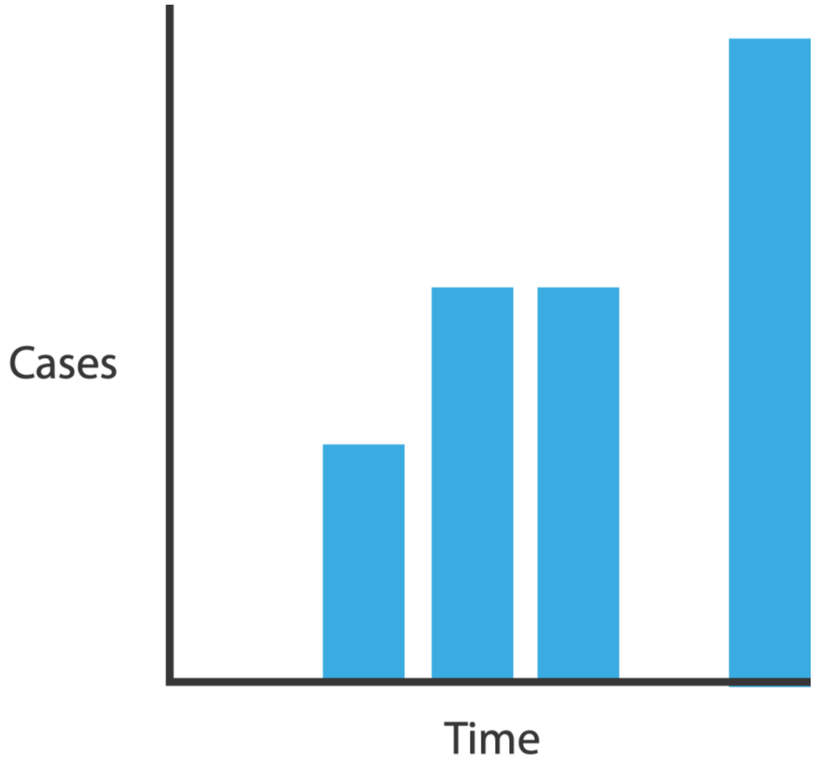

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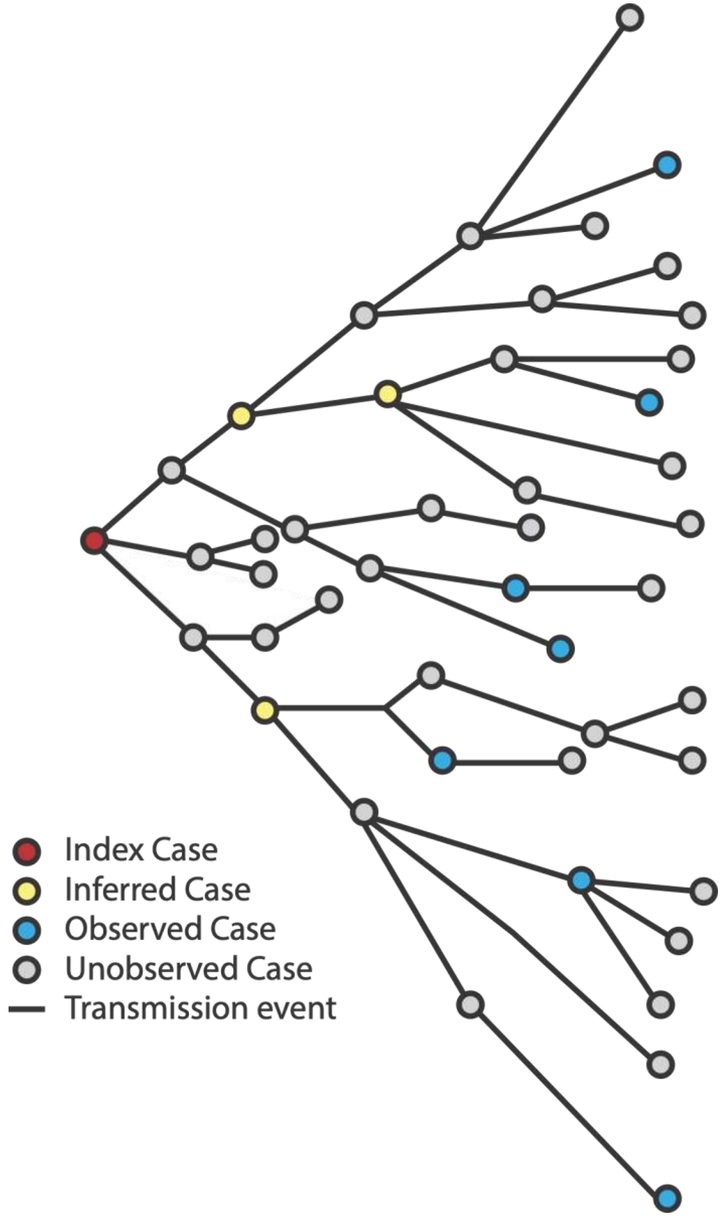
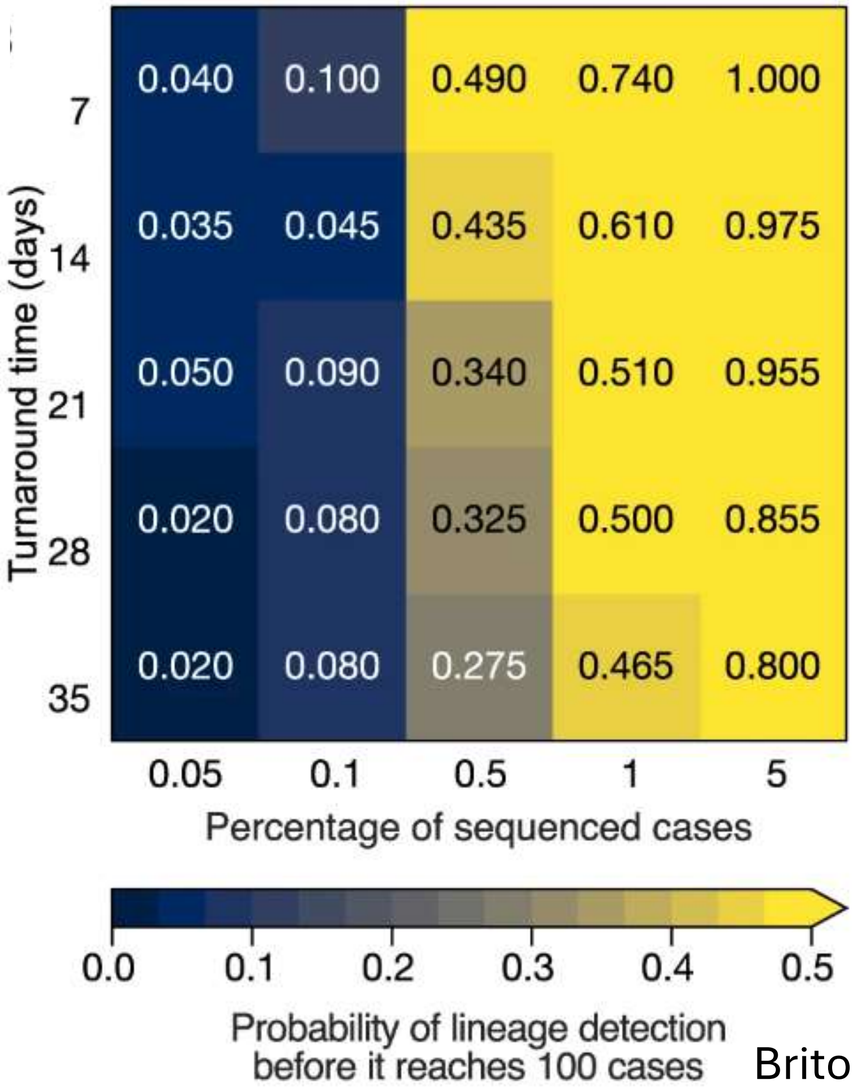
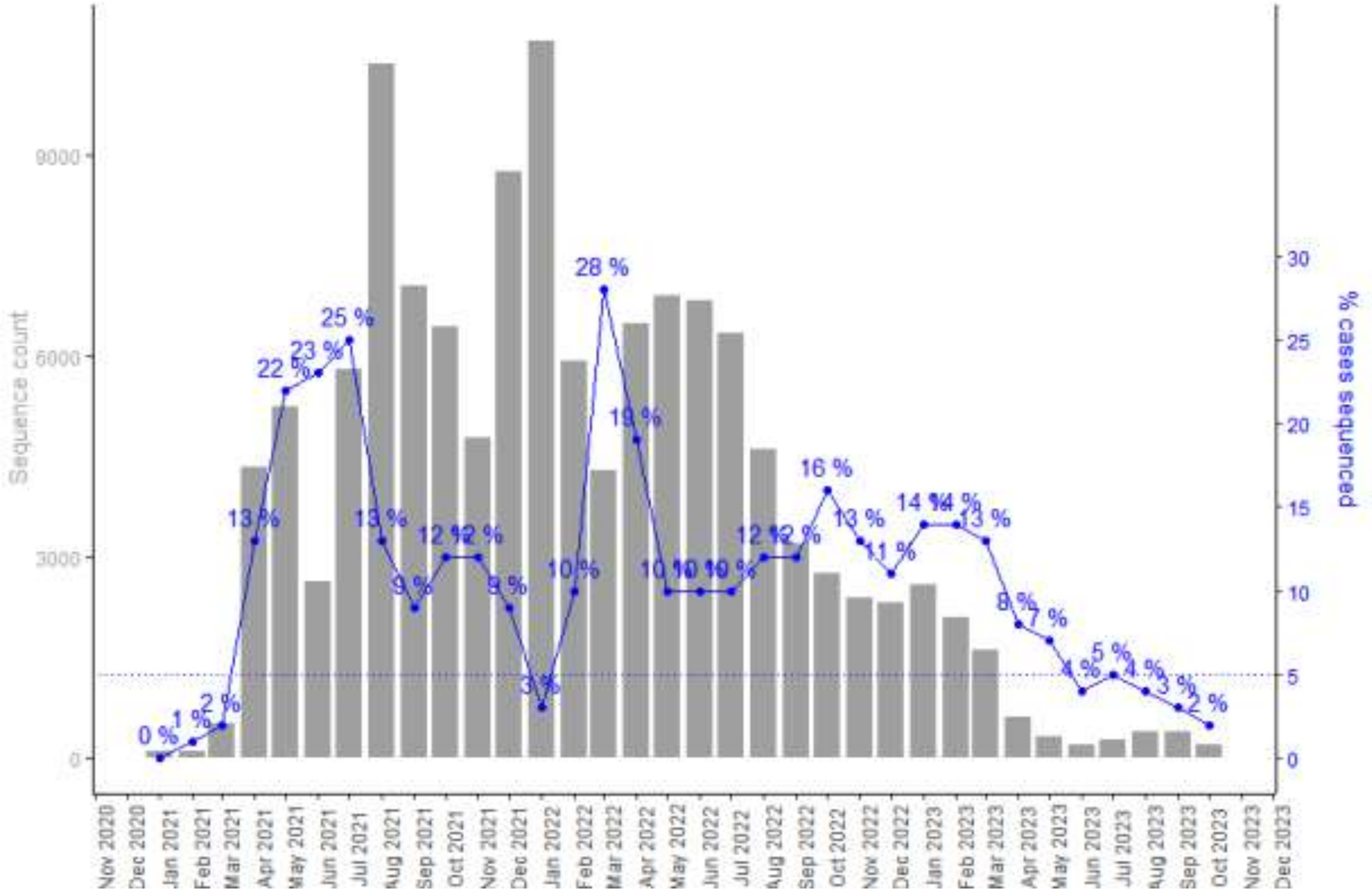




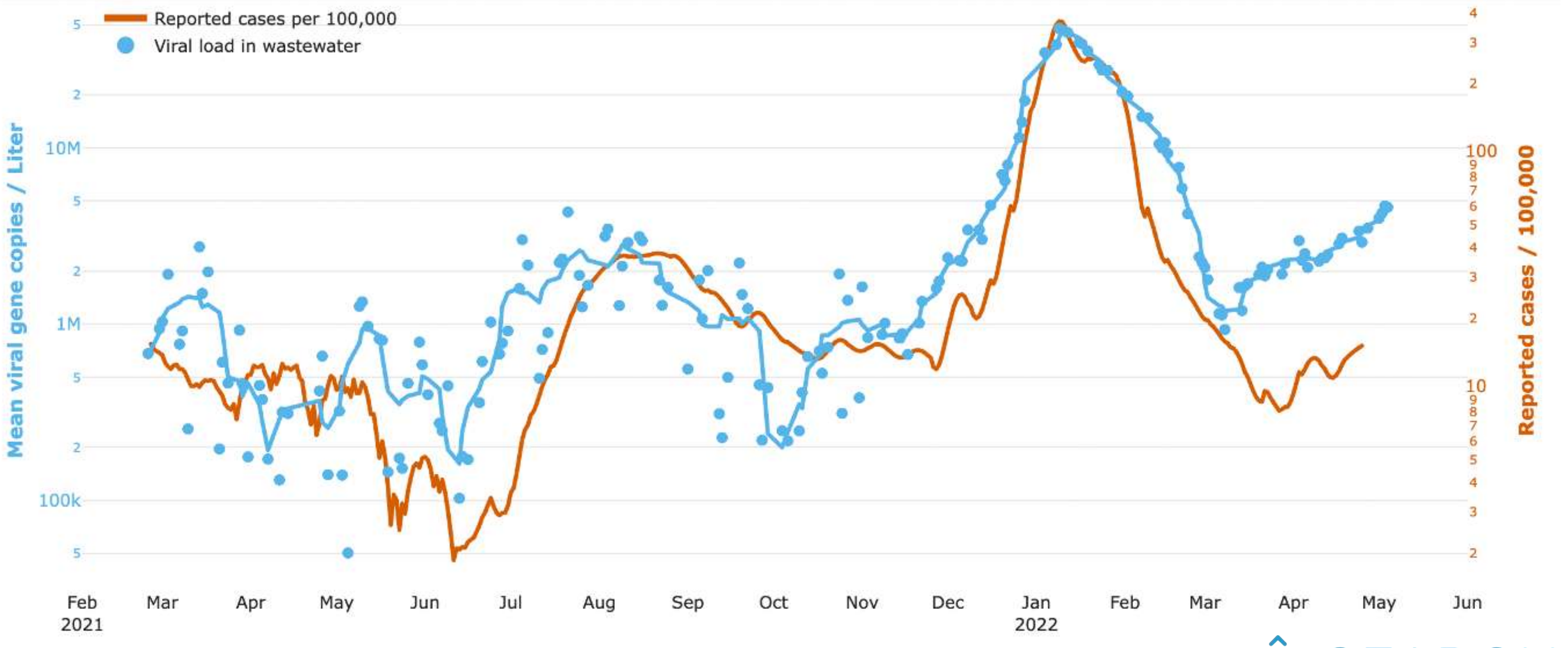
Brito et al., 2022

Under baseline conditions, few samples are sequenced



Washington State Department of Health

Wastewater provides an alternative data source



SEARCH
San Diego Epidemiology and Research for COVID Health

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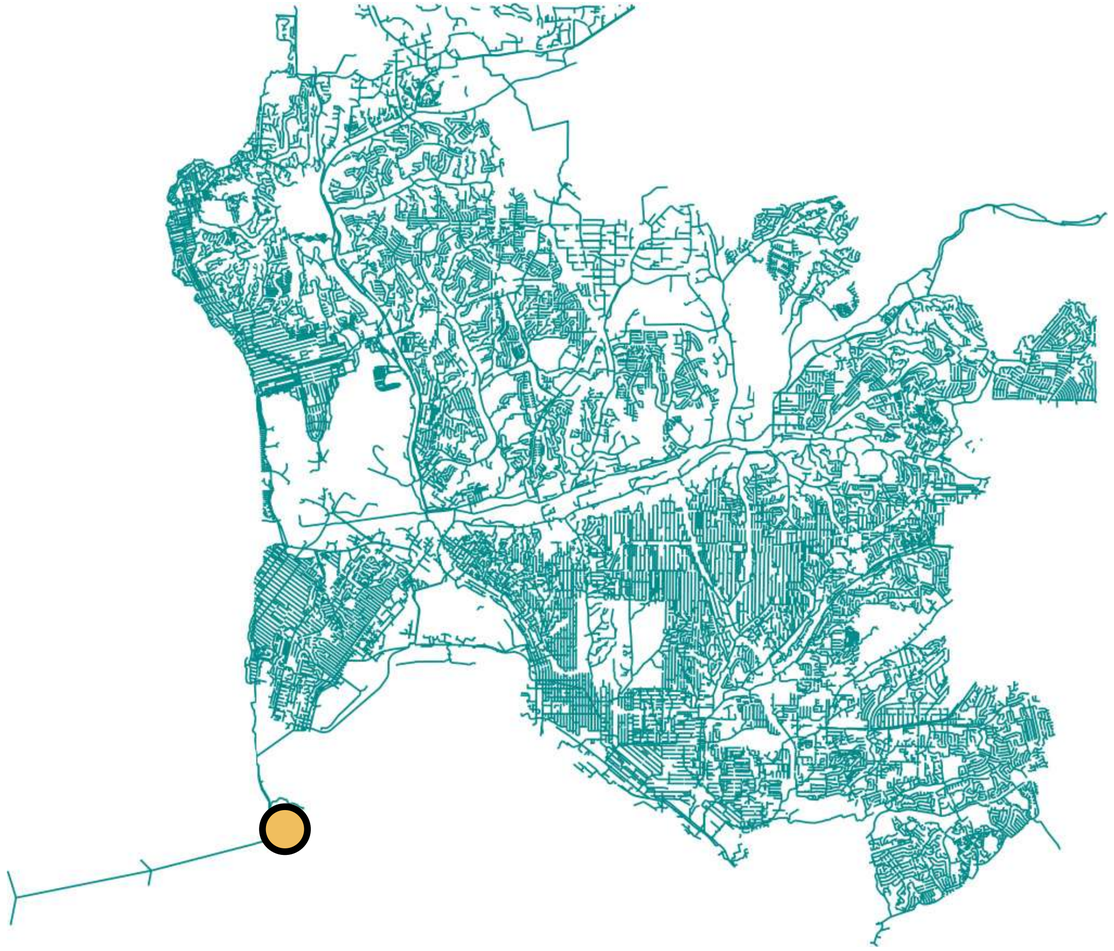

Efficient

- Cost-effective
- Low-effort sample collection
- Only small changes to lab workflows

Comprehensive

- Community-wide representation
- Limits sampling bias
- Potential to track pathogen lineage dynamics through sequencing

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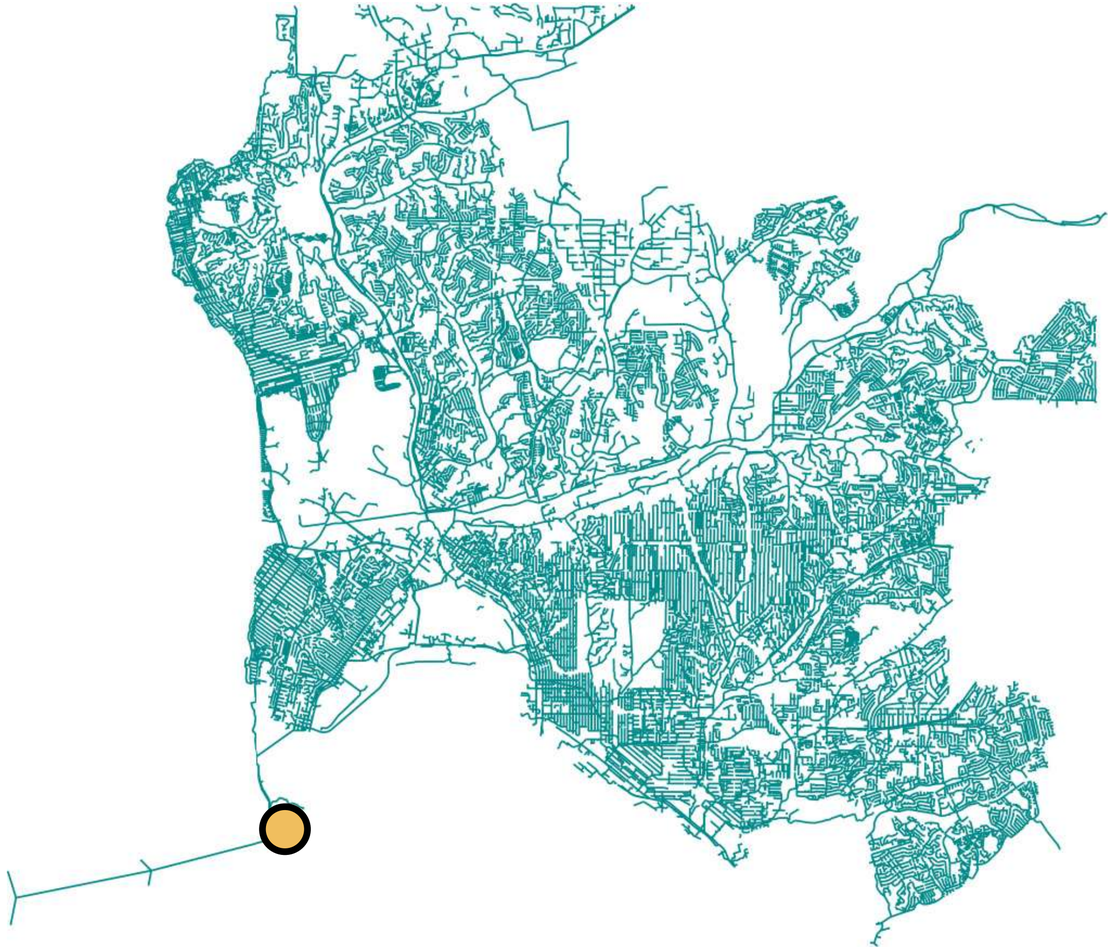

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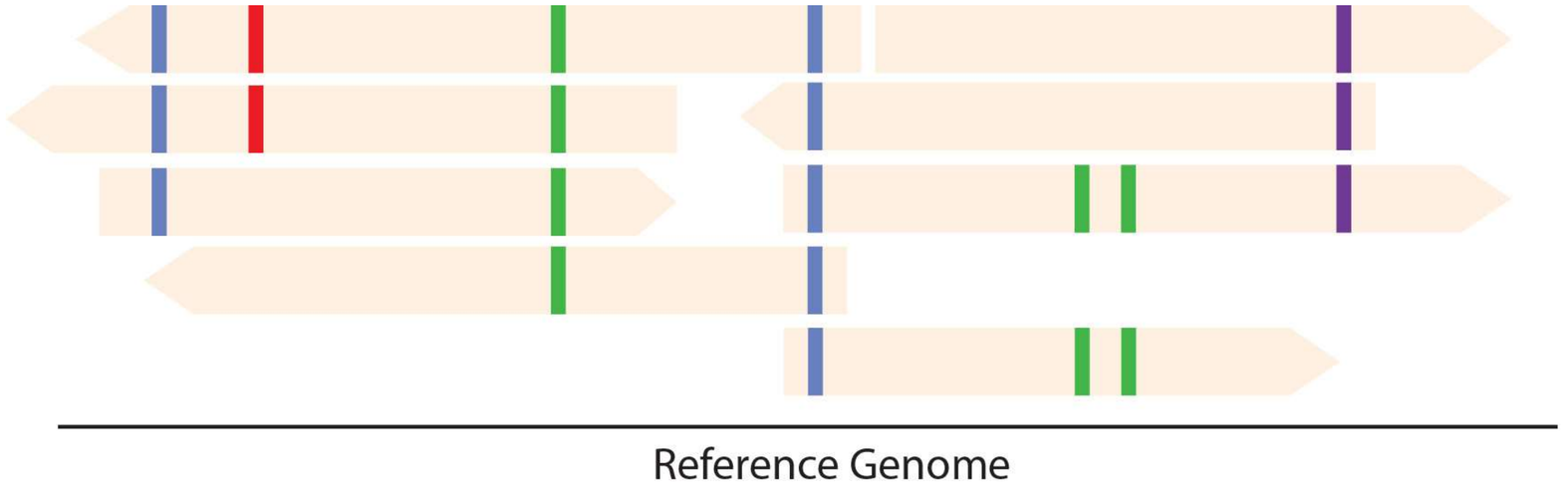

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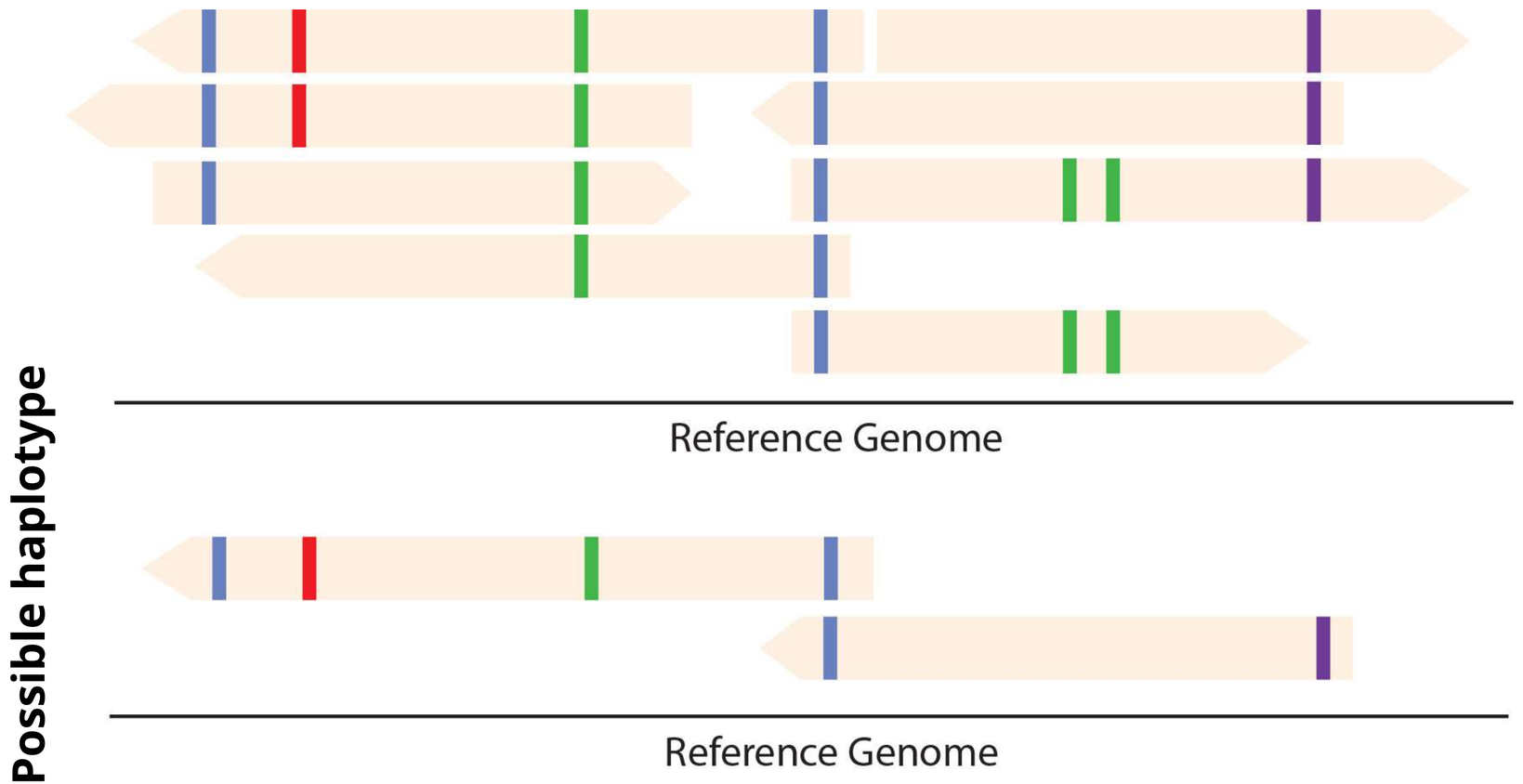

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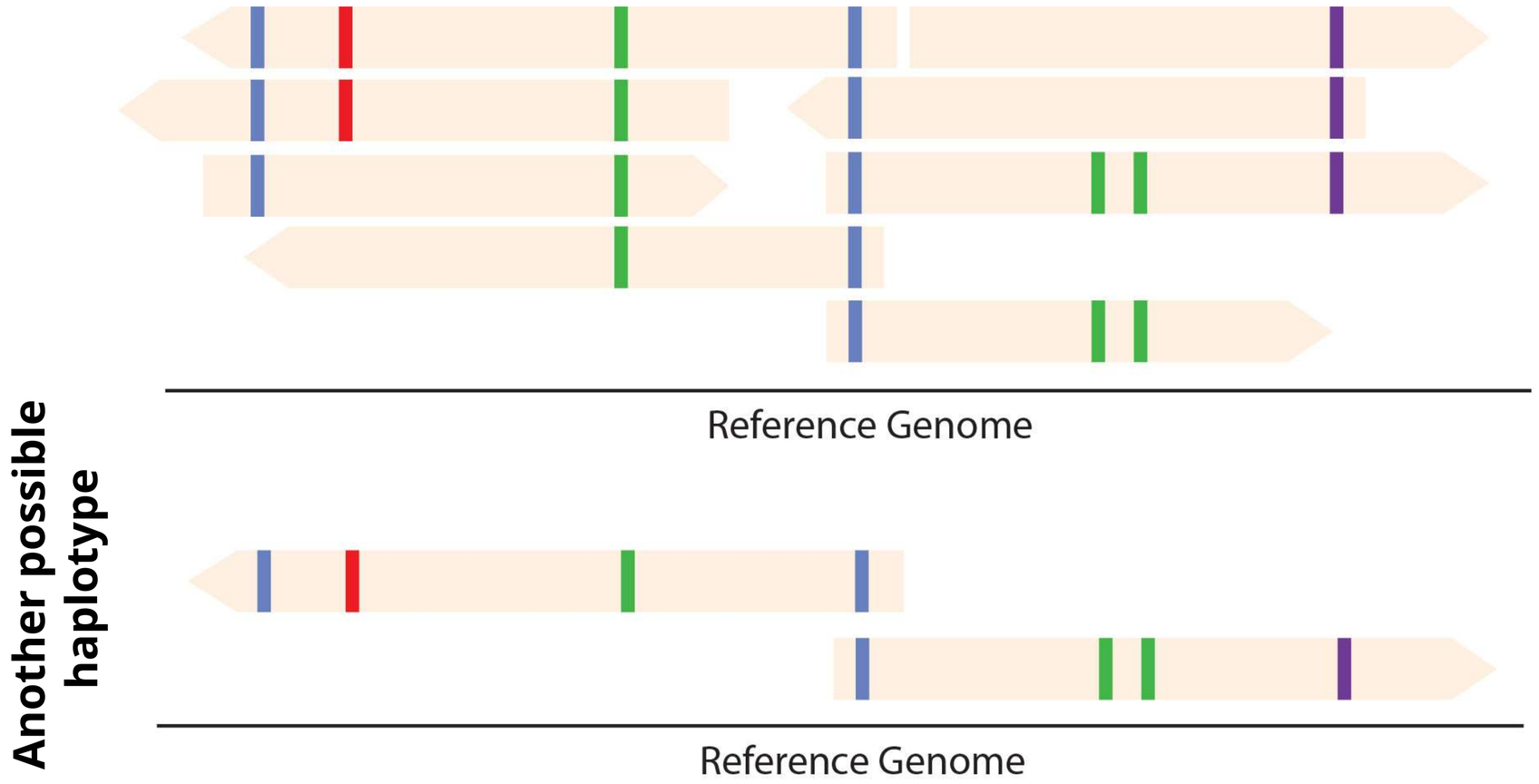
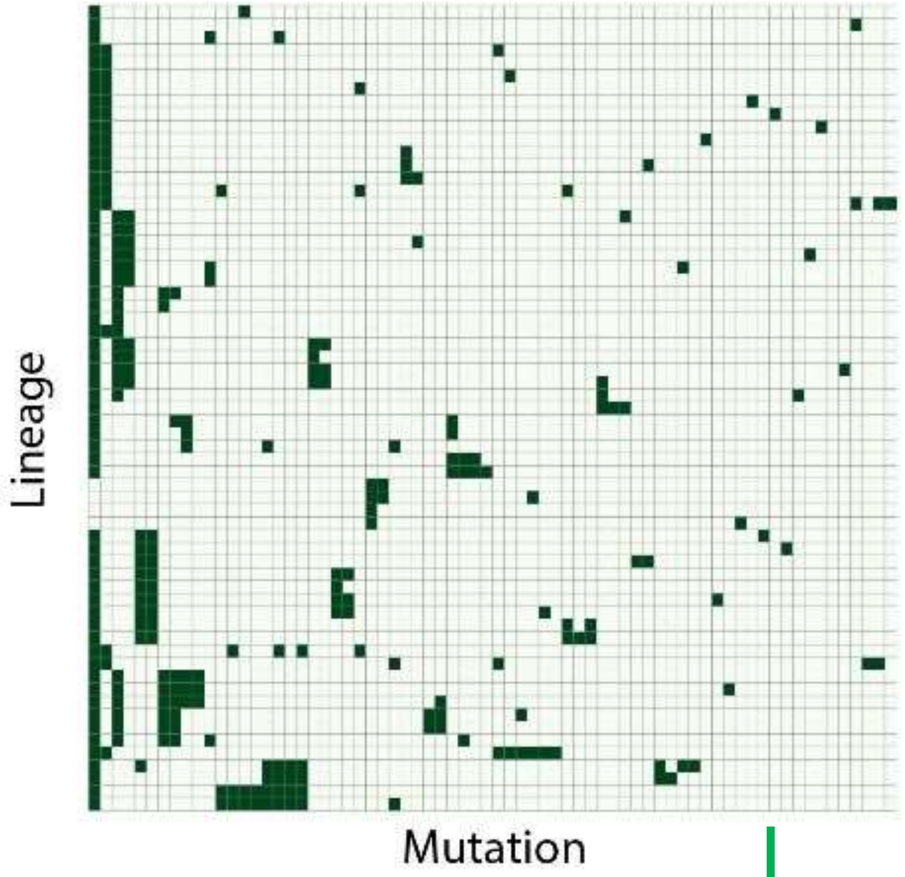
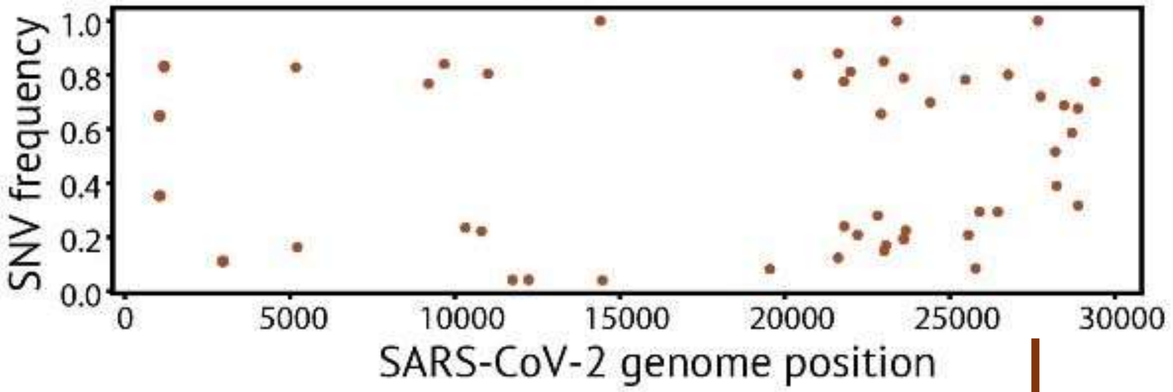


Need another approach to recover evolutionary dynamics from mixtures

Lineage Barcoding



Detection of Single Nucleotide Variants

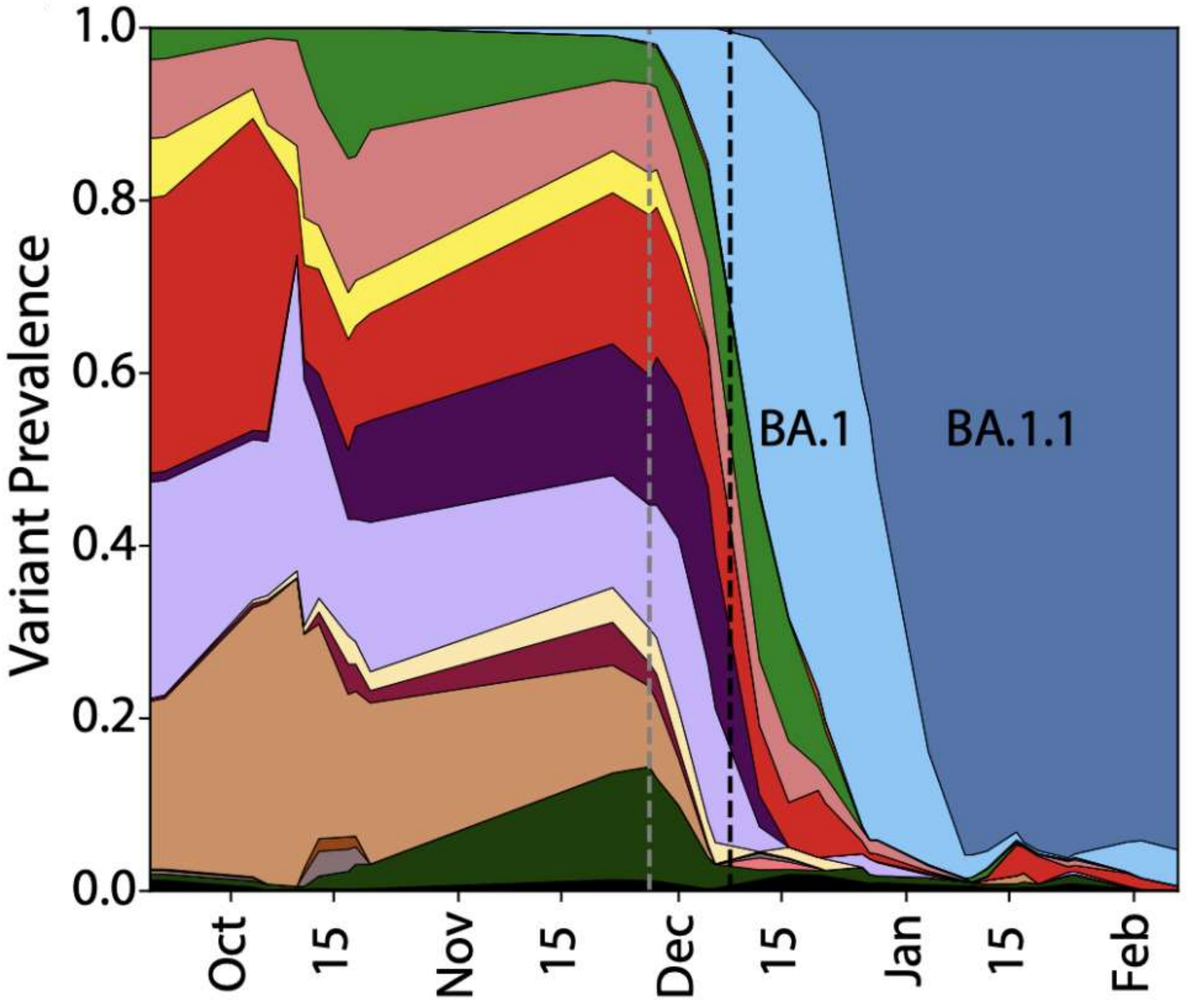


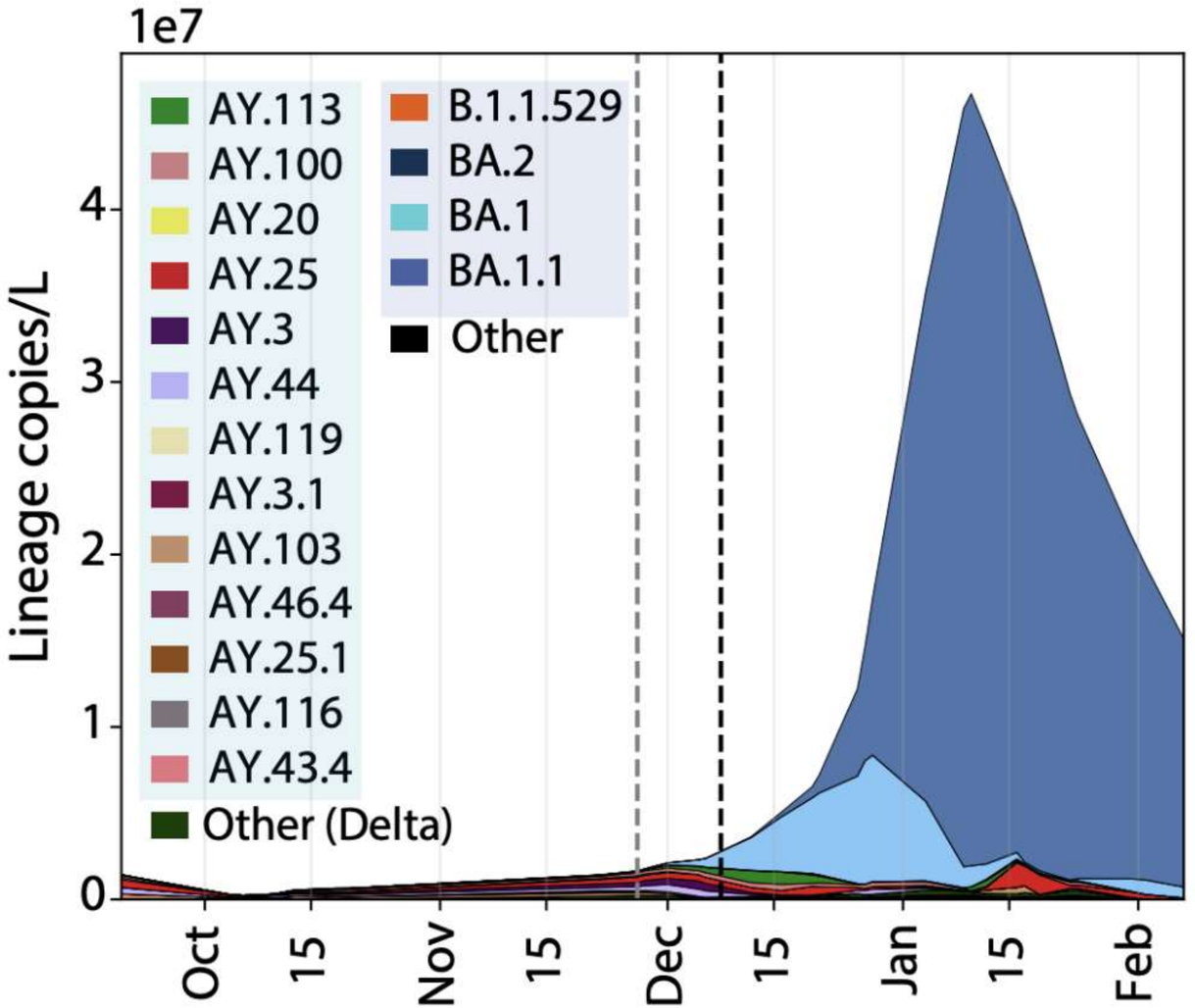
Depth-weighted de-mixing

$$\hat{x} = \underset{\substack{x \geq 0 \\ \sum x = 1}}{\operatorname{argmin}} \; ||A^T x - b||_{1W}$$

> 4000 SARS-CoV-2 lineages

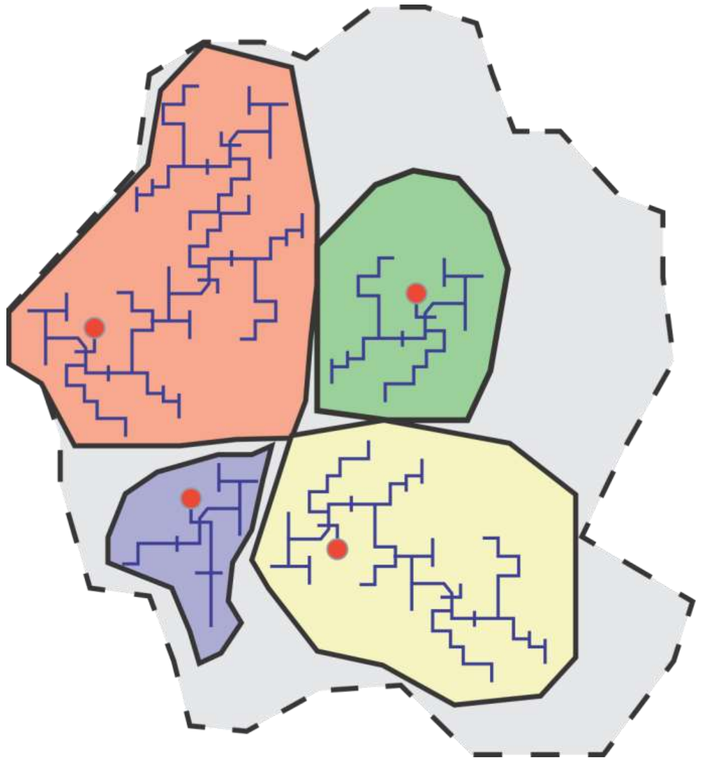
Freyja-enabled surveillance: Omicron in San Diego



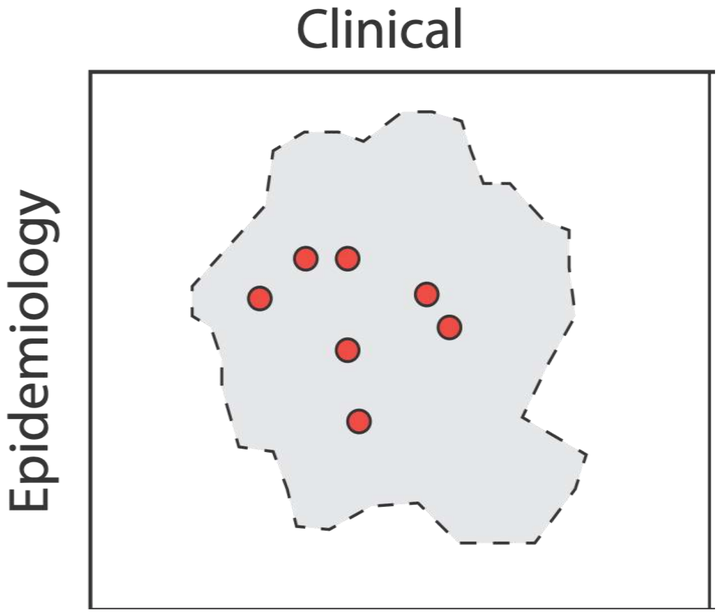


Karthikeyan and Levy et al., 2022

Integrated surveillance: An example region



Wastewater enables comprehensive, robust



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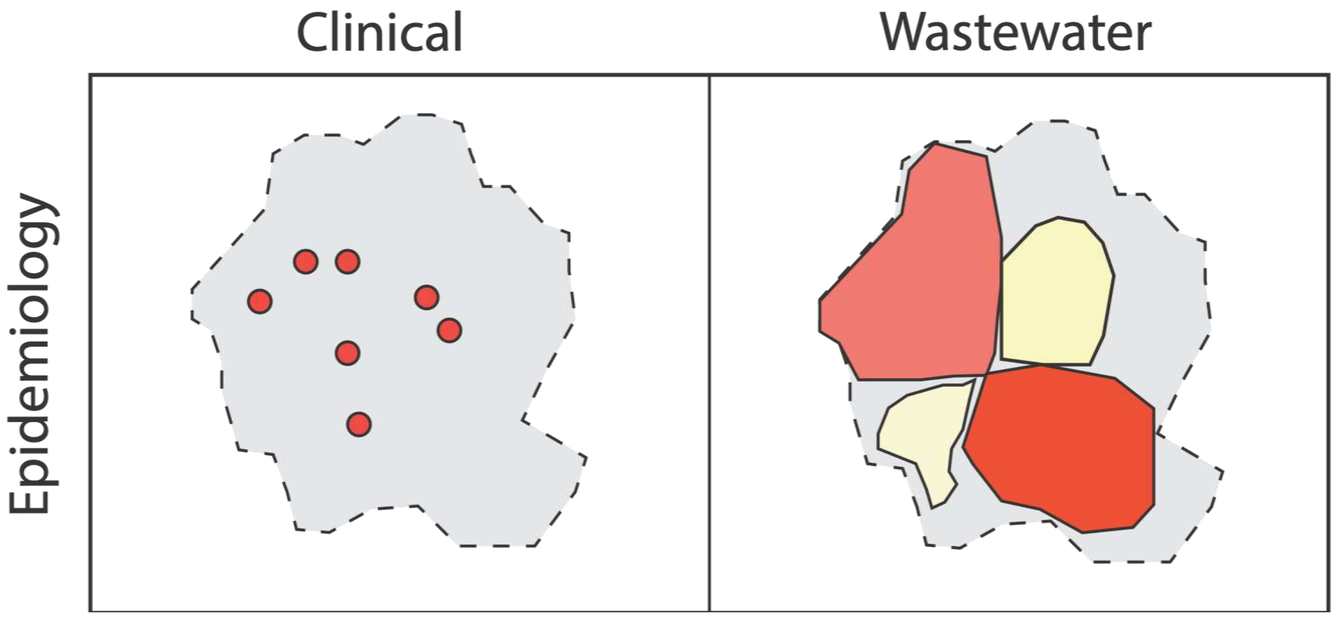

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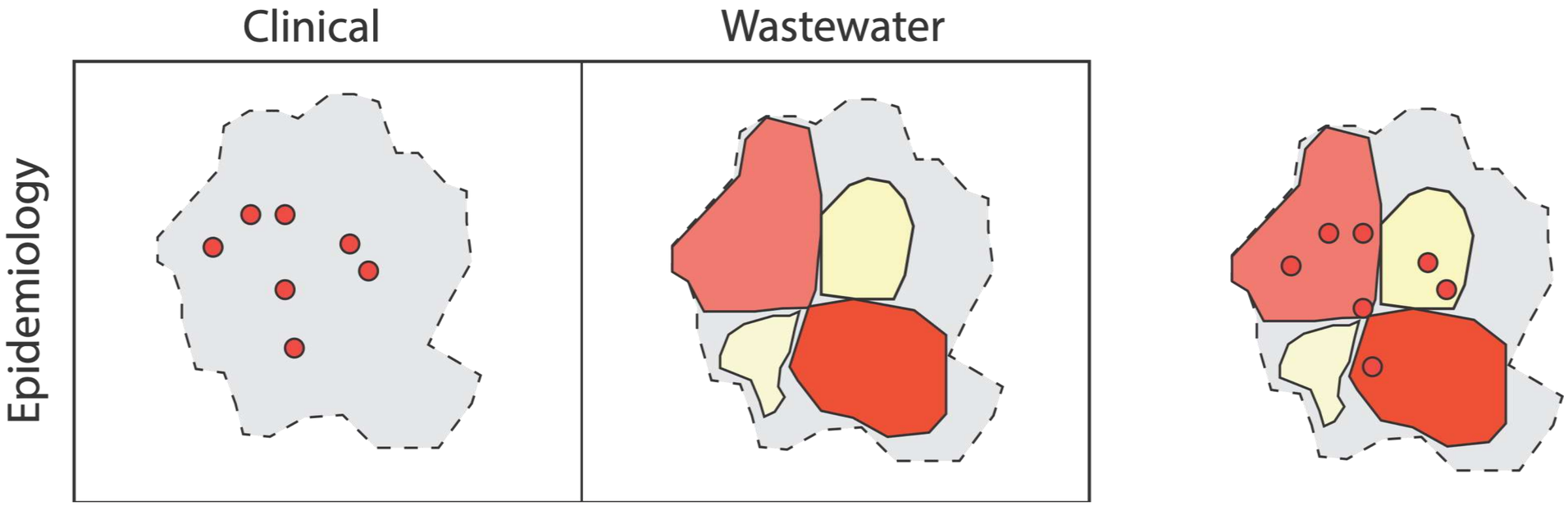

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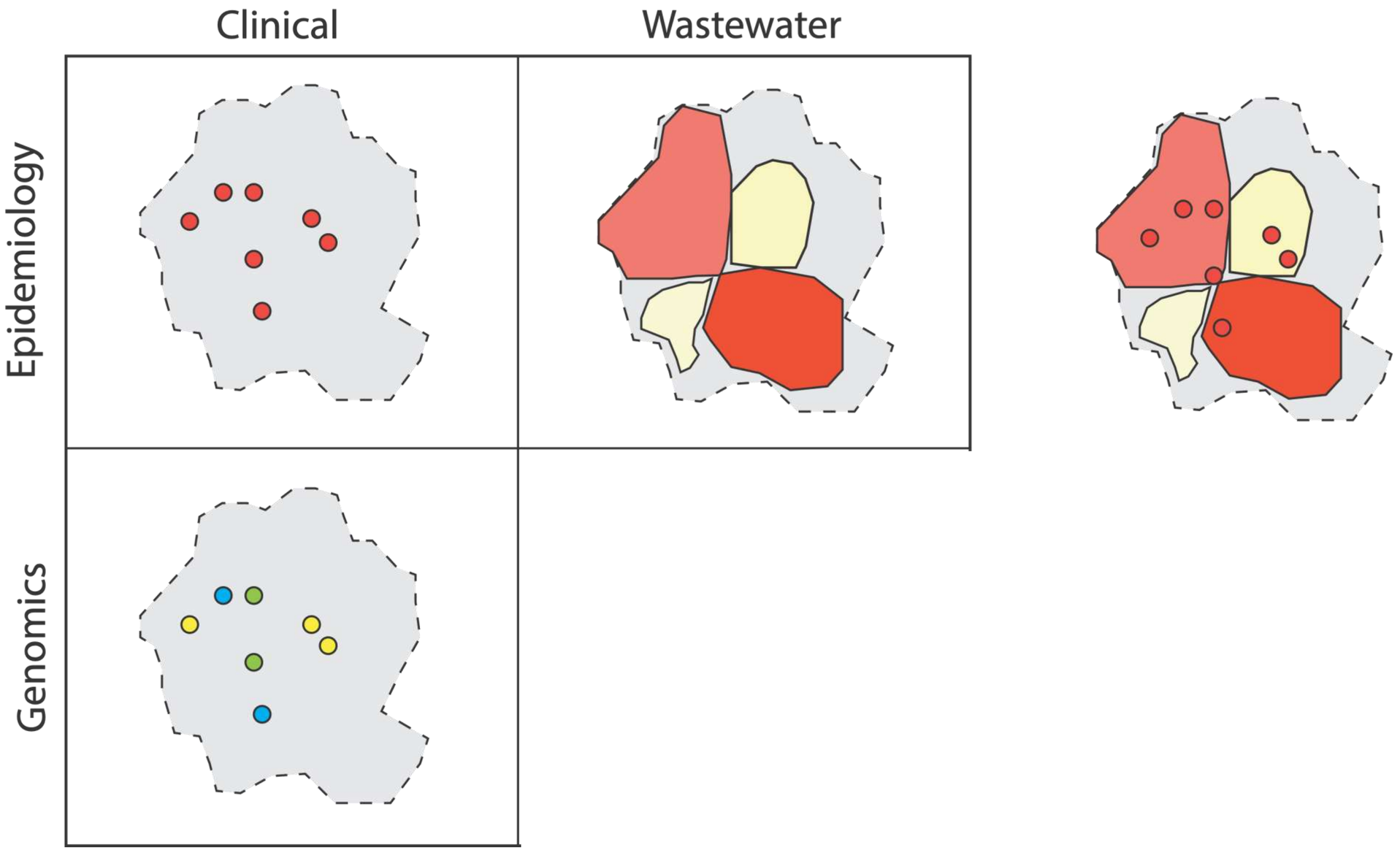

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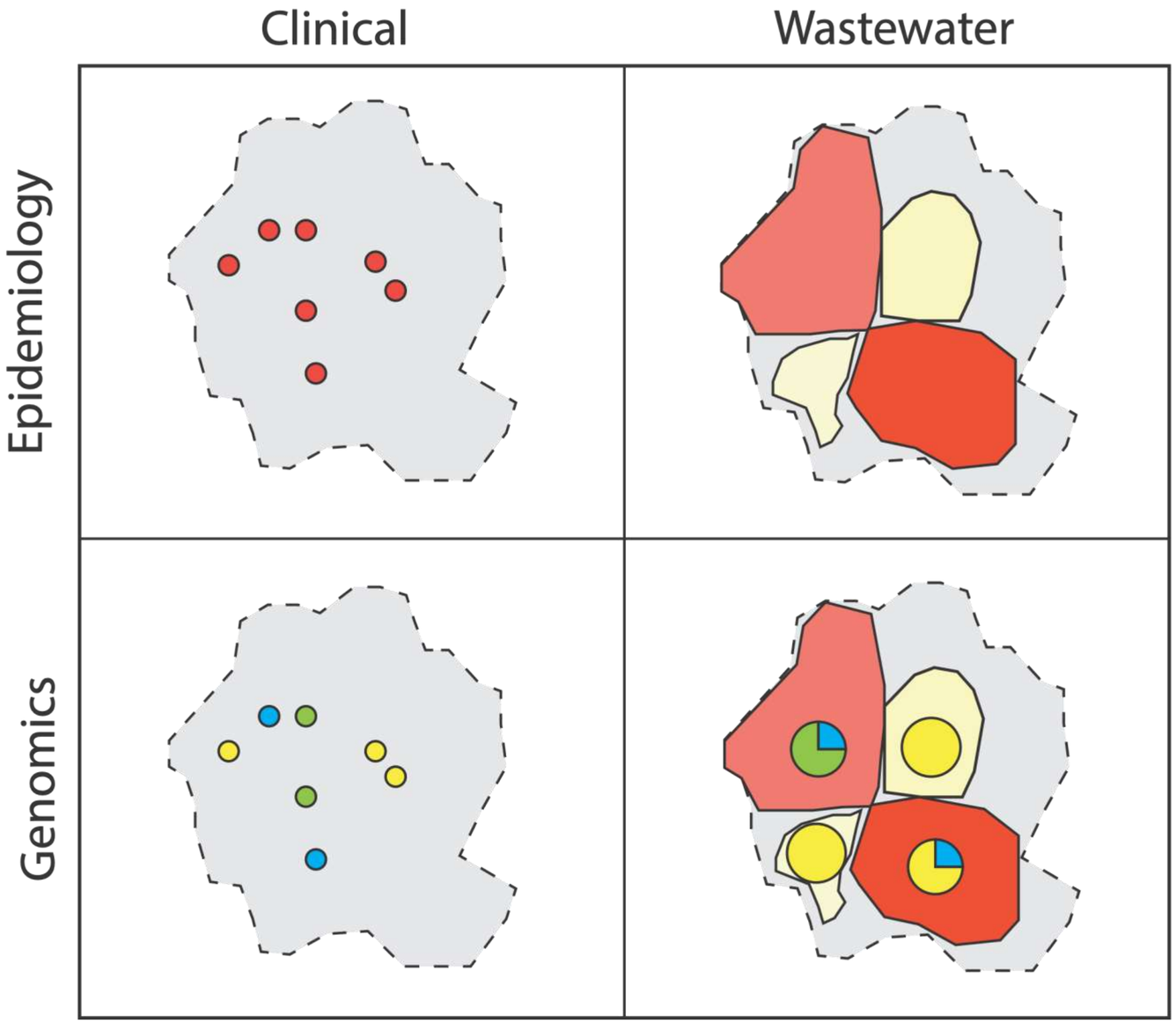

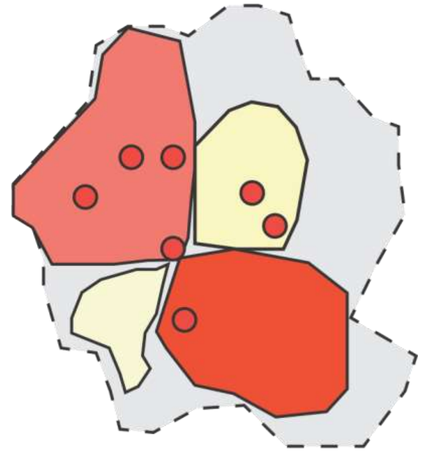

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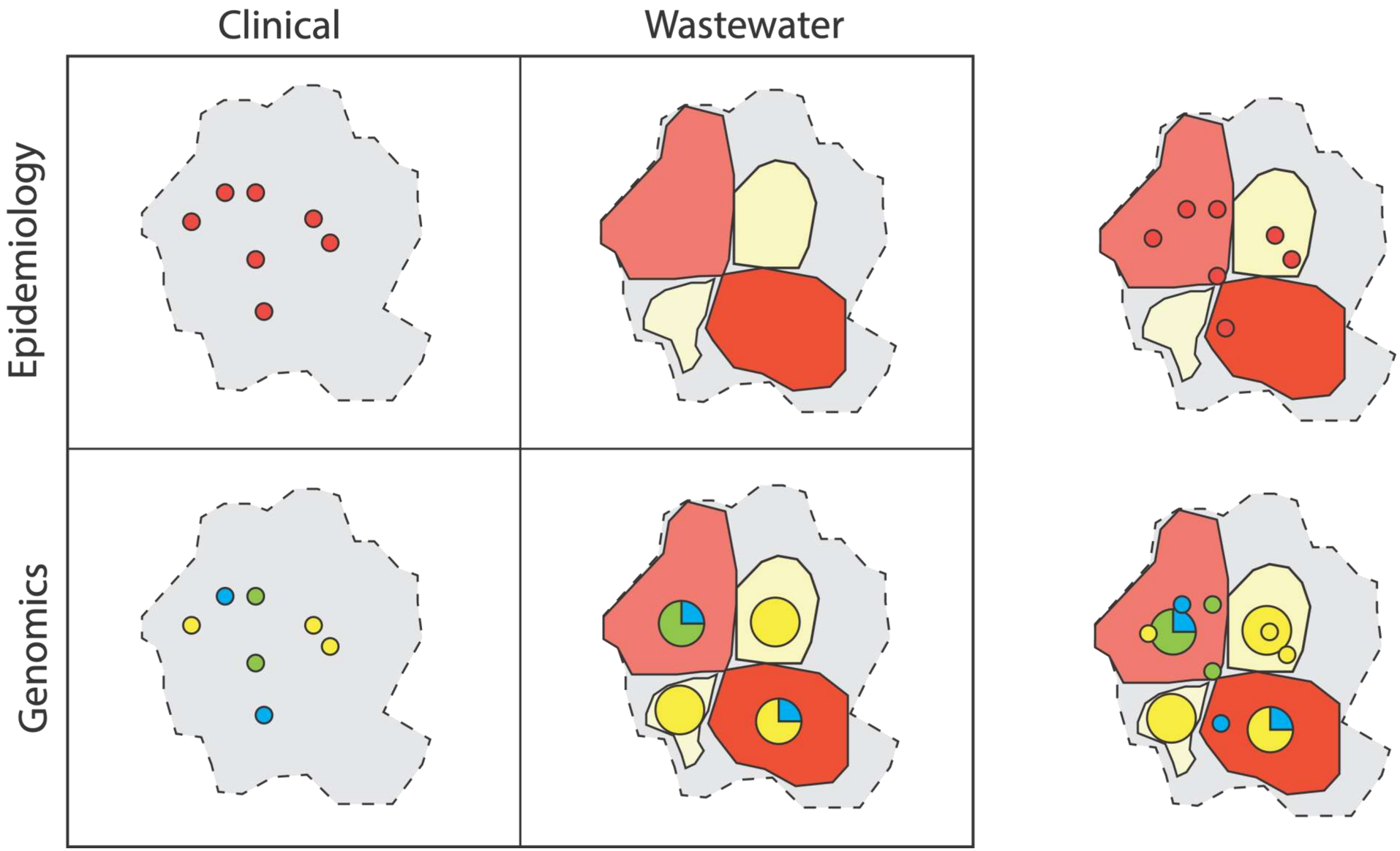

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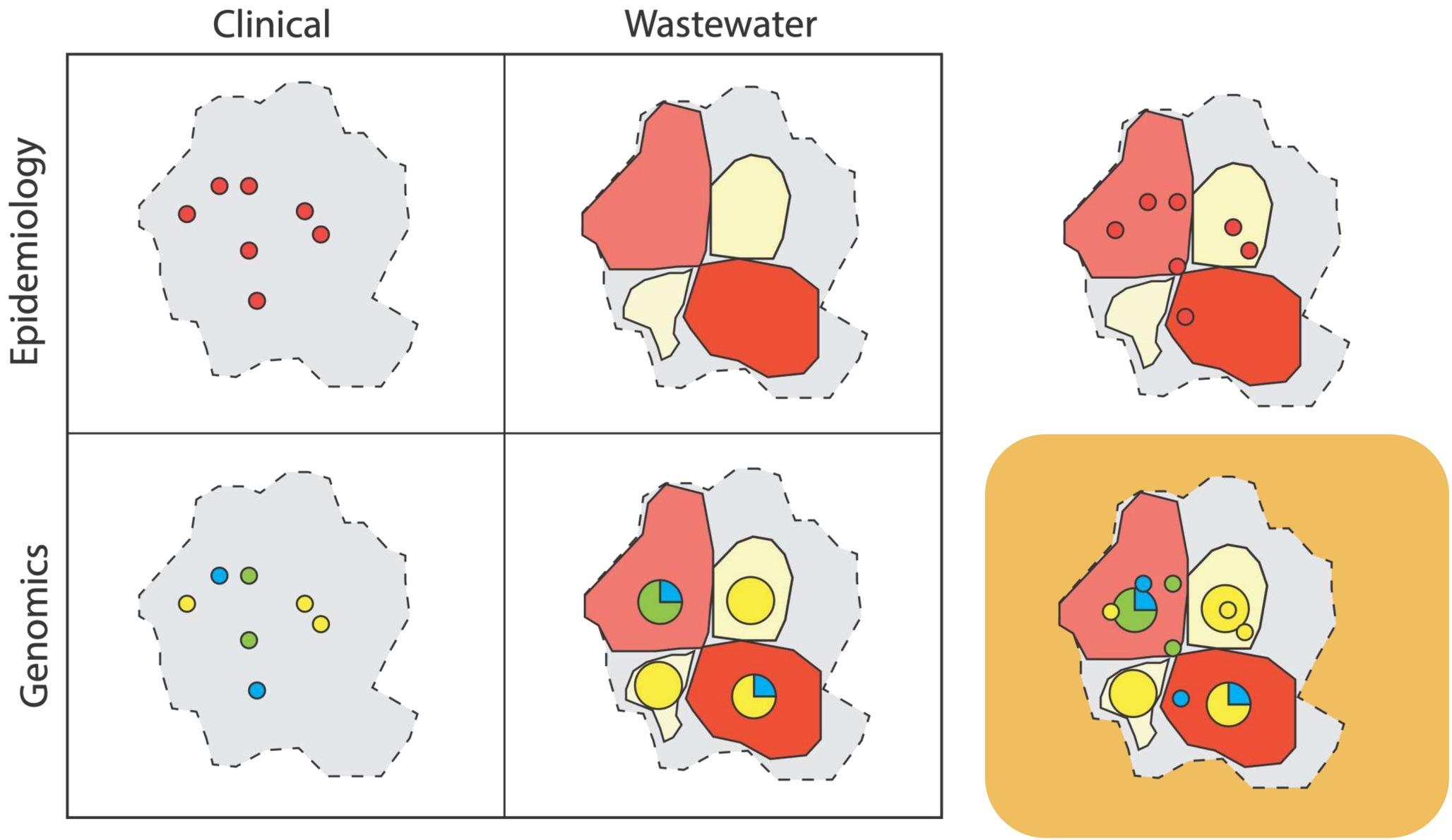
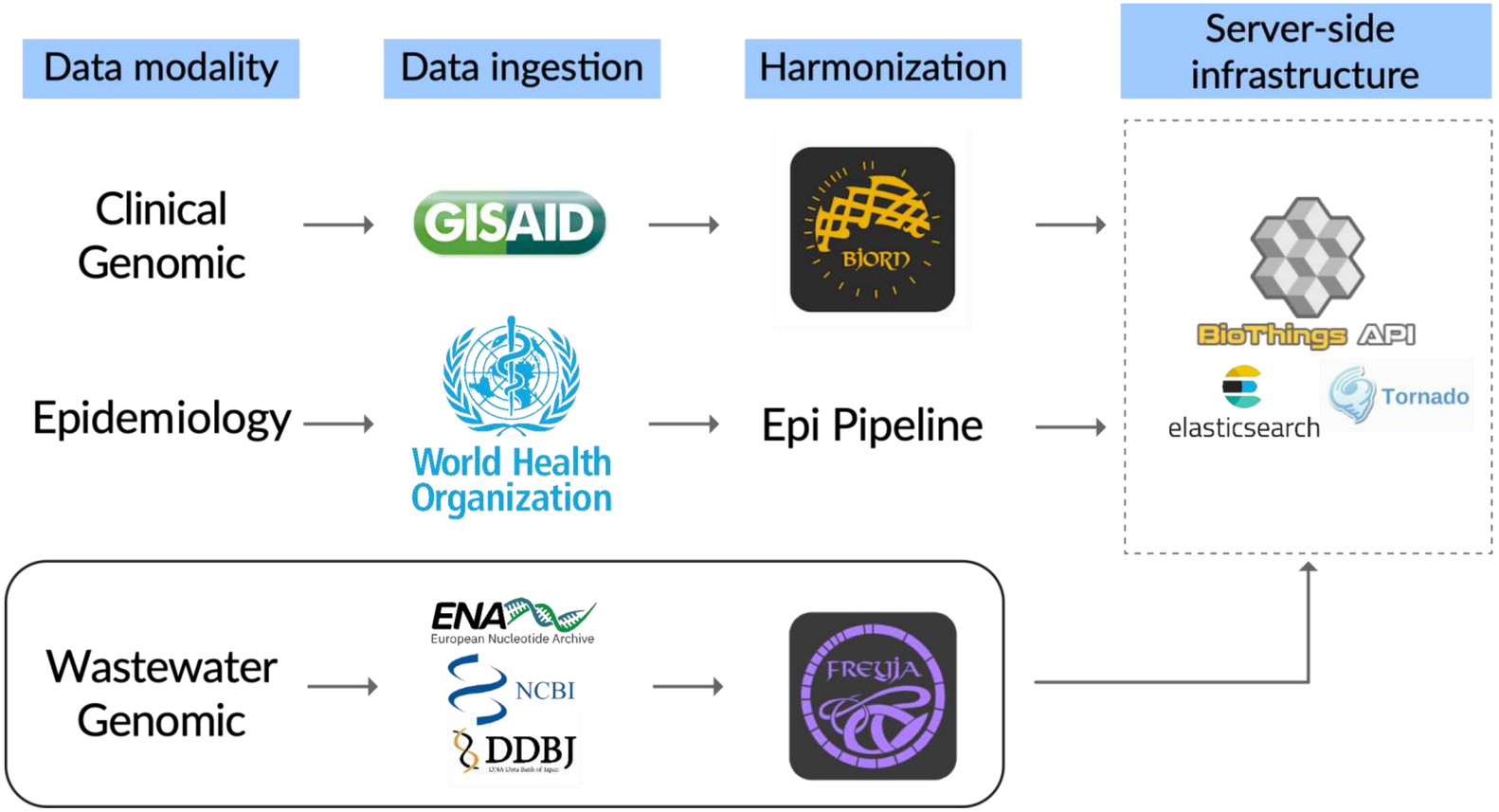


Multi-modal, pandemic scale data platform



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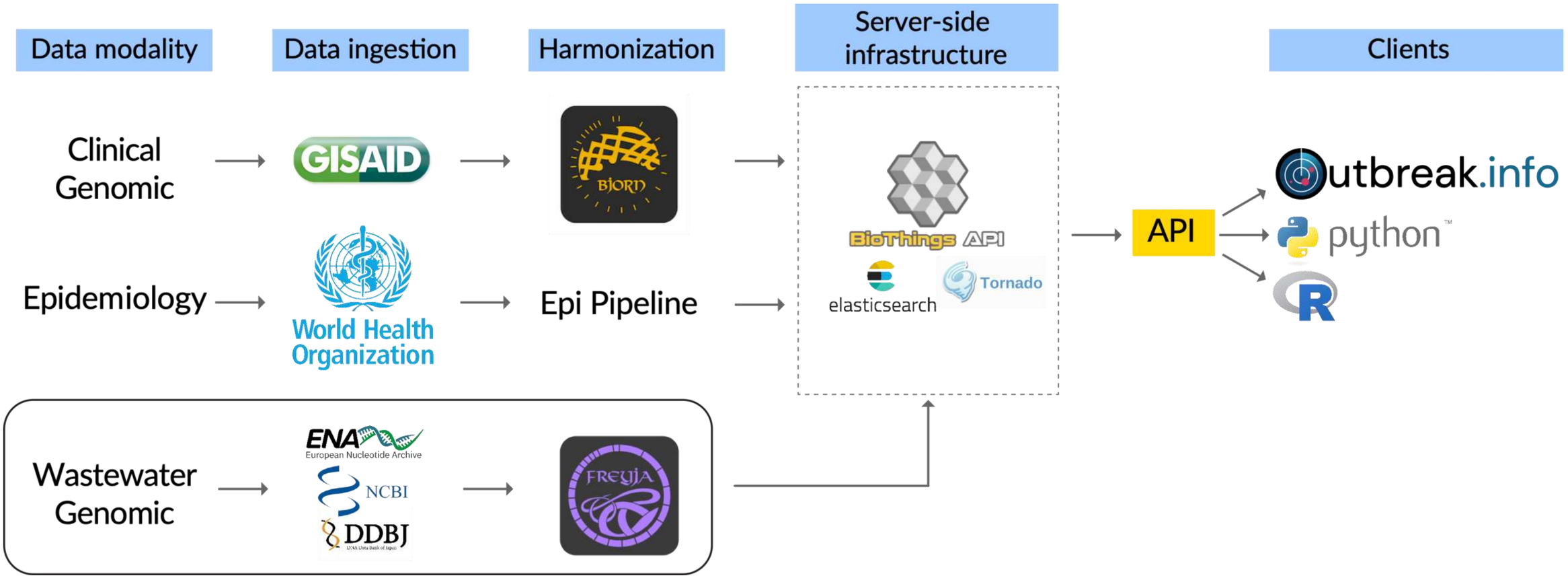
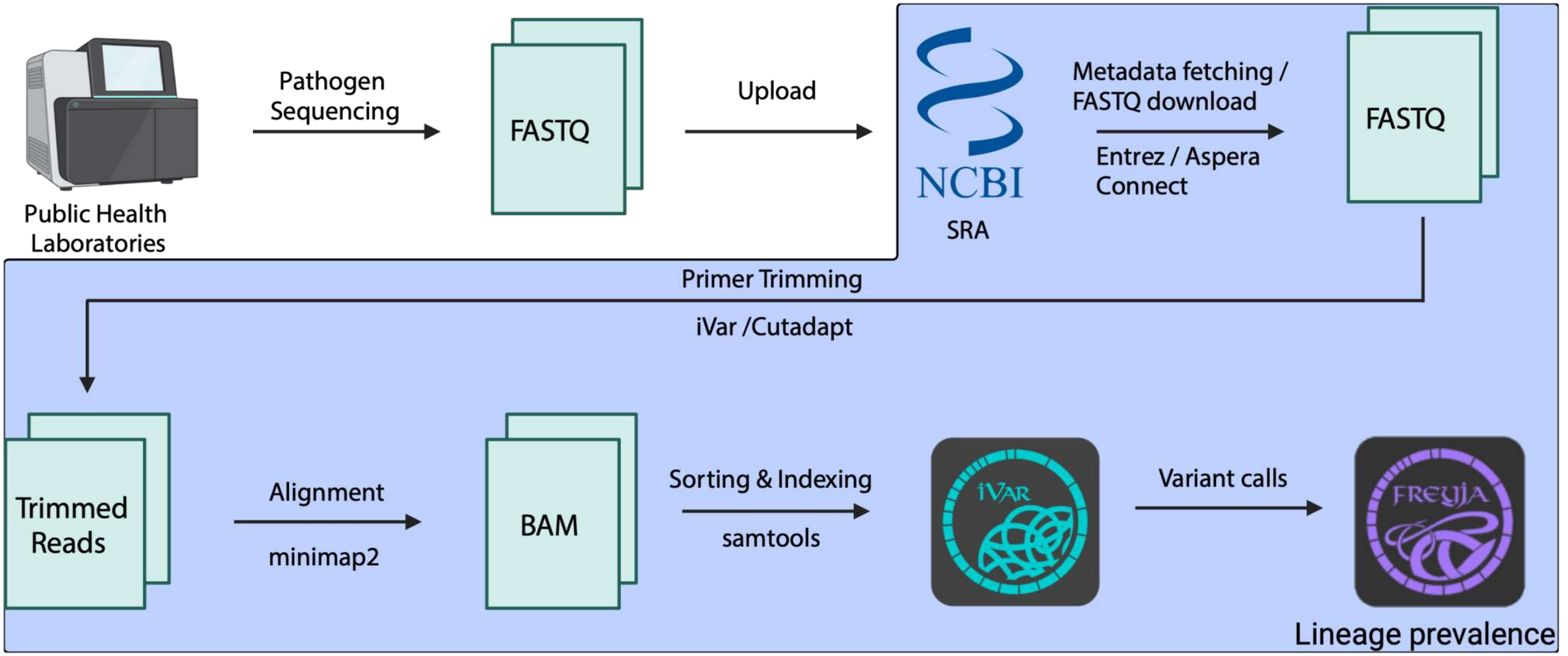
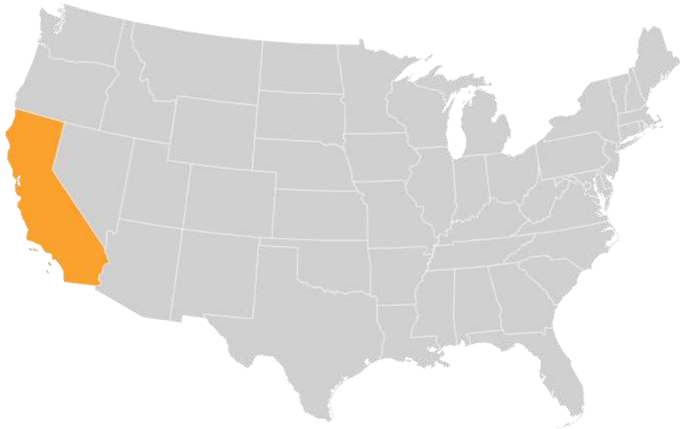


Scalable wastewater bioinformatic pipeline



Scalable, multimodal surveillance data streams

Tracking SARS-CoV-2 burden in CA



outbreak.info

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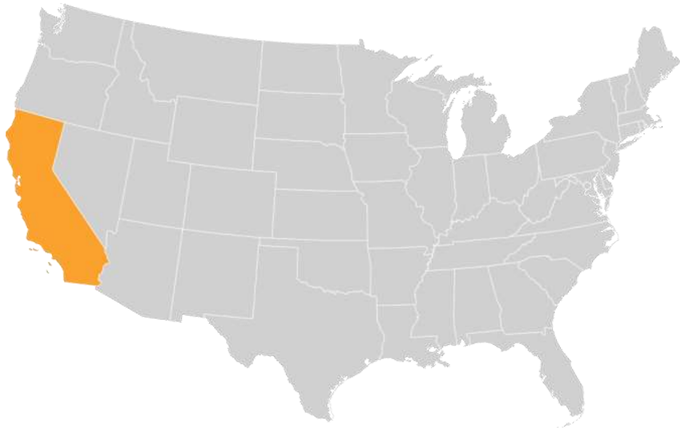

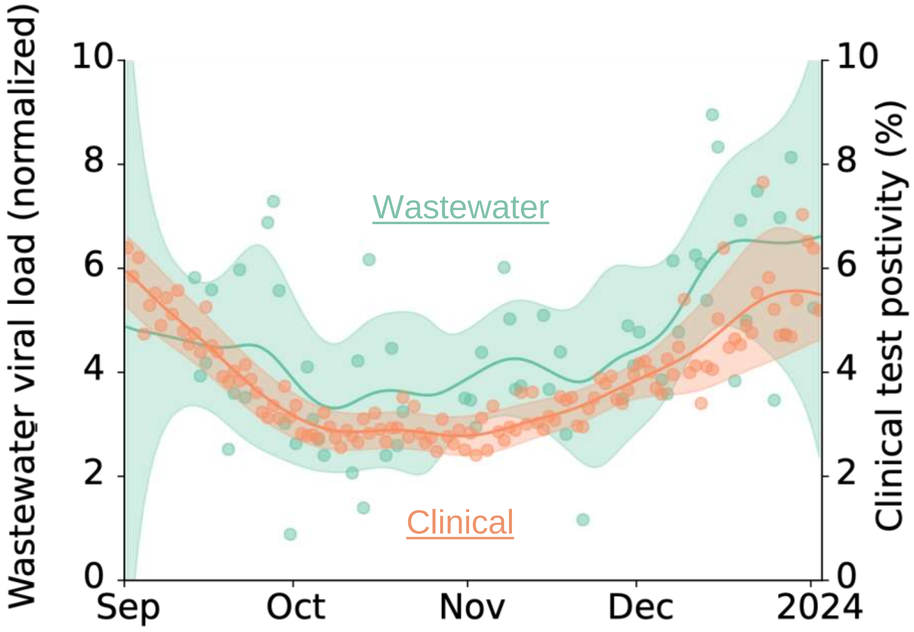

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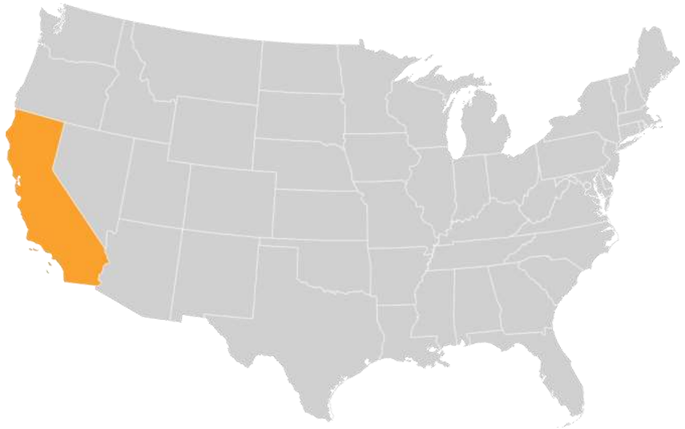

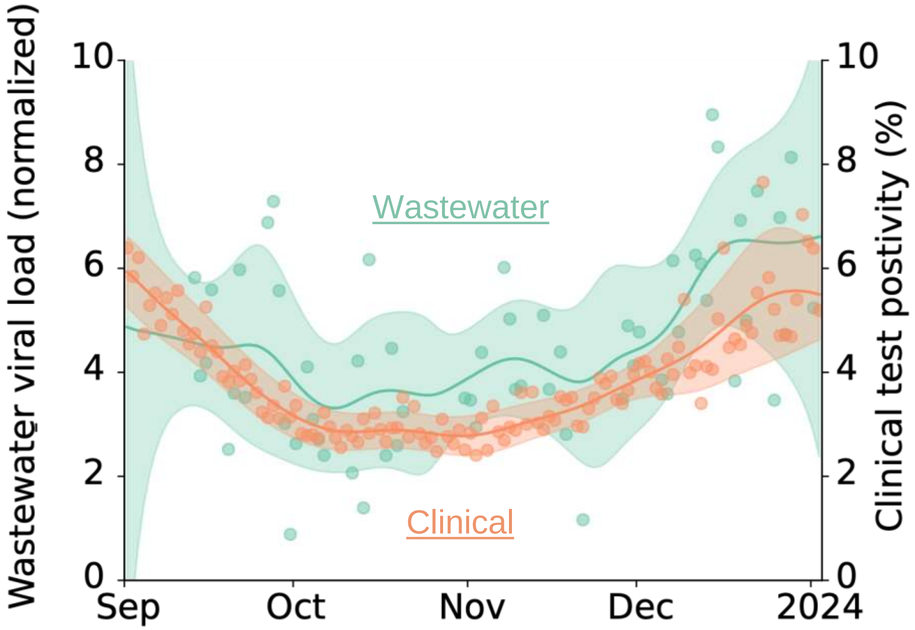

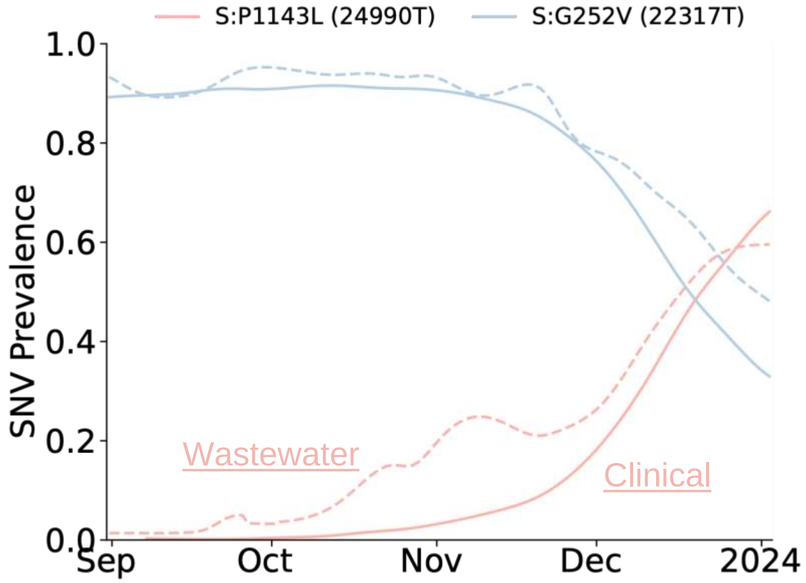

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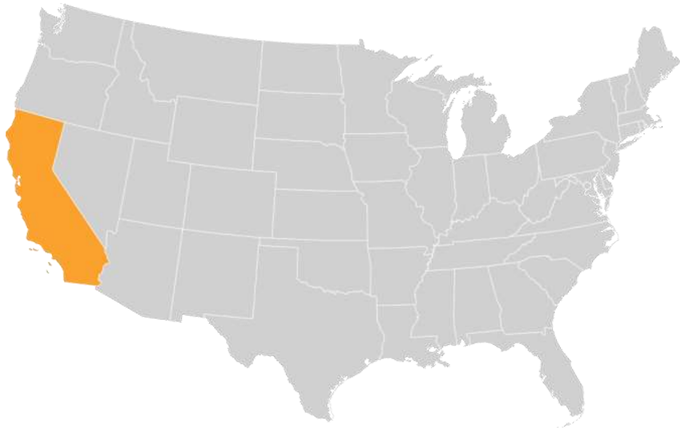

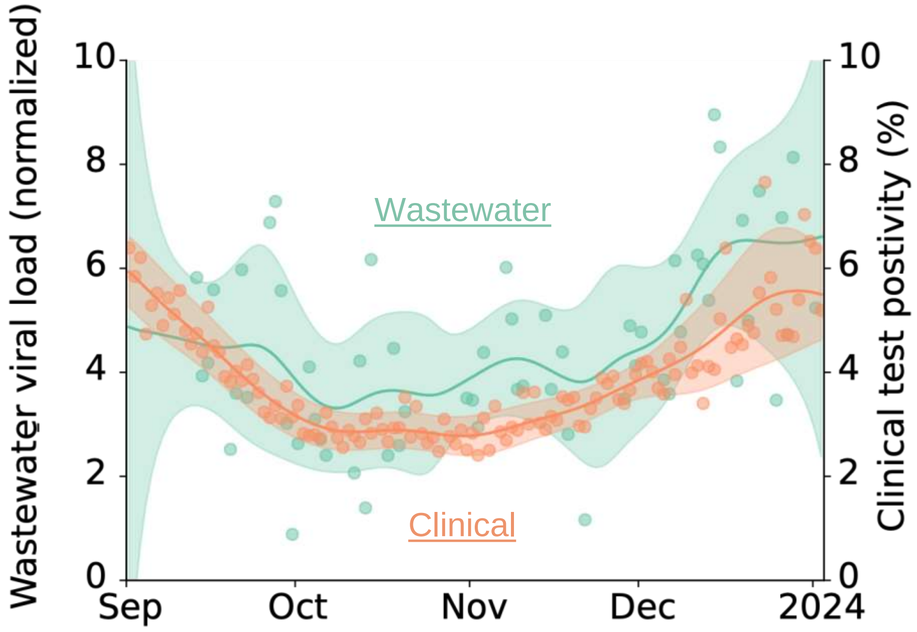

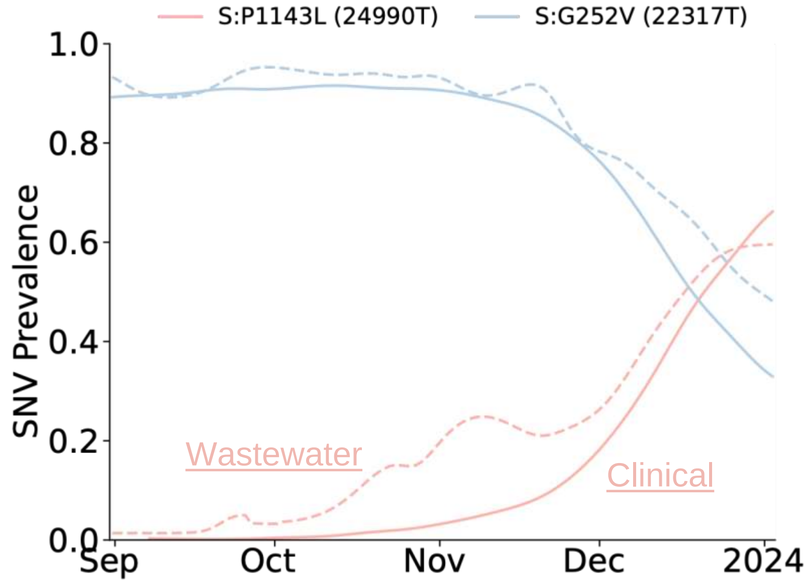

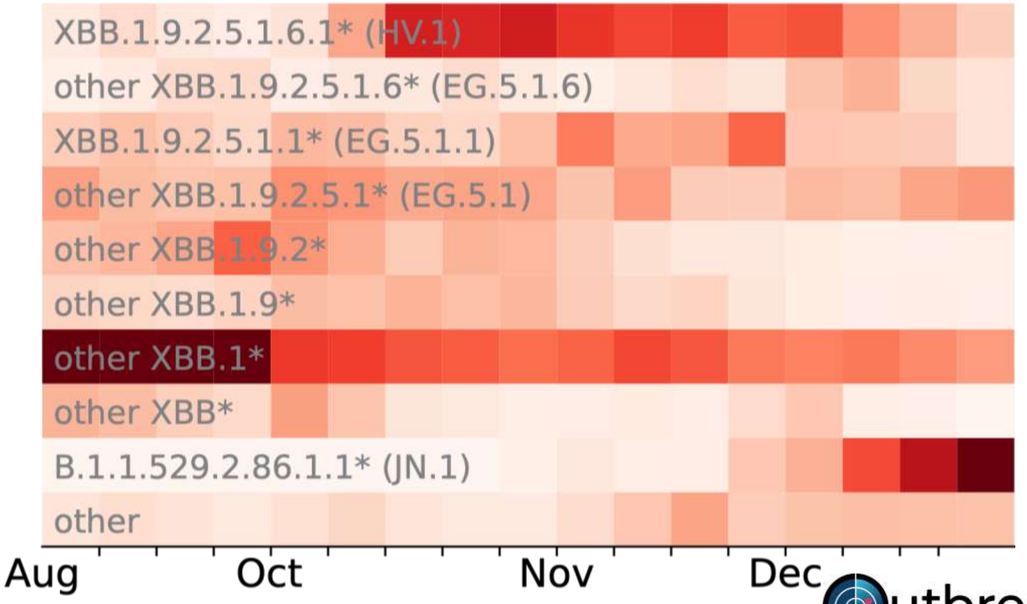

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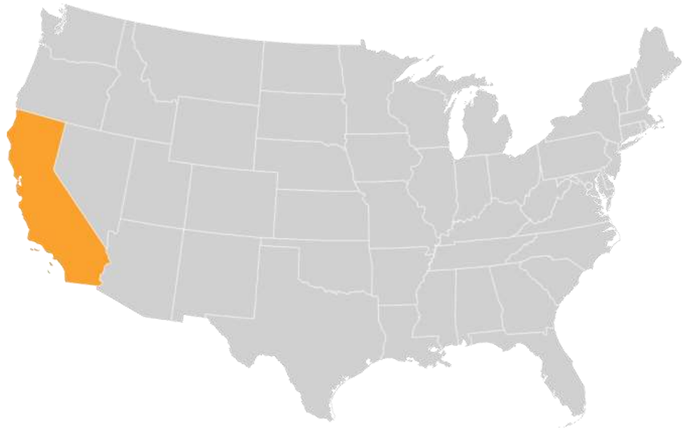

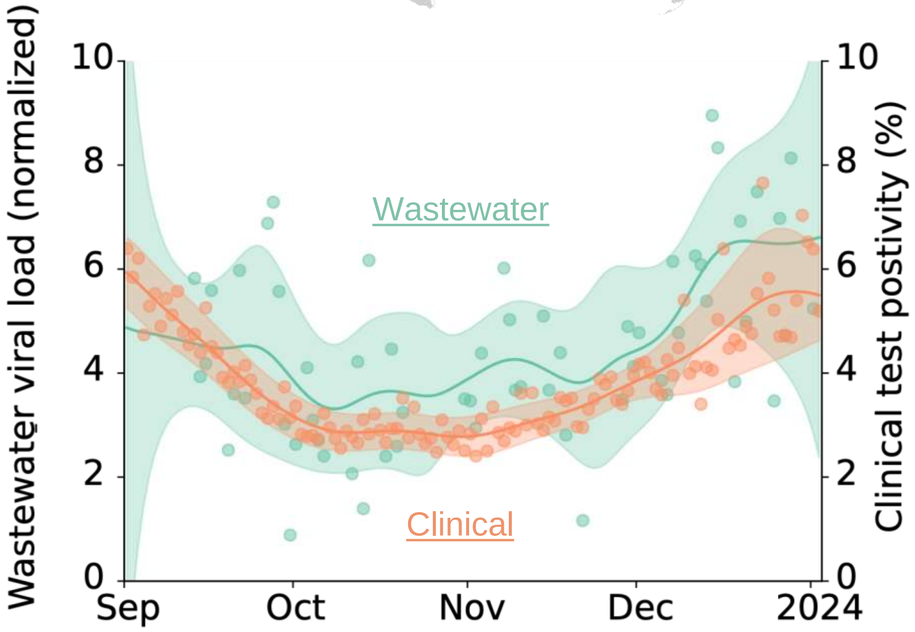

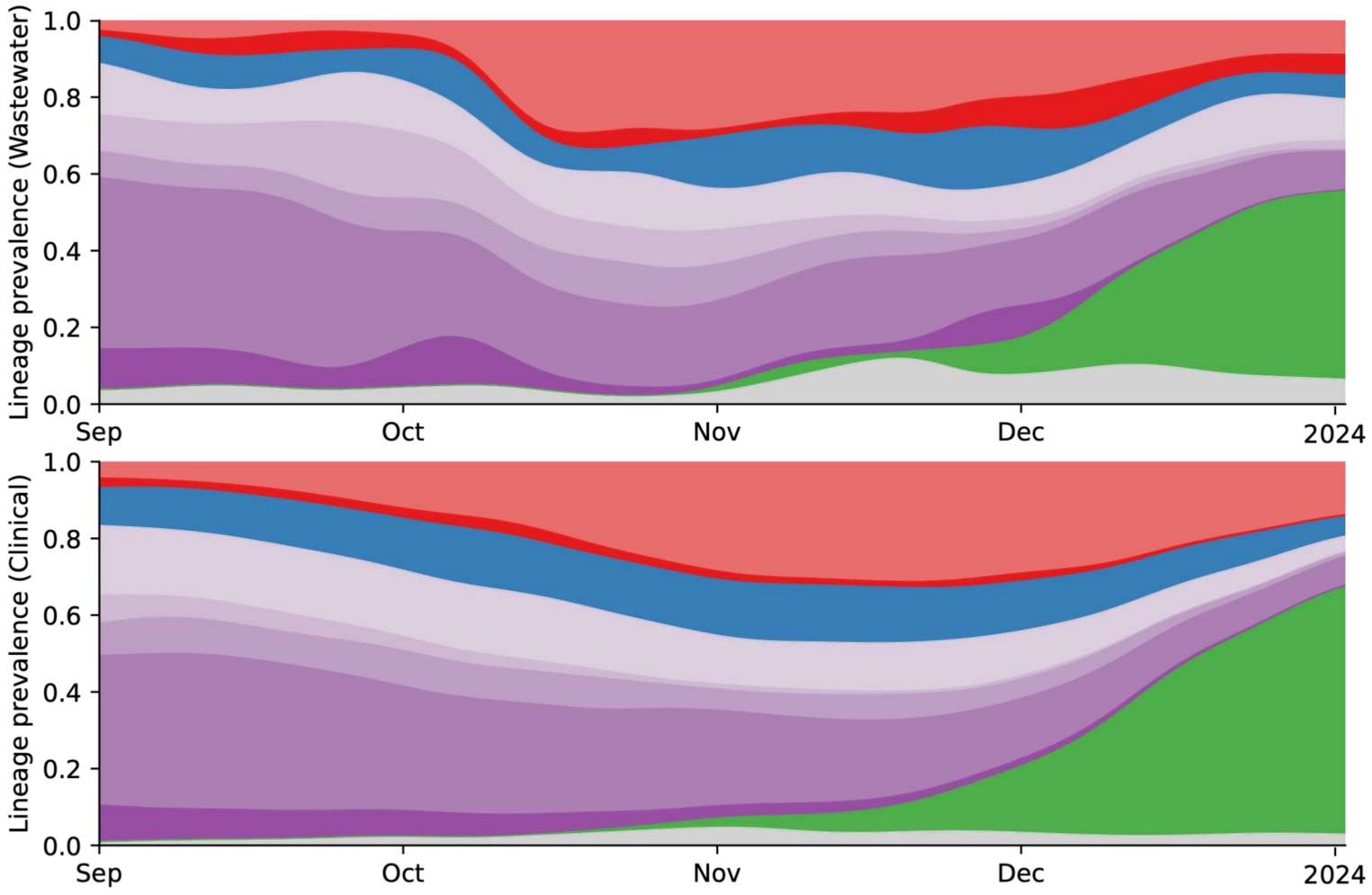

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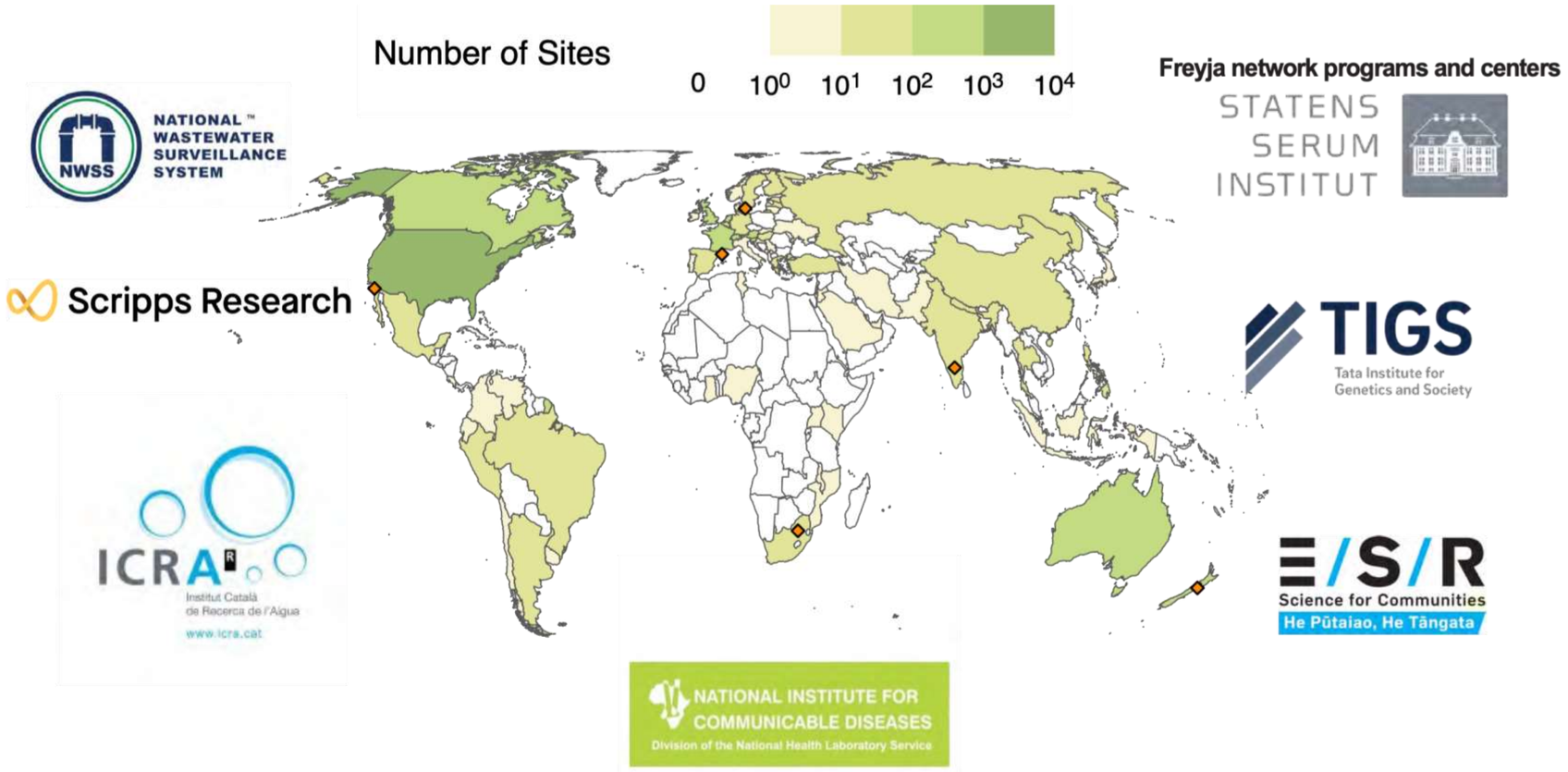
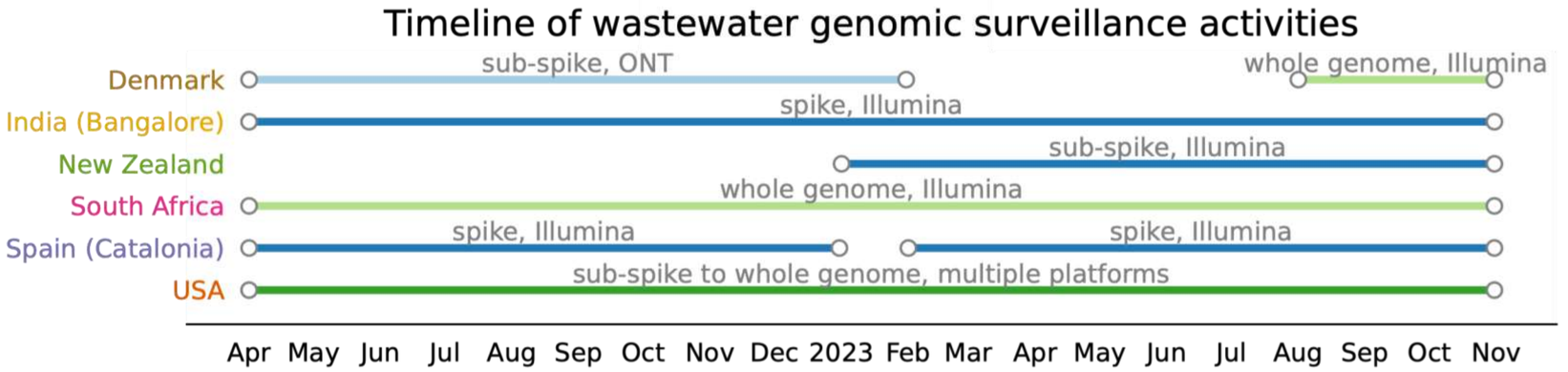
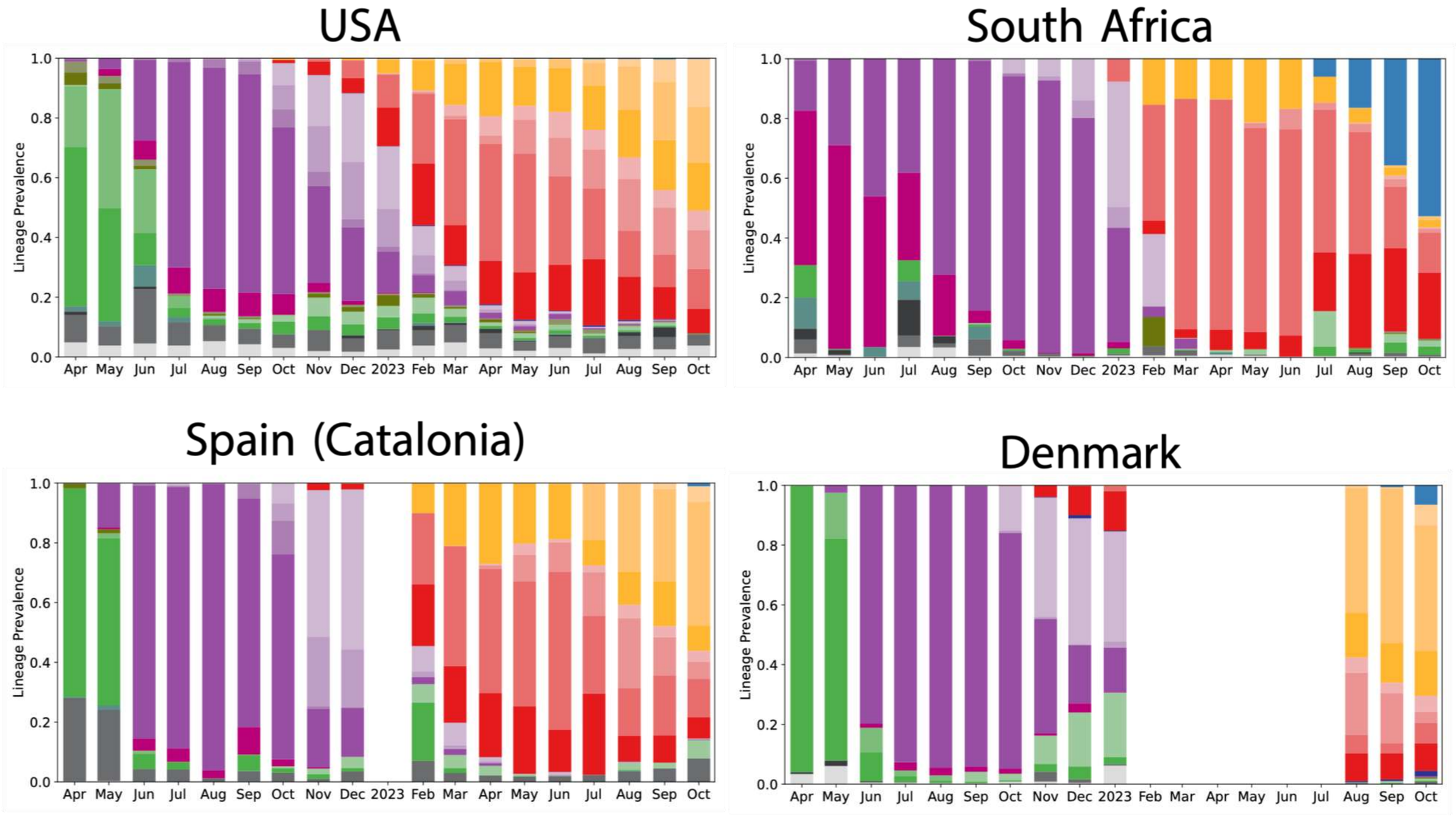
Deployment via our collaborative network



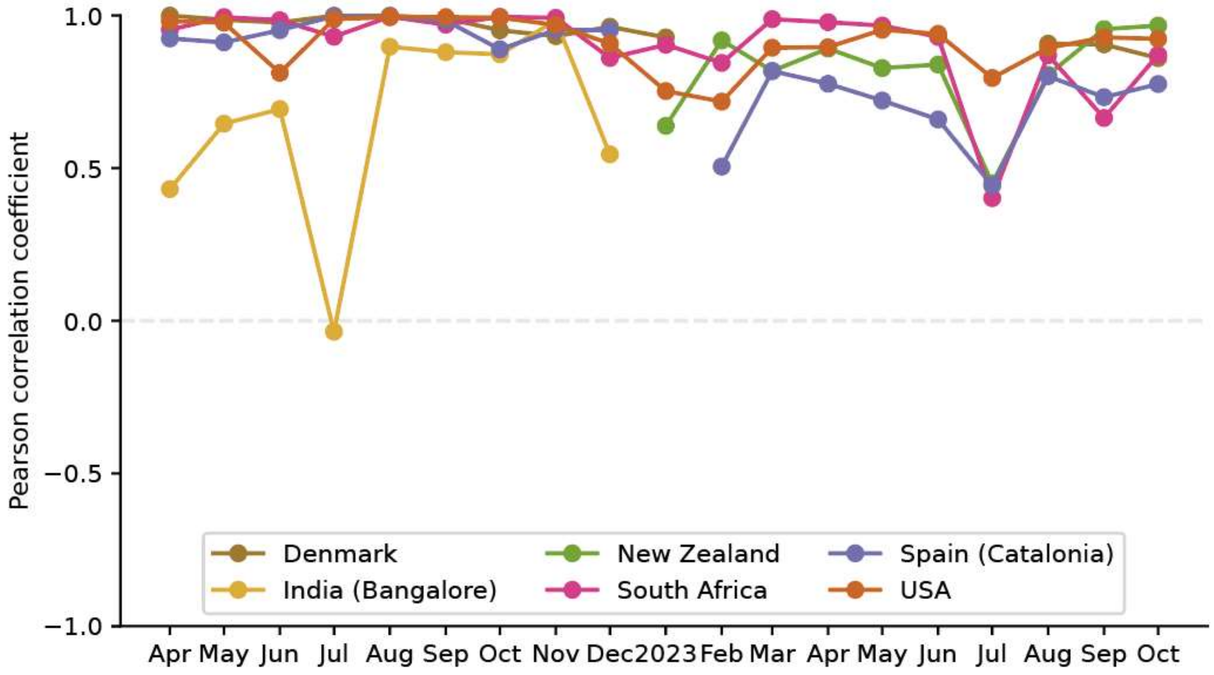


Regional and national wastewater sentinel programs

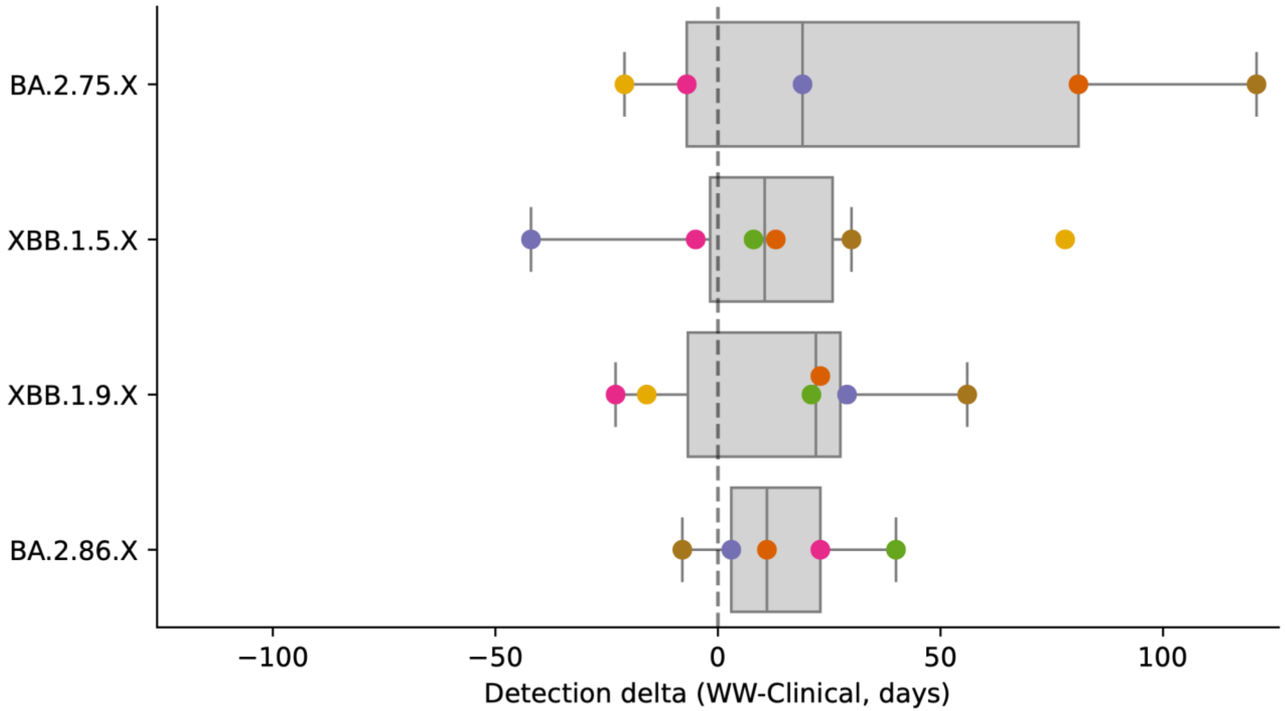


Wastewater consistently acts as a leading indicator

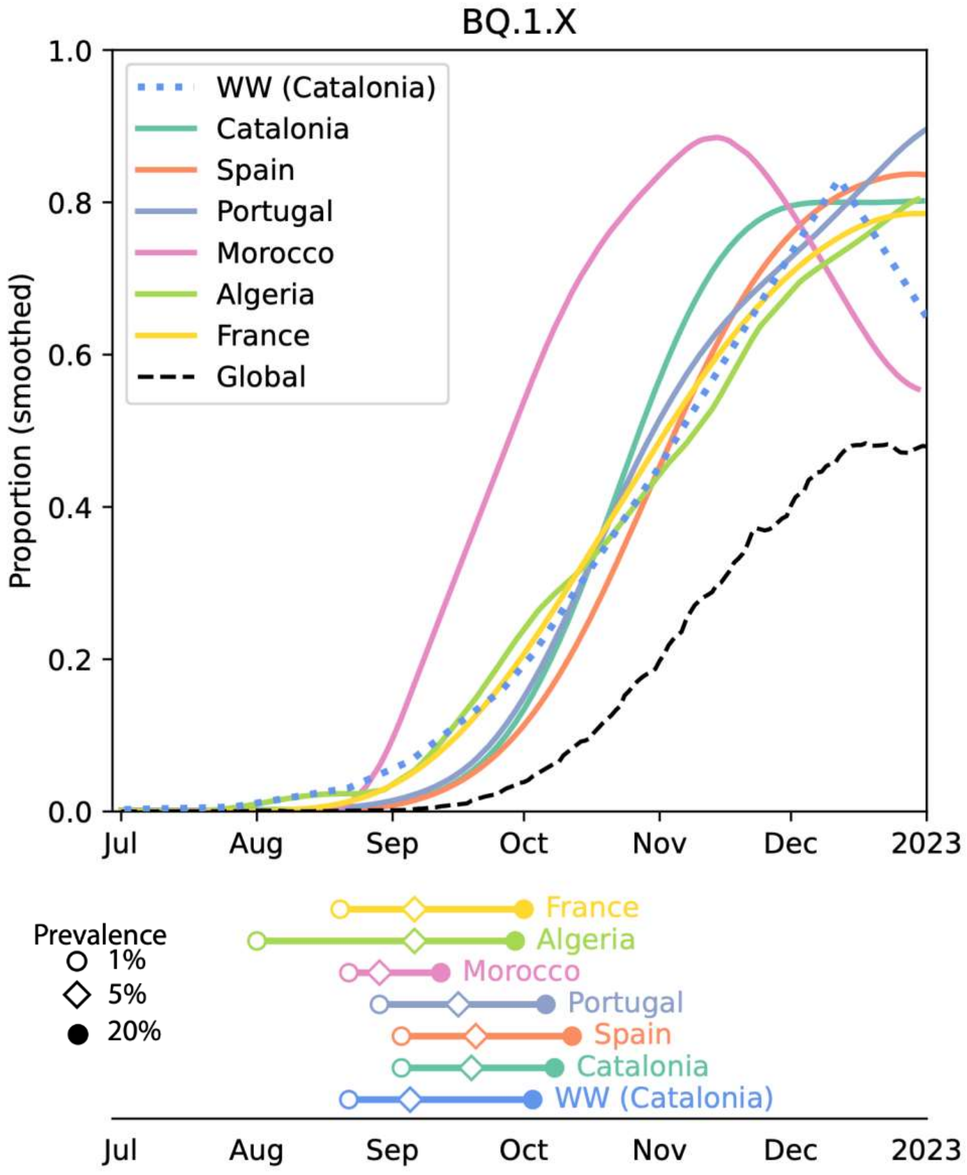
Highly correlated to clinical genomics



Earlier lineage detection via wastewater



Enhanced regional outbreak tracking and prediction



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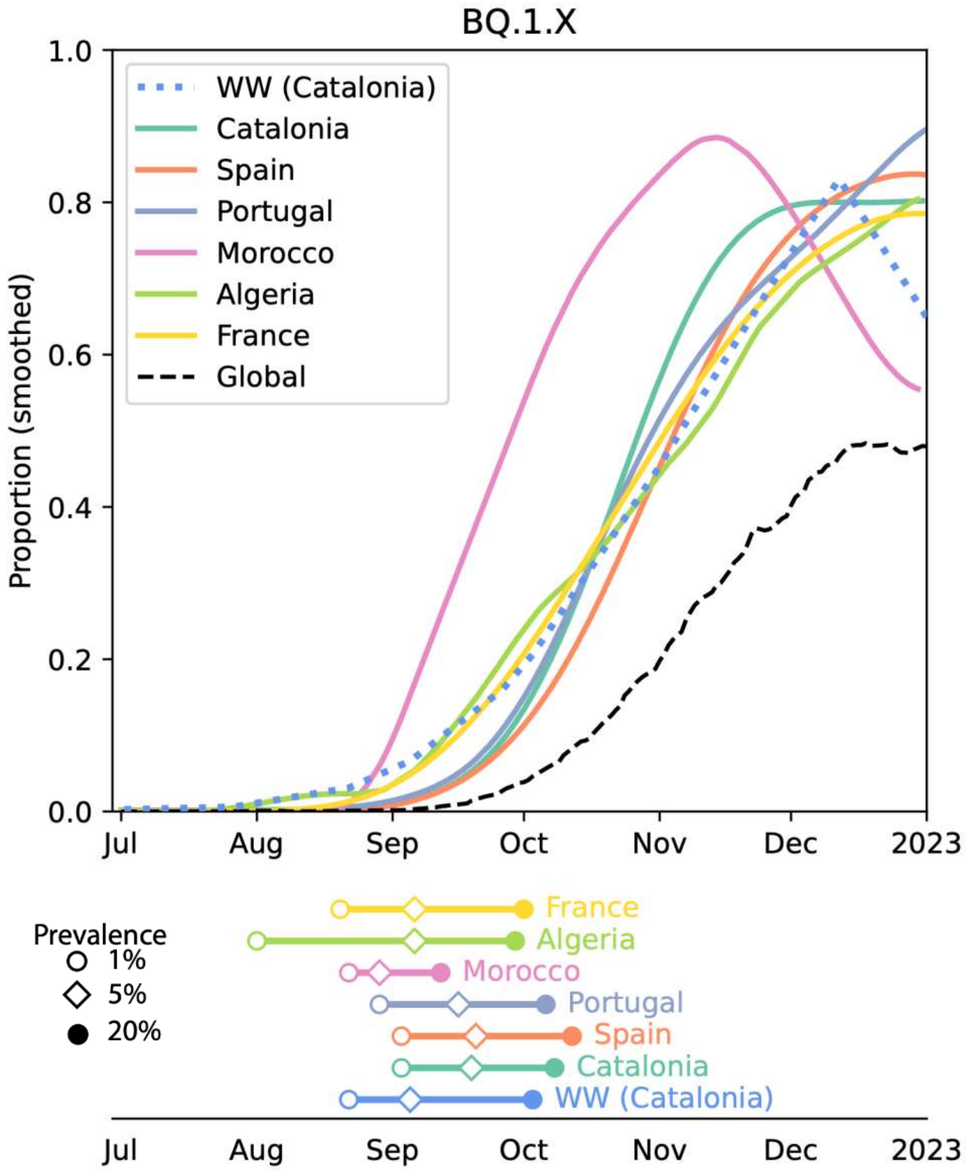
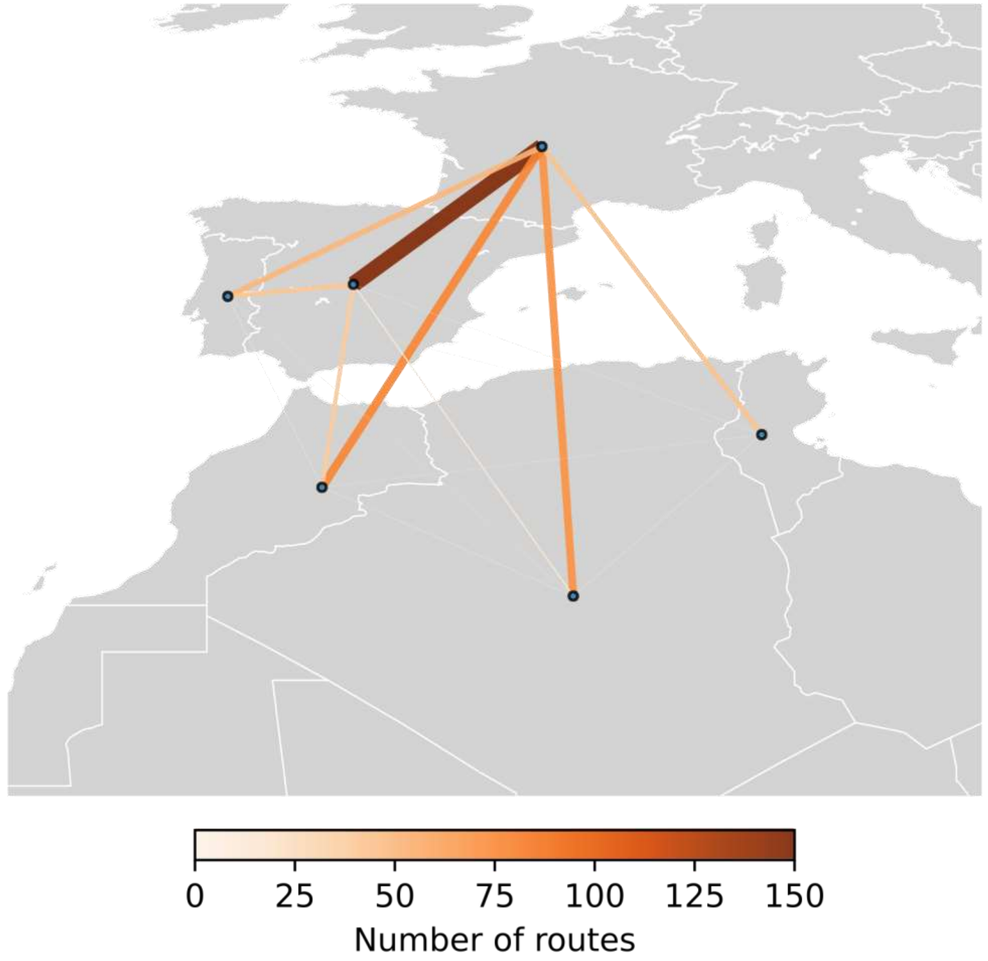
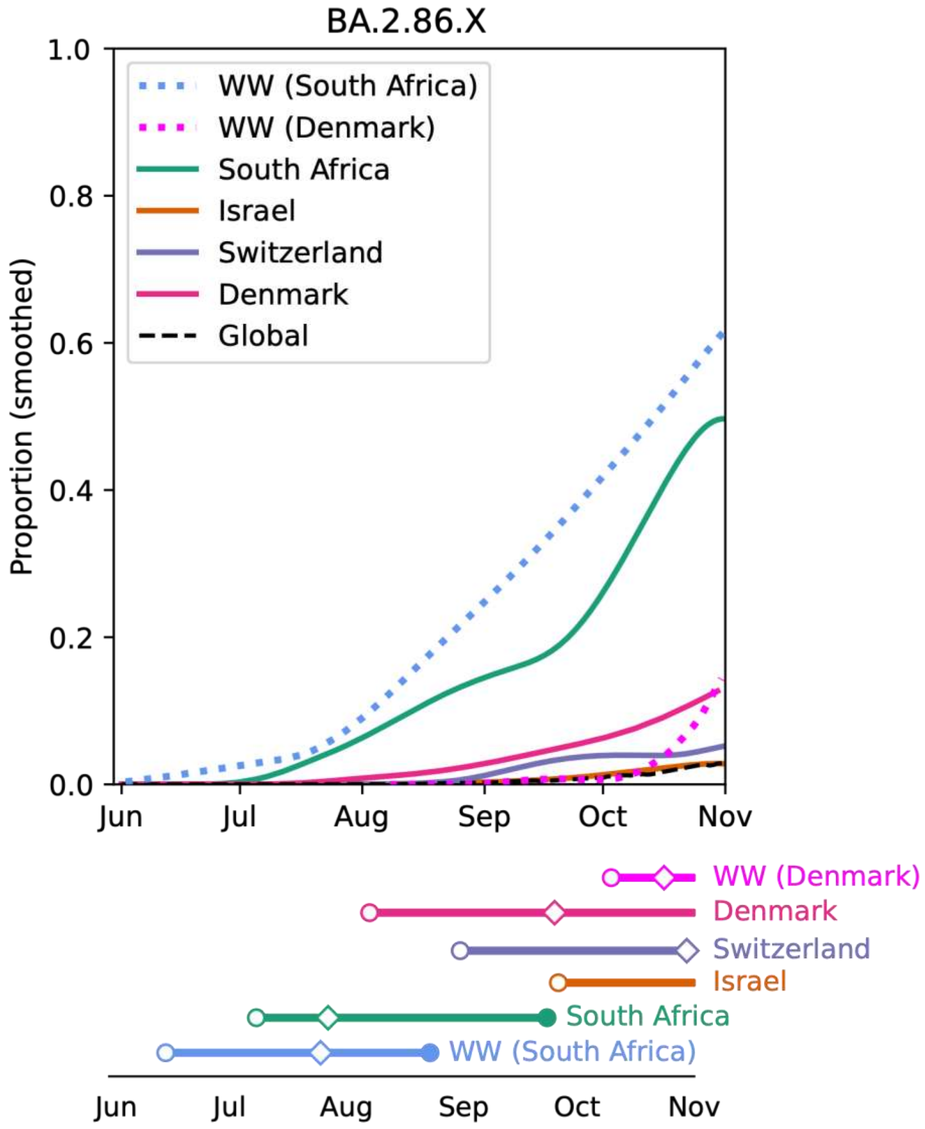




Wastewater provided first BA.2.86 detections



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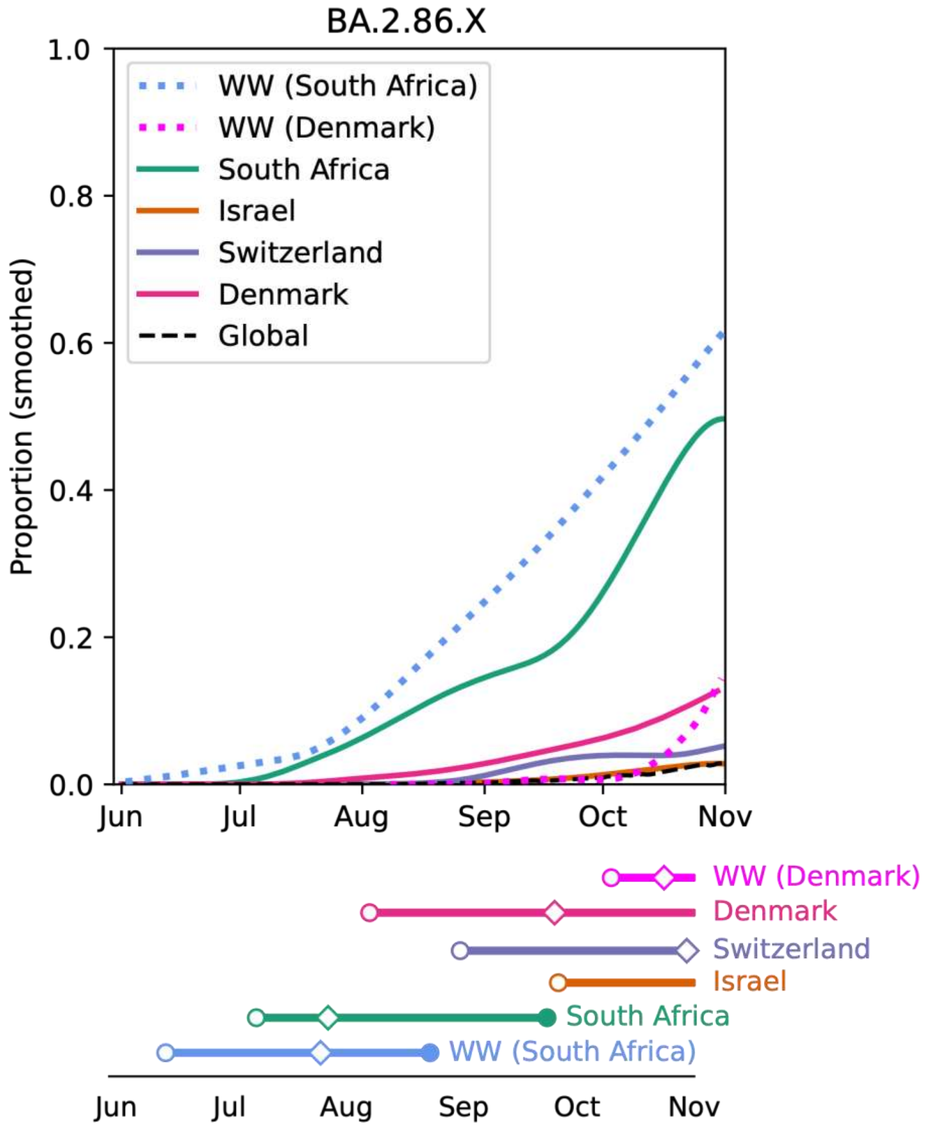
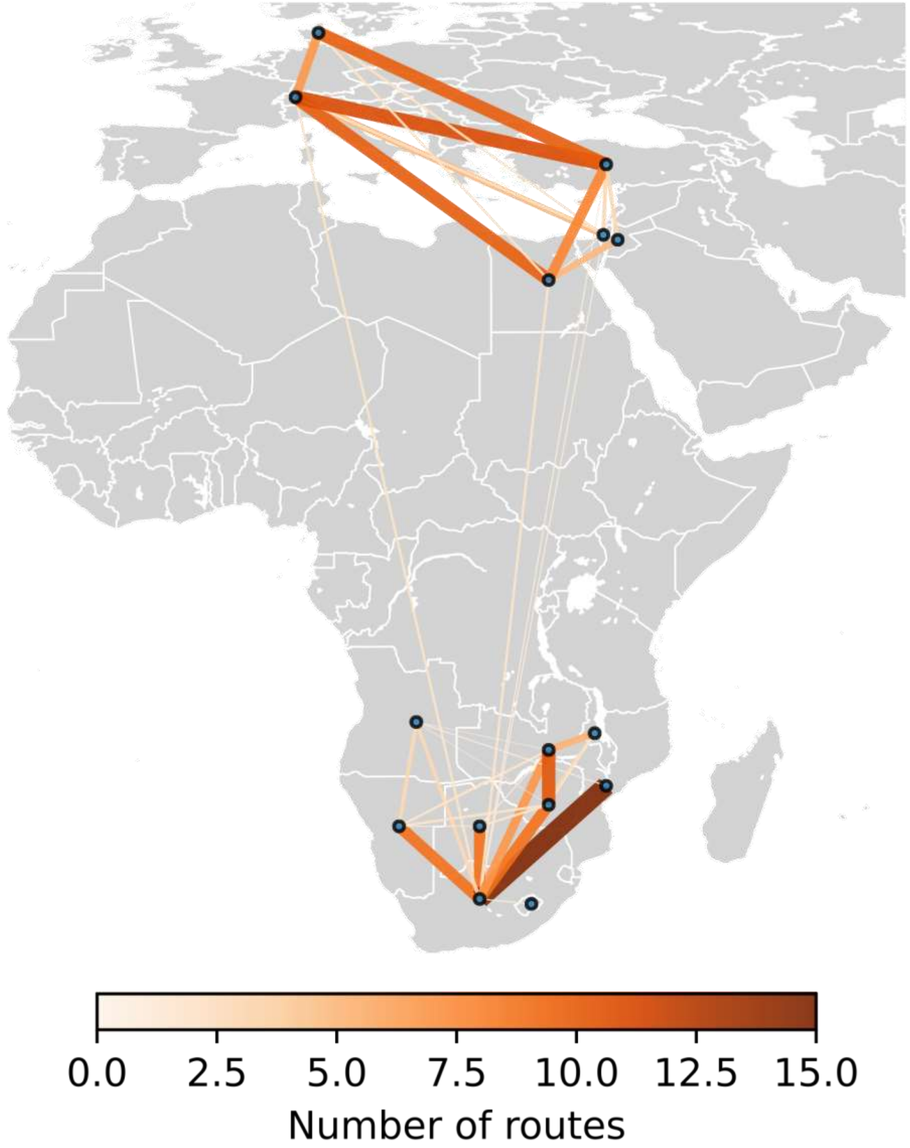
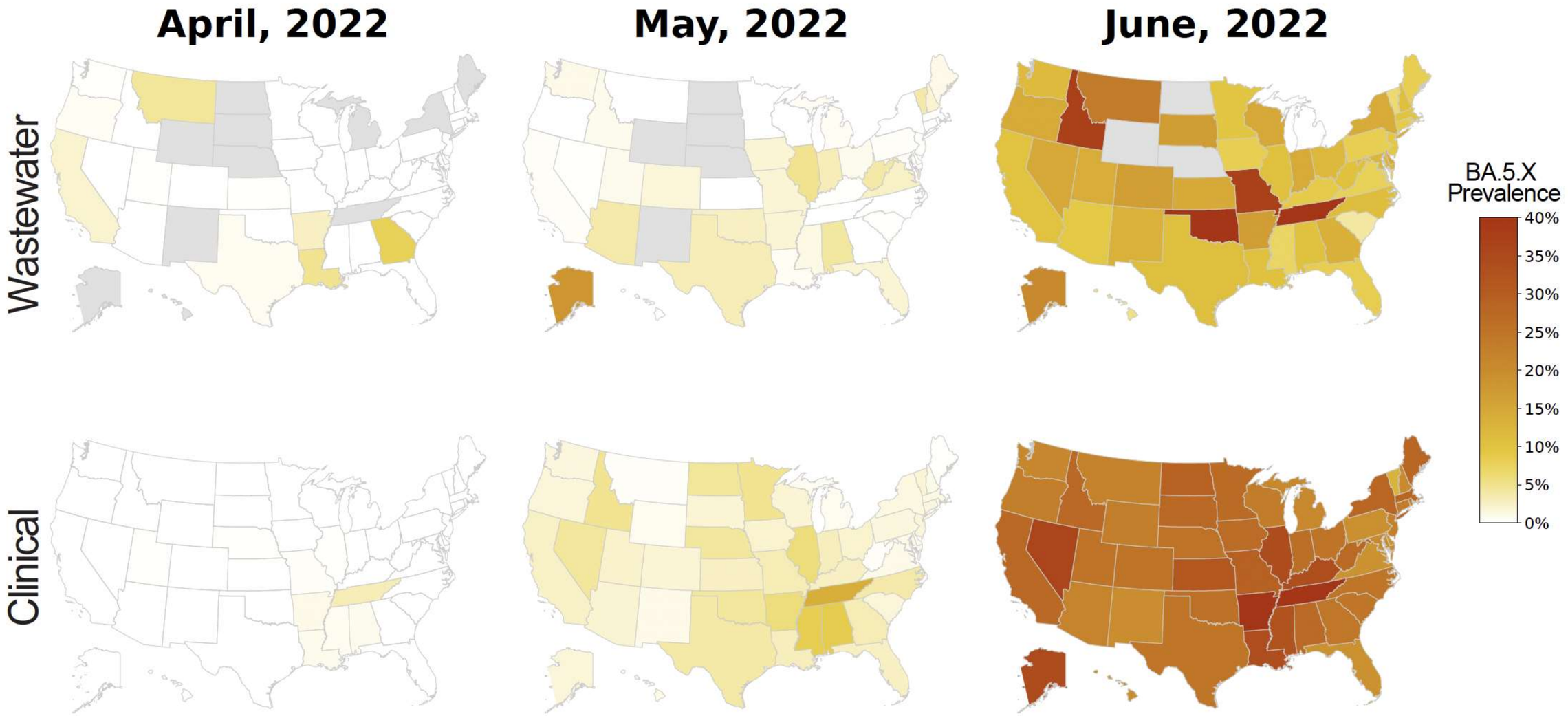
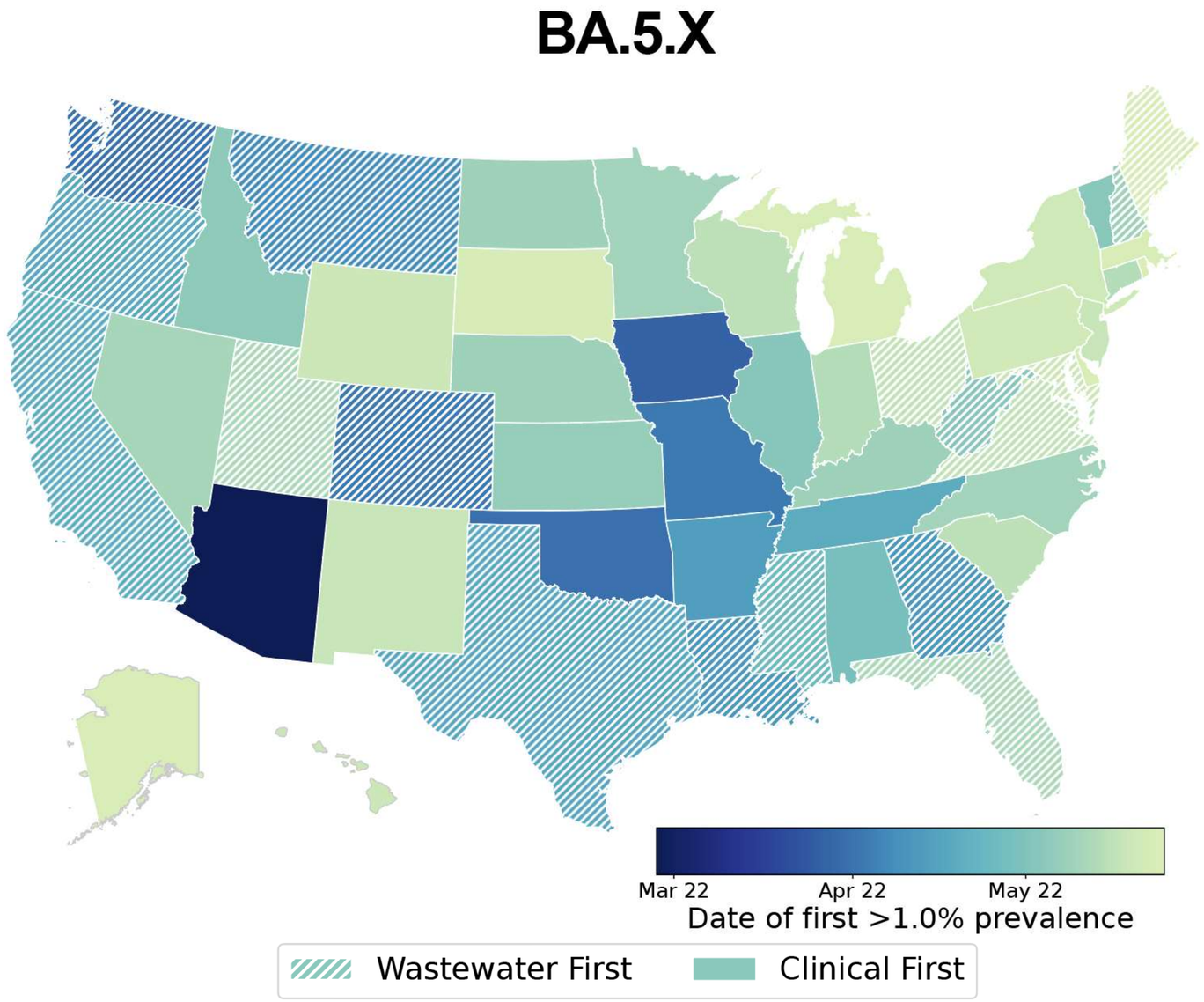




Intra-national monitoring with tunable spatial resolution

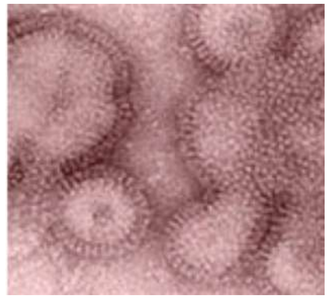


Combining for more robust, comprehensive monitoring

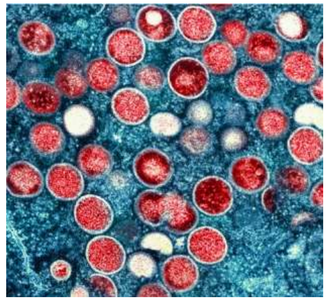


With less clinical data, wastewater is increasingly important

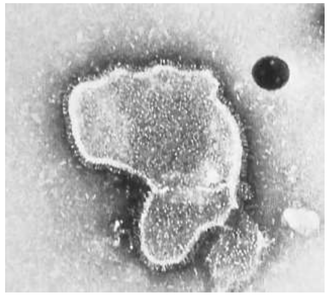
Influenza



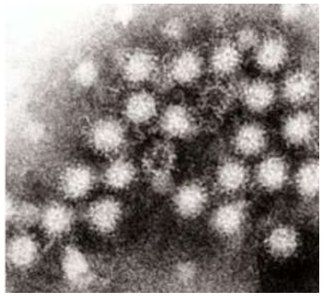
Mpox

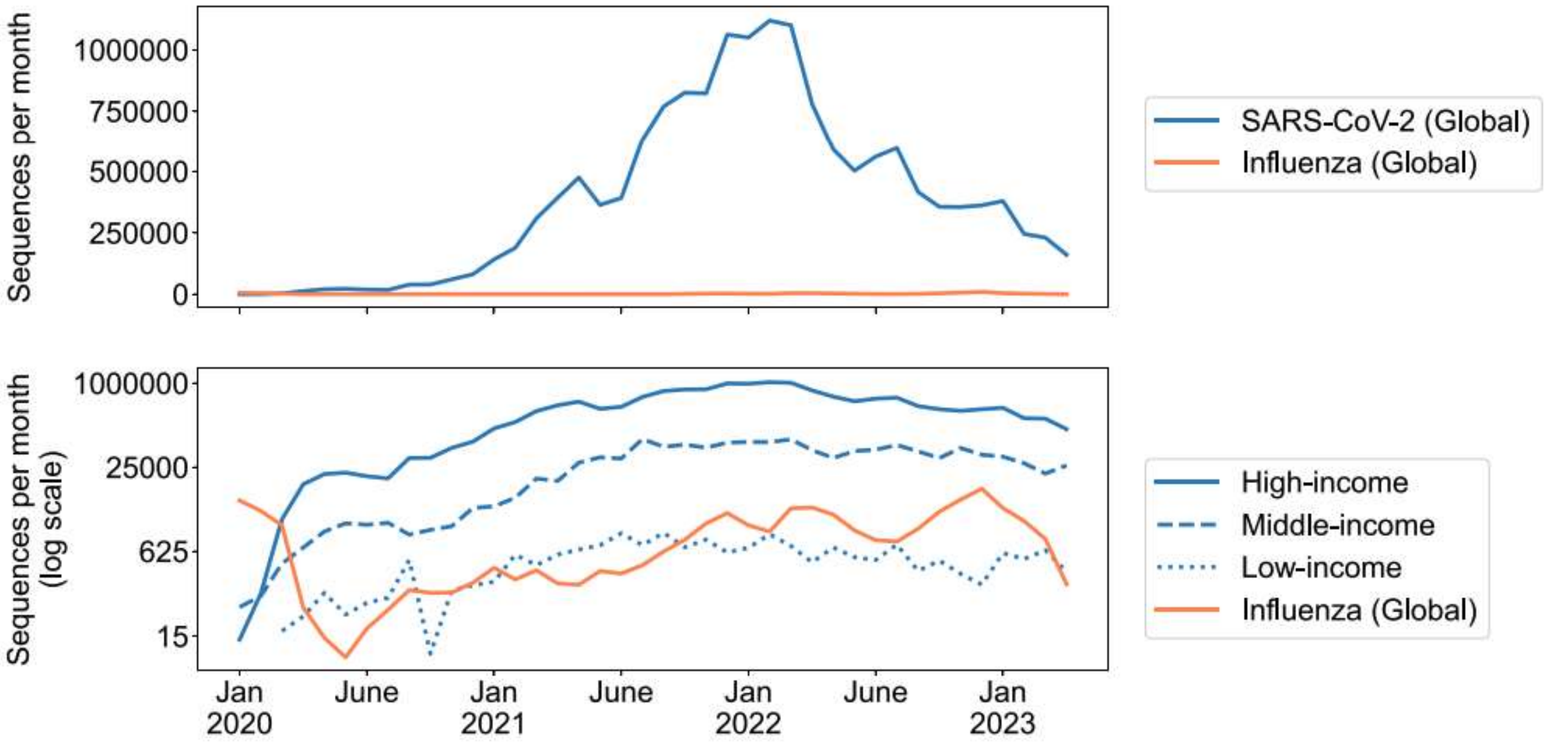


RSV



Norovirus





Ladner and Sahl, 2023

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OUTBREAK TRACKING AT SCALE

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GenBank NCBI
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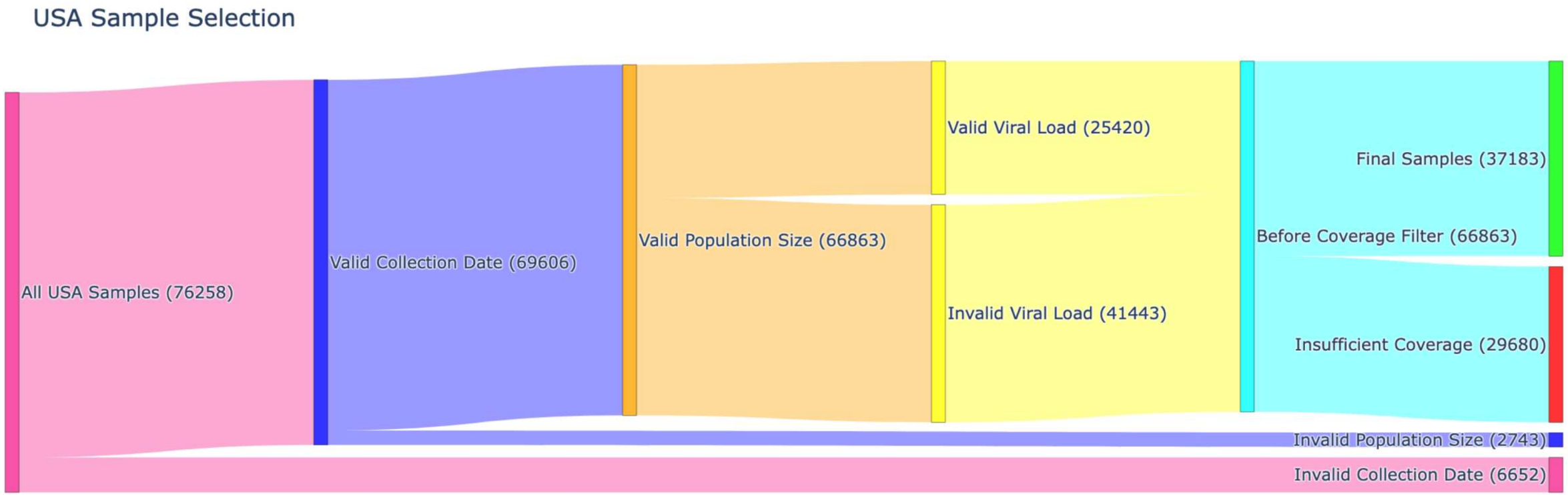
NWSS
NATIONAL WASTEWATER SURVEILLANCE SYSTEM

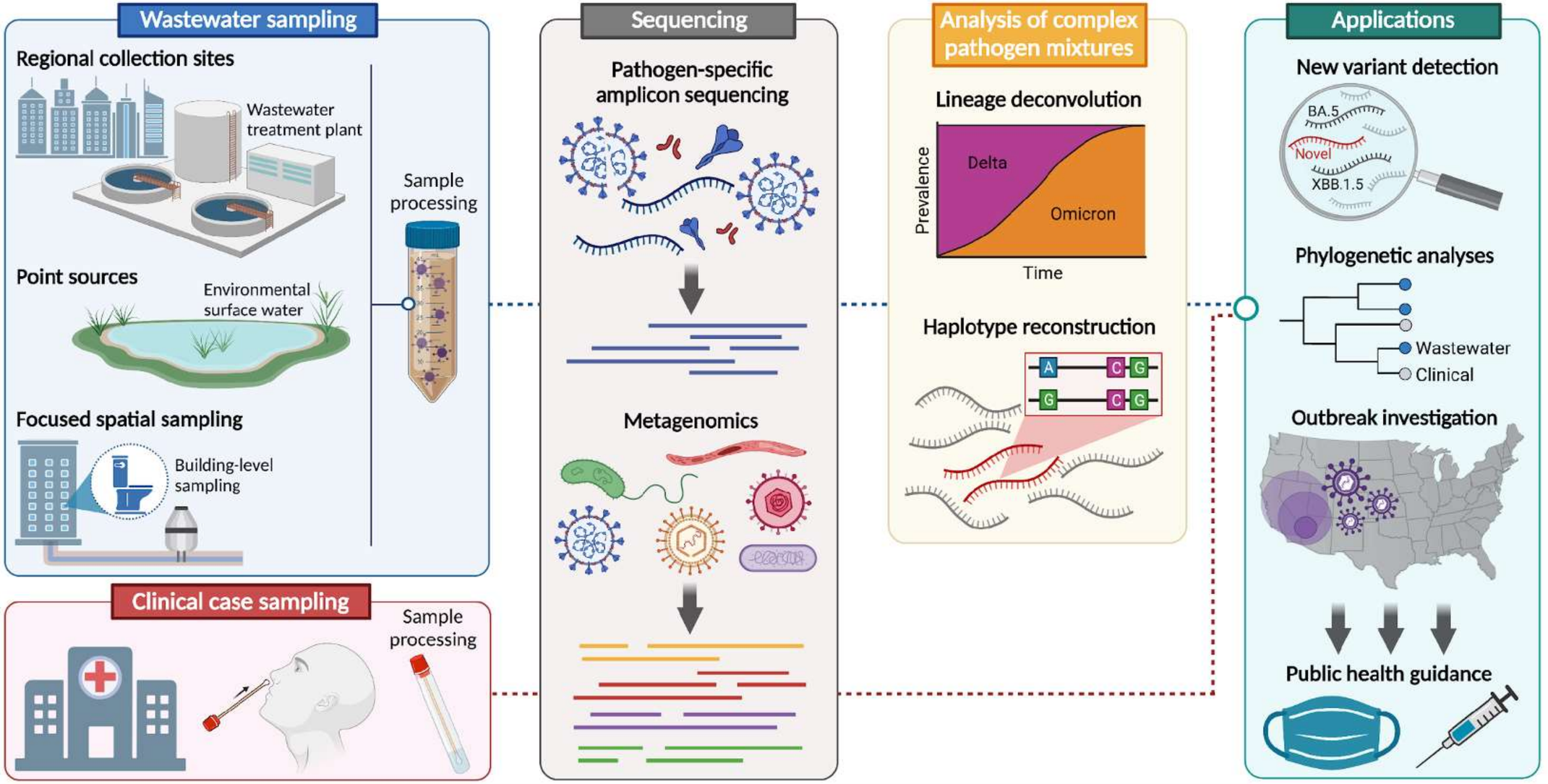
NIH National Institute of Allergy and Infectious Diseases

BILL & MELINDA GATES foundation

Quality assessment across the US



Wastewater integrated genomic surveillance across diverse contexts



Karthikeyan, Levy et al., Nature 2022

Levy et al., Science 2023