University of Regina | Faculty of Science

Wastewater surveillance of COVID-19

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Richard Agecoutay/CBC - image credit)

Federal, Provincial and Territorial Wastewater Surveillance Network

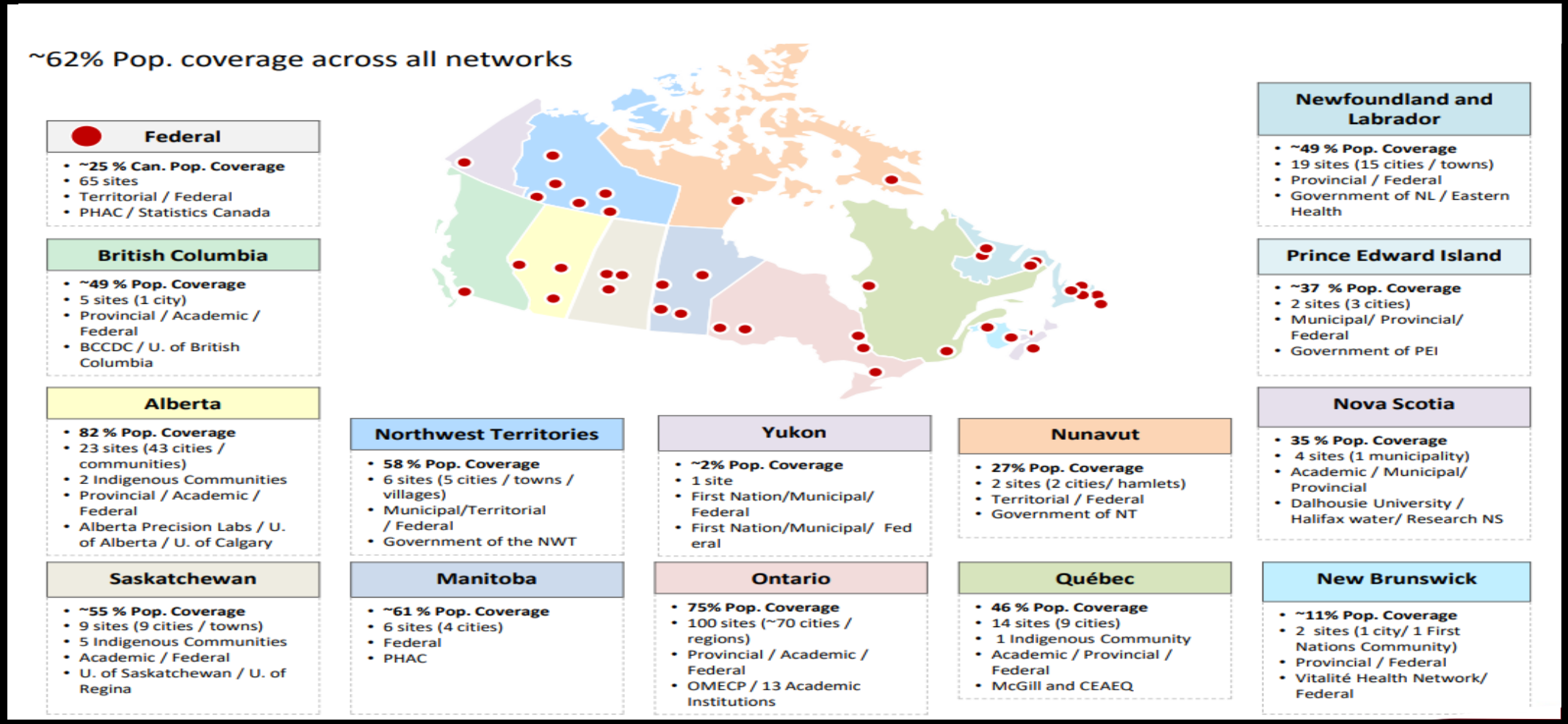
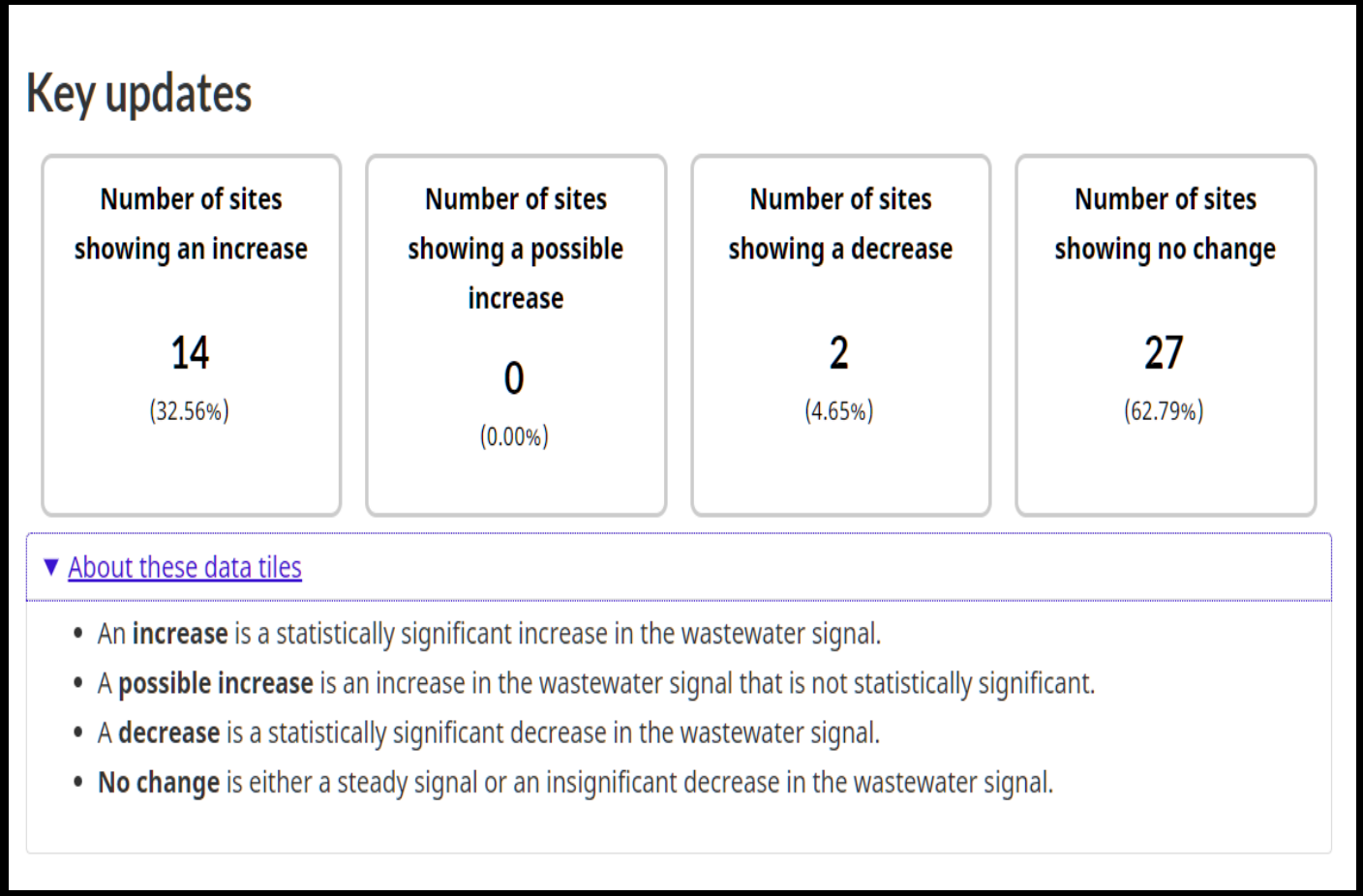


Figure from: https://nccid.ca/wp-content/uploads/sites/2/2022/09/WWS_Map_September2022.pdf

COVID-19 last week

- Regina:
  - SARS-CoV-2 levels remain stable at low levels (<10 cp/mL)



https://health-infobase.canada.ca/covid-19/wastewater/

Institute of Environmental Change and Society

- Research Institute at the University of Regina
  - Integrated Numeric Analysis Facility
  - Stressor Quantification Facility
  - Cellular Impacts Facility

Dr. Peter R. LEAVITT
Co-Director

Dr. Kerri FINLAY
Co-Director

Dr. Tzu-Chiao CHAO
Head of CIF

Dr. Nicole HANSMEIER
Associate Professor

Dr. Leah CHIBWE
Head of SQF

Dr. Bruno SOARES
Head of INAF

https://www.iecs-uregina.ca/

Biodesign Institute

- Arizona State University
- Biodesign Institute, Center for Environmental Health Engineering
  - Department of Chemistry and Environmental Engineering

Arizona State University

Team

RESEARCH AND INNOVATION CENTRE
Institute of Environmental Change and Society

REGINA, SK

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Why (waste)water?

- “One Health” perspective:
  - Integrative, multisectoral, and unifying approach
  - Goal: achieving optimal health outcomes by recognizing the interconnection between people, animals, plants, and their shared environment

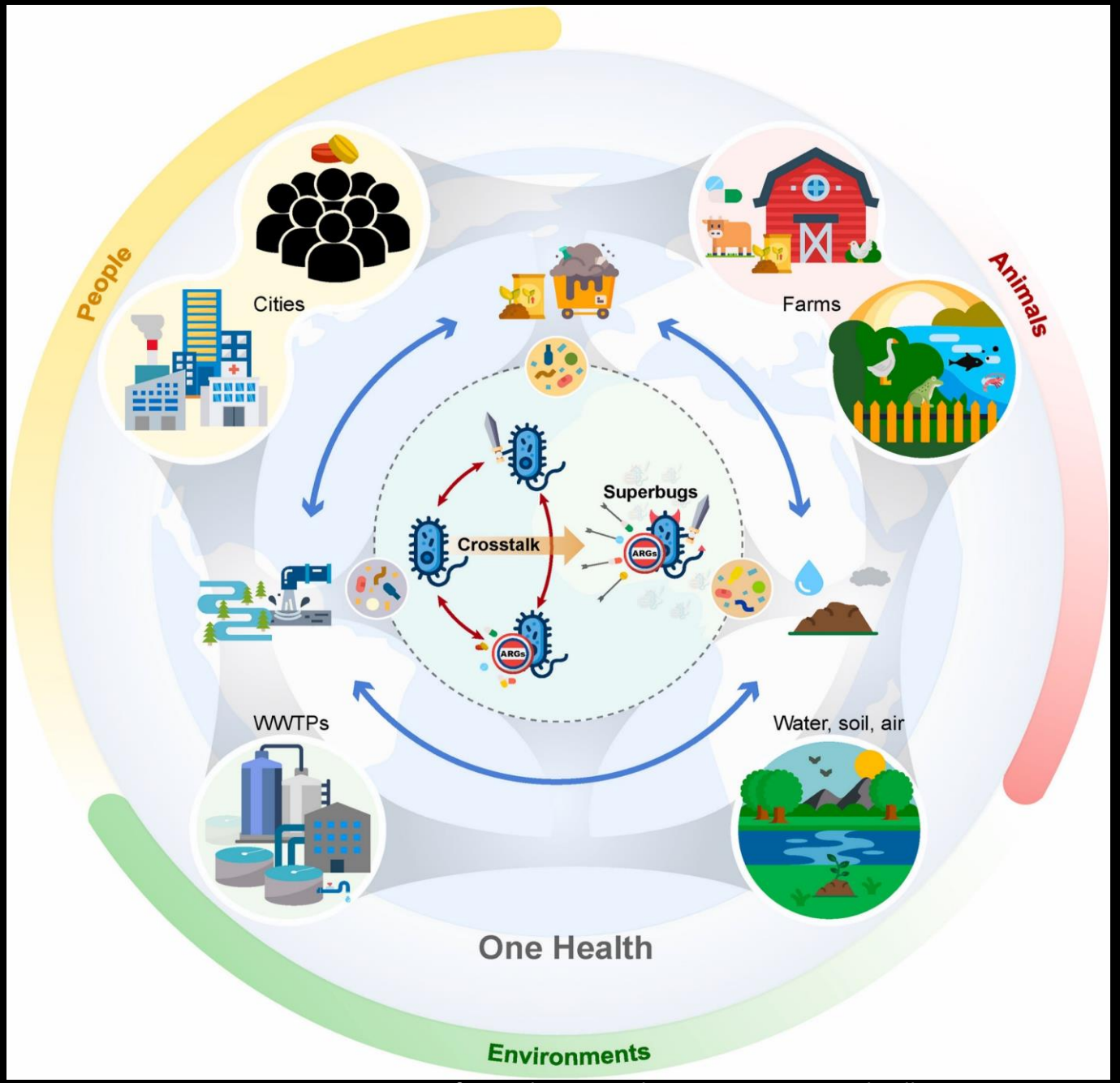
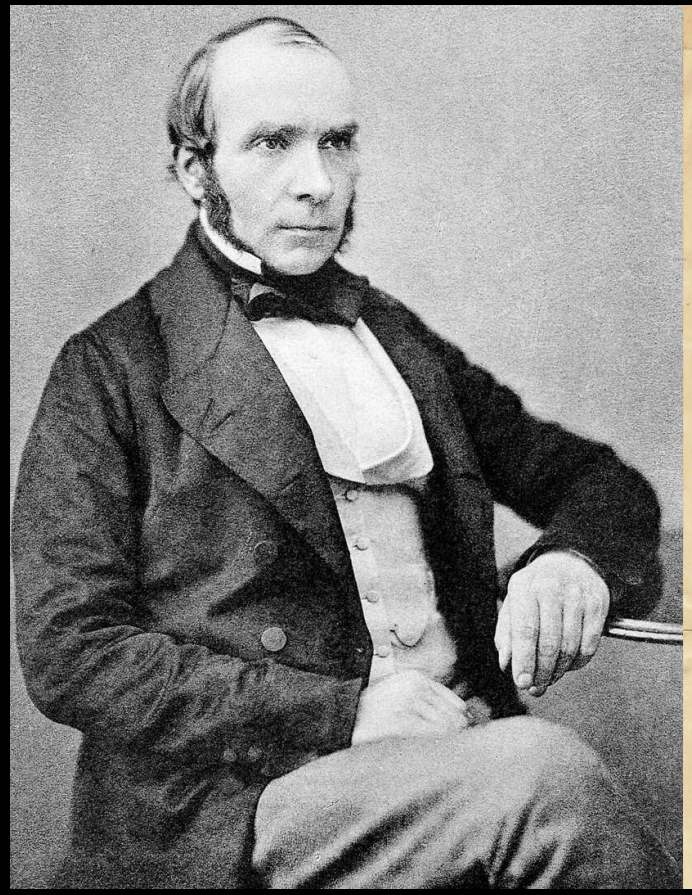
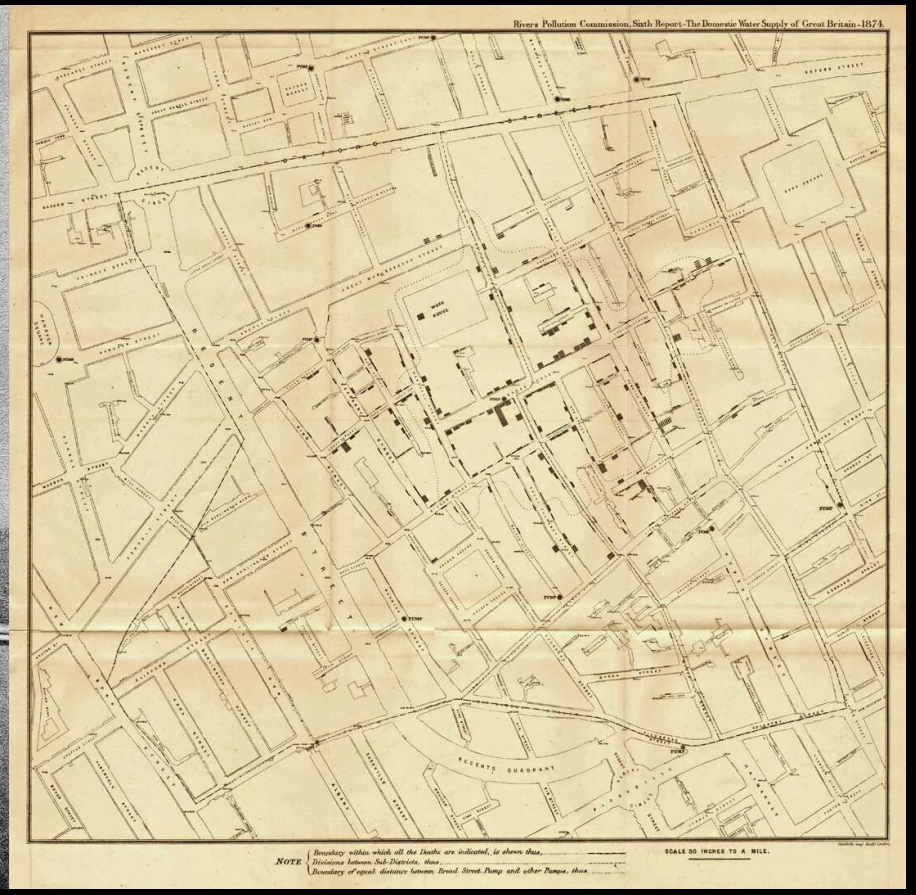


Figure from: Zhuang et al. 2021 Environmental Pollution 285, 117402

(Waste)water as disease reservoir





John Snow, 1854. Map of cholera clusters caused by sewage-polluted water linked to public water pump on Broad Street, London

Figure from: William Bynum 2013, Nature 495, 169-170

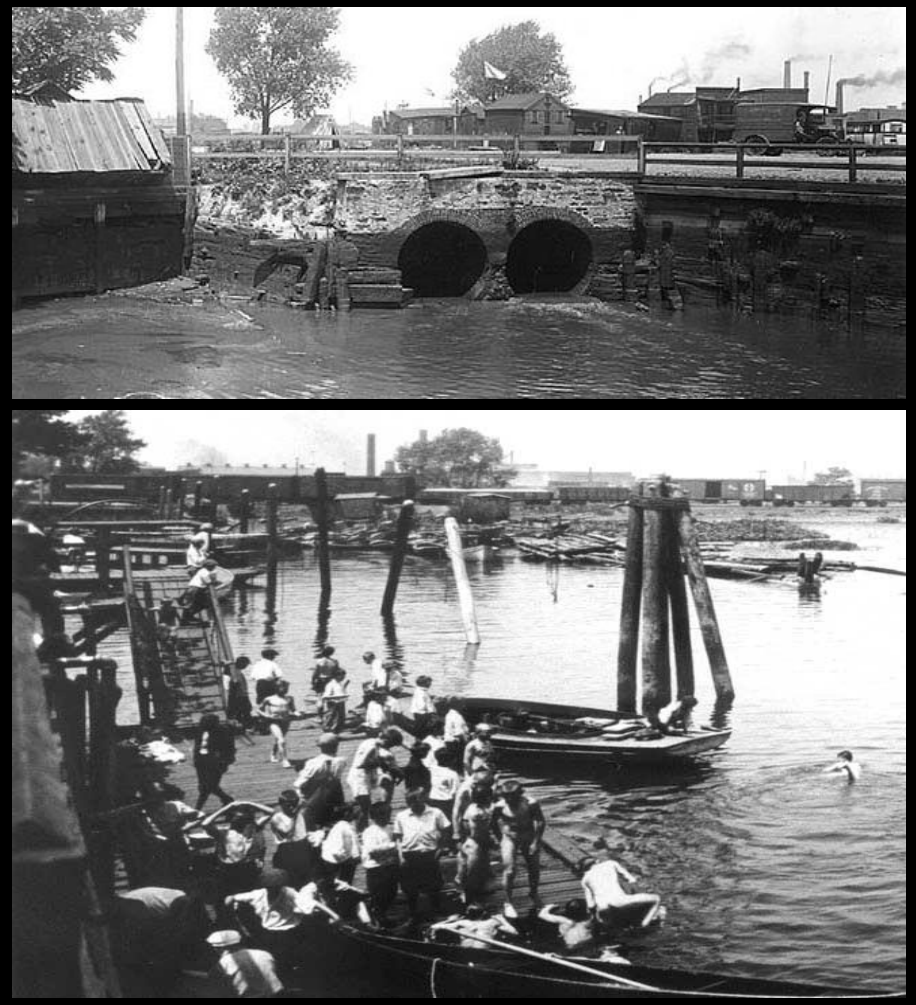
Wastewater as diagnostic tool

Poliomyelitic Virus in Sewage

JOHN R. PAUL, JAMES D. TRASK, AND C. S. CULOTTA Authors Info & Affiliations

SCIENCE · 15 Sep 1939 · Vol 90, Issue 2333 · pp. 258-259 · DOI: 10.1126/science.90.2333.258

- Pilot for poliovirus detection:
  - Charleston, South Carolina (1939)
  - Detroit, Michigan (1940)
  - Buffalo, New York (1940)



Sewer discharging from the Allegheny Avenue Sewer at Pier 126 in Philadelphia. 15 July 1918. Children swimming. Same day, same pier. (Philadelphia Water Department.)

Wastewater as diagnostic tool

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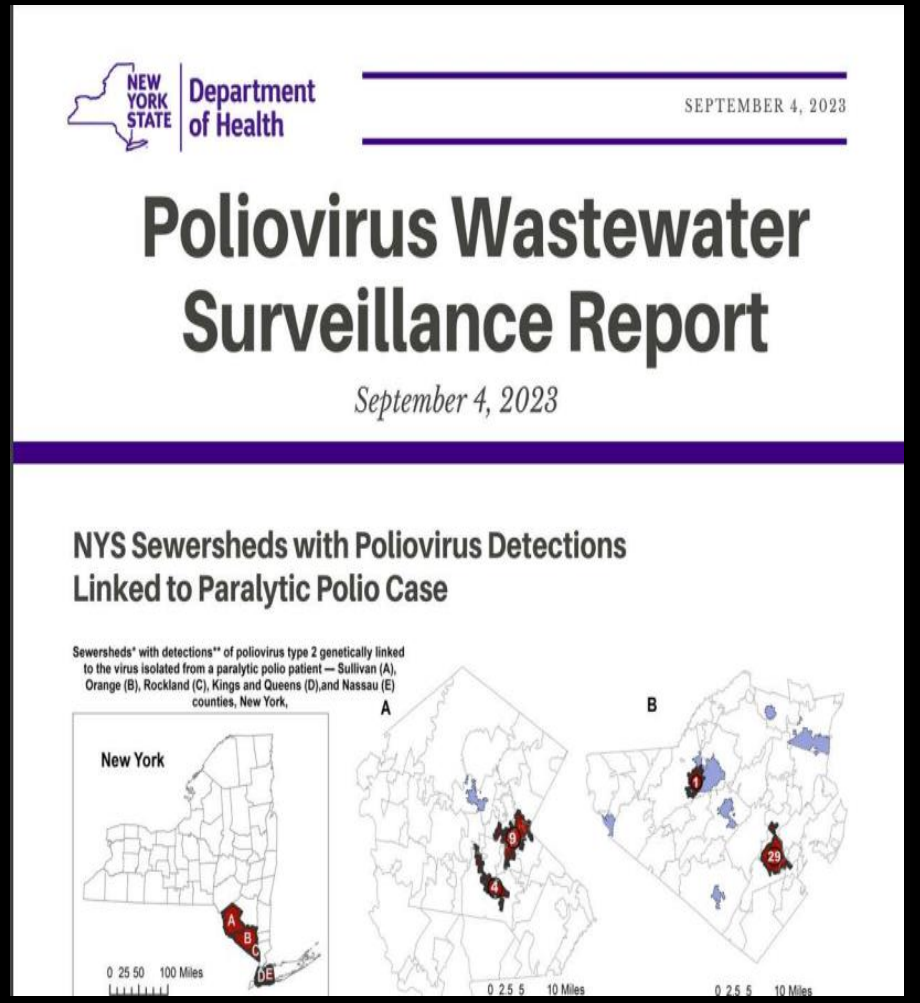
- Pilot for poliovirus detection:
  - Charleston, South Carolina (1939)
  - Detroit, Michigan (1940)
  - Buffalo, New York (1940)
- Verification tool for polio eradication (Global Polio Eradication Initiative)



NEW YORK STATE Department of Health

SEPTEMBER 4, 2023

Poliovirus Wastewater Surveillance Report

September 4, 2023

NYS Sewersheds with Poliovirus Detections Linked to Paralytic Polio Case

Sewersheds* with detections** of poliovirus type 2 genetically linked to the virus isolated from a paralytic polio patient — Sullivan (A), Orange (B), Rockland (C), Kings and Queens (D),and Nassau (E) counties, New York,

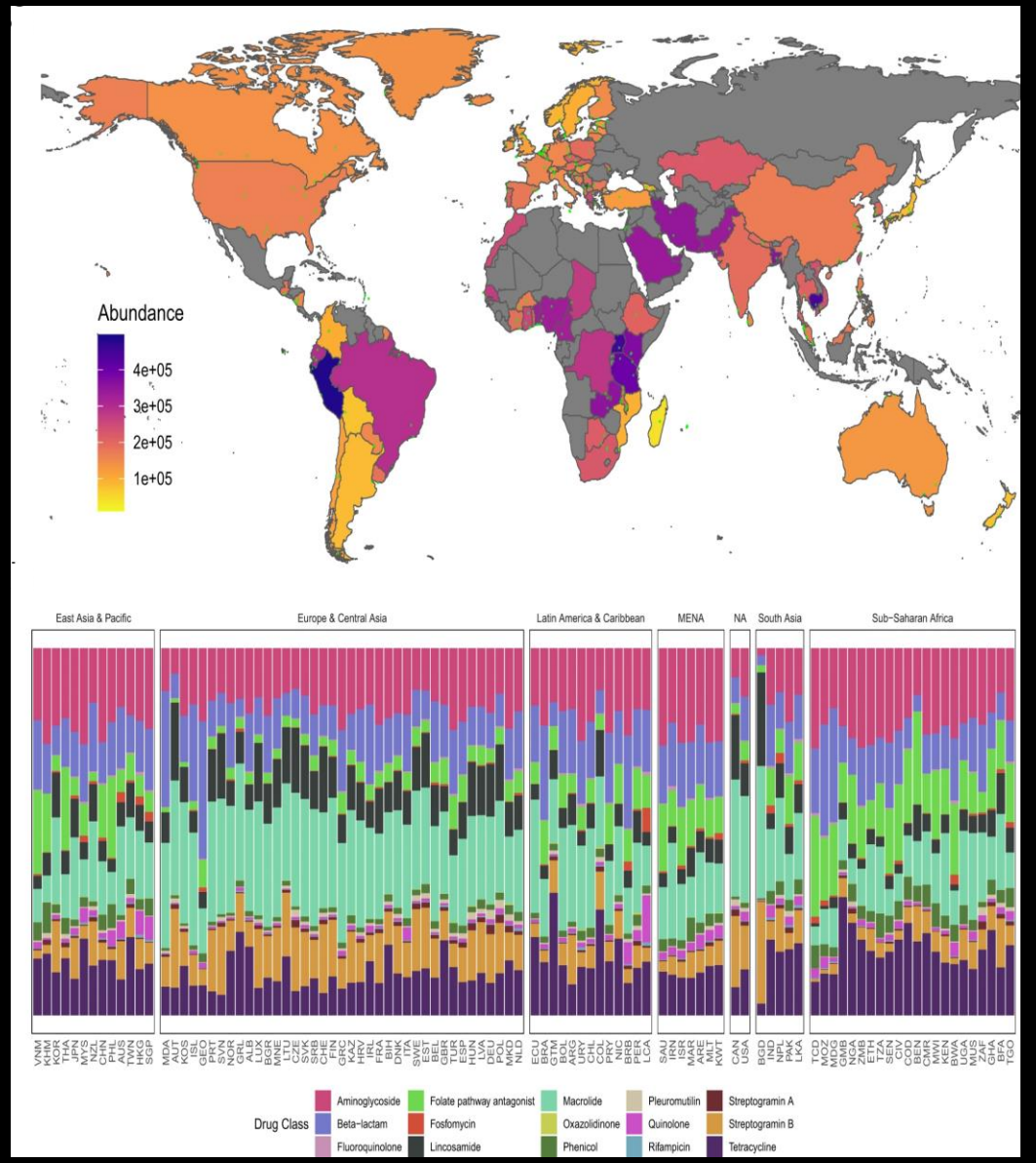
Wastewater as diagnostic tool

Genomic analysis of sewage from 101 countries reveals global landscape of antimicrobial resistance

Patrick Munk, Christian Brinch, Frederik Duus Møller, Thomas N. Petersen, Rene S. Hendriksen, Anne Mette Seyfarth, Jette S. Kjeldgaard, Christina Aaby Svendsen, Bram van Bunnik, Fanny Berglund, Global Sewage Surveillance Consortium, D. G. Joakim Larsson, Marion Koopmans, Mark Woolhouse & Frank M. Aarestrup

Nature Communications **13**, Article number: 7251 (2022) | Cite this article

- Wastewater monitoring used for enteric pathogens (water quality, wastewater use)
- Antimicrobial resistance tracking



Choropleth of the world colored by the country-wise average total AMR load and stacked bar chart of relative abundances per drug class per country.

Munk et al. 2022 Nature Communication 13, 7251

Wastewater as diagnostic tool

Cocaine in surface waters: a new evidence-based tool to monitor community drug abuse

Research | Open Access | Published: 05 August 2005 | 4, Article number: 14 (2005)

- Drug monitoring (licit and illicit):
  - Europe since 2007

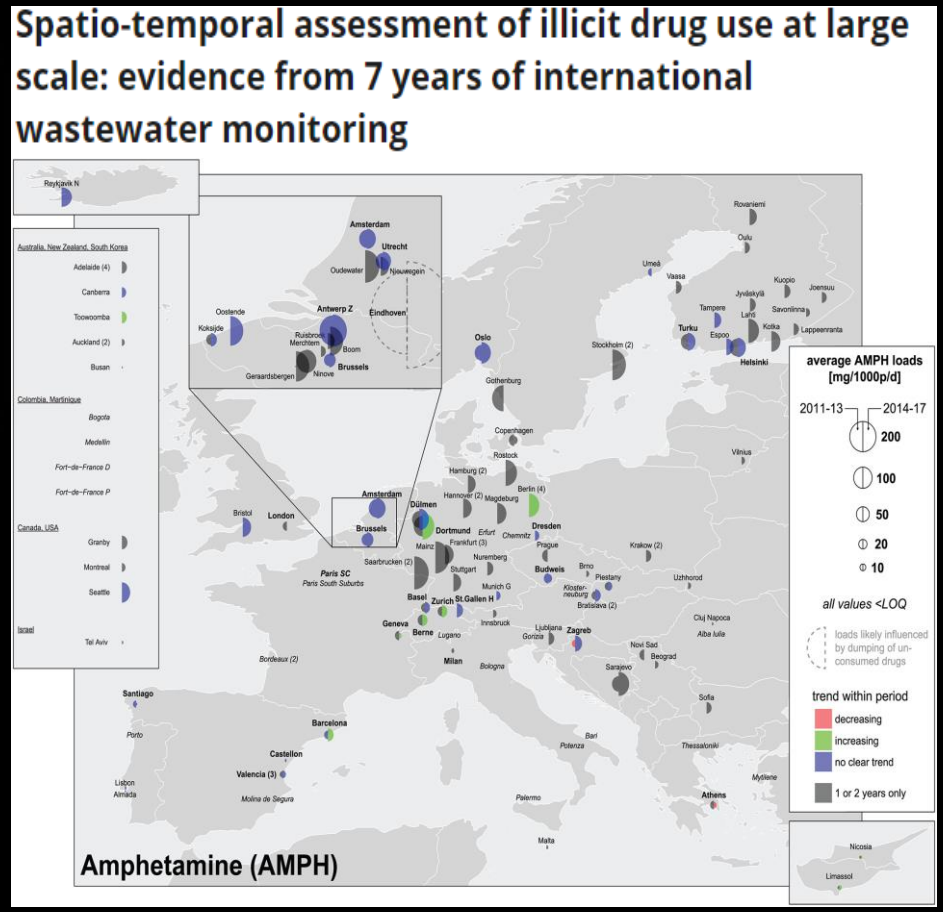


Fig. Mean population-normalized amphetamine loads (mg/1000 people/day) 2011–13 versus 2014–17

Gonzalez-Marino et al. 2019 Addiction 115, 1090-120

Wastewater as diagnostic tool

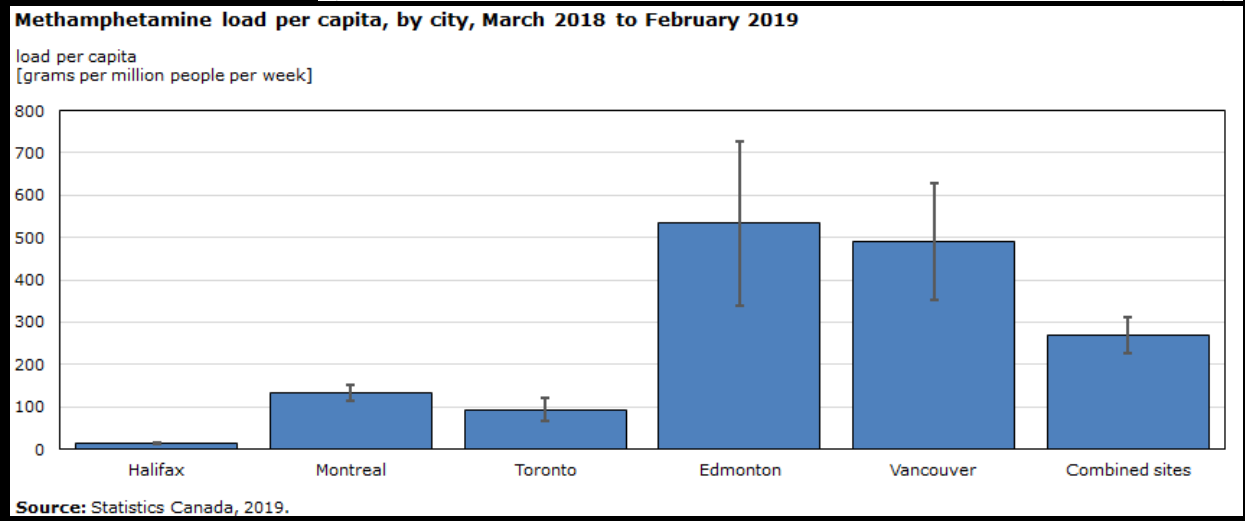
Cocaine in surface waters: a new evidence–based tool to monitor community drug abuse

Research | Open Access | Published: 05 August 2005 | 4, Article number: 14 (2005)

- Drug monitoring (licit and illicit):
  - Europe since 2007
  - Pilot in Canada in 2018/19

Wastewater Pilot-Test Design

Test Site	Wastewater Treatment Plants	2018 Population (millions of people)
Central Halifax	3	0.2
Montreal Island	1	2.0
Toronto City	4	2.8
Edmonton City	1	1.0
Vancouver metro area	5	2.5
Total	**14**	**8.4**

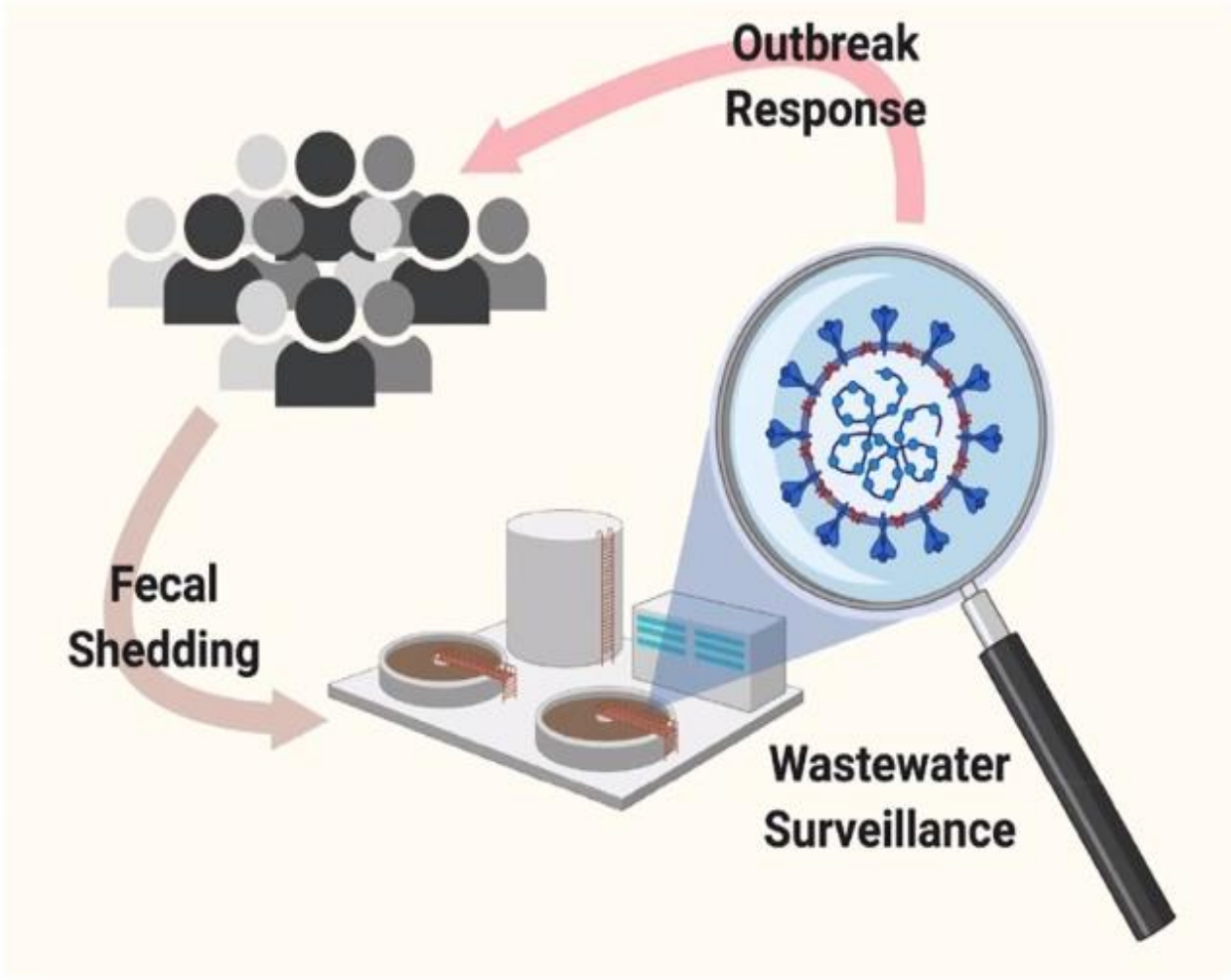


https://www150.statcan.gc.ca/n1/pub/11-621-m/11-621-m2019004-eng.htm

Wastewater-Based Surveillance (WBS)

- Testing at scale
- Low bias
- Low cost, fast

- Open questions for SARS-CoV-2:
  - Sensitivity (early warning for outbreaks)
  - Trend monitoring?
  - (Sub-)variant monitoring?



Bivens et.al. (2020) *Environ. Sci. Technol.*

Does WBS work for COVID-19?

Letters | Annals of Internal Medicine • Vol. 172 No. 12 • 16 June 2020

SARS-CoV-2–Positive Sputum and Feces After Conversion of Pharyngeal Samples in Patients With COVID-19 FREE

Chen Chen, PhD, Guiju Gao, MD, Yanli Xu, MD, Lin Pu, MD, Qi Wang, MD, Liming Wang, PhD, ...

View all authors +

Author, Article, and Disclosure Information

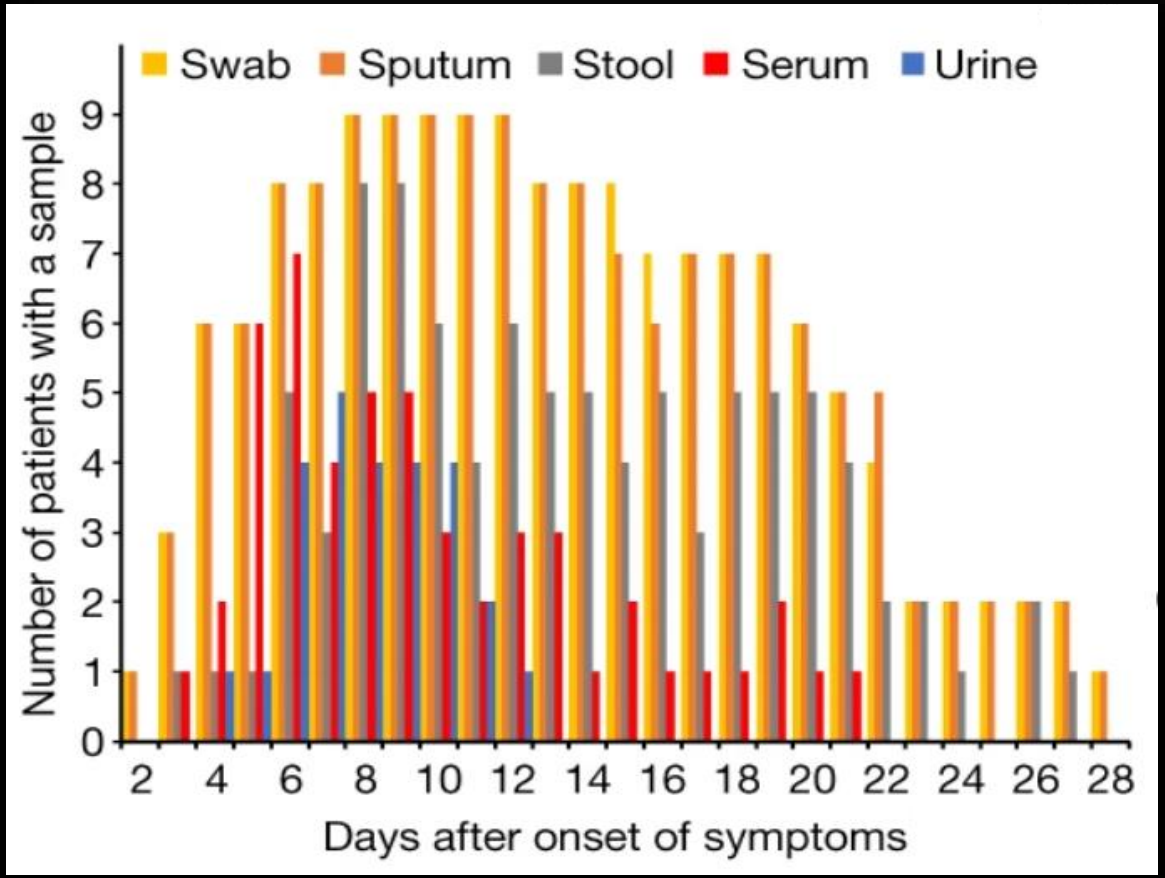
https://doi.org/10.7326/M20-0991

- Detection of fecal presence of SARS-CoV-2
- E.g.:
  - Chen et al. 2020
  - Woelfel et al. 2020

Nature. 2020 May;581(7809):465-469. doi: 10.1038/s41586-020-2196-x. Epub 2020 Apr 1.

Virological assessment of hospitalized patients with COVID-2019

Roman Wölfel [#1], Victor M Corman [#2], Wolfgang Guggemos [#3], Michael Seilmaier [3], Sabine Zange [1], Marcel A Müller [2], Daniela Niemeyer [2], Terry C Jones [2,4], Patrick Vollmar [1], Camilla Rothe [5], Michael Hoelscher [5], Tobias Bleicker [2], Sebastian Brünink [2], Julia Schneider [2], Rosina Ehmann [1], Katrin Zwirglmaier [1], Christian Drosten [6], Clemens Wendtner [7]



Woelfel et al. 2020 Nature 581, 465-469

Does WBS work for COVID-19?

- Biodesign Institute, Center for Environmental Health Engineering
  - Dr. Rolf Halden's team
- Degradation of SARS-CoV-2 testing:
  - Fast degradation
  - Stable low-level residual presence

Dr. Rolf HALDEN
Professor & Center Director

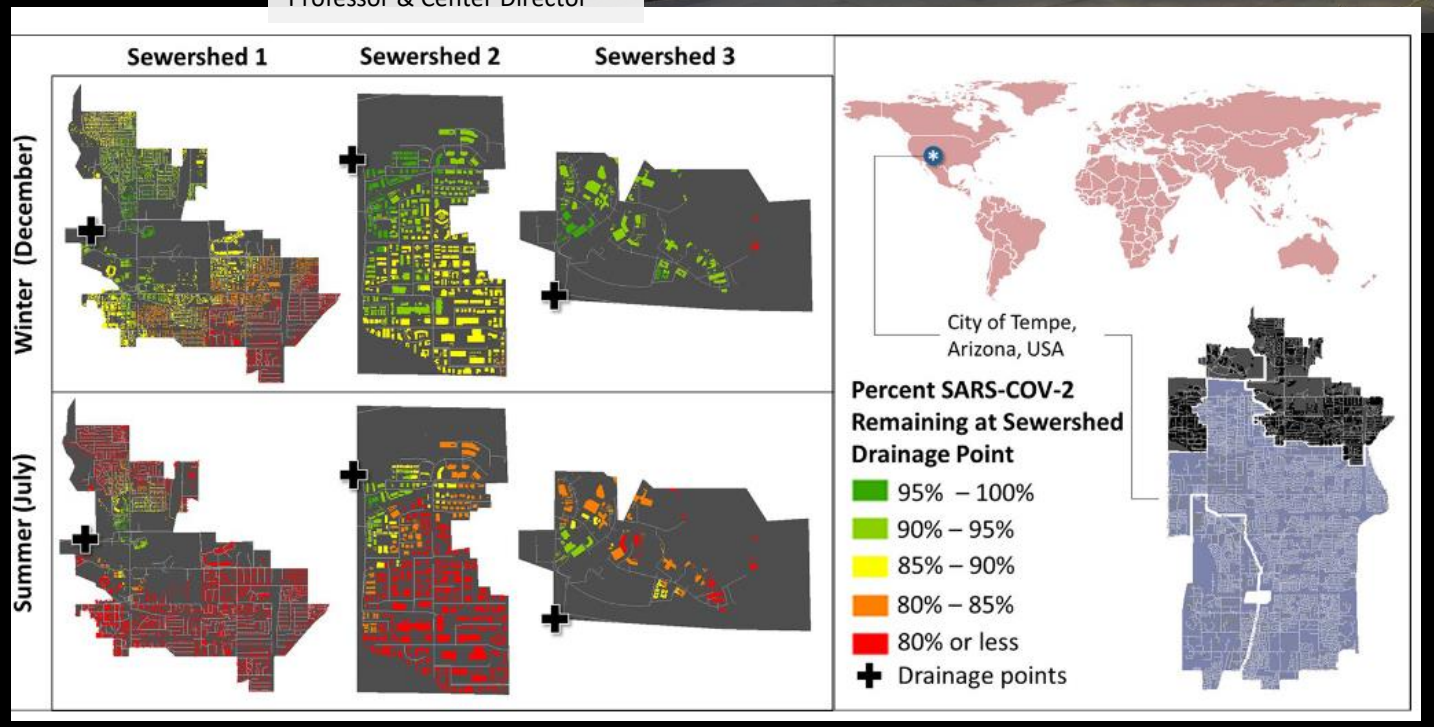
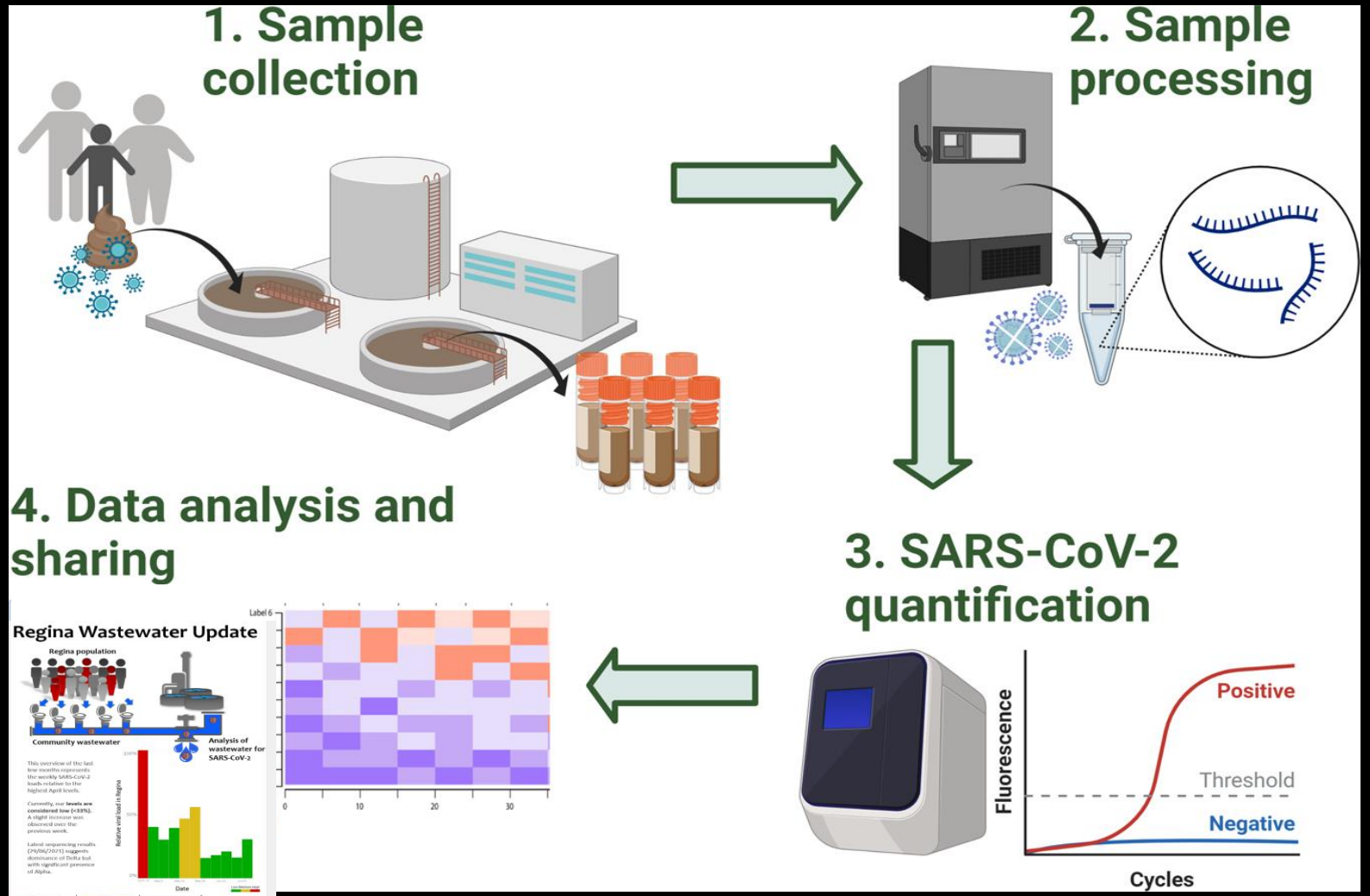


Figure from Hart and Halden 2020 Science of the Total Environment 730, 138875

Wastewater surveillance of SARS-CoV-2



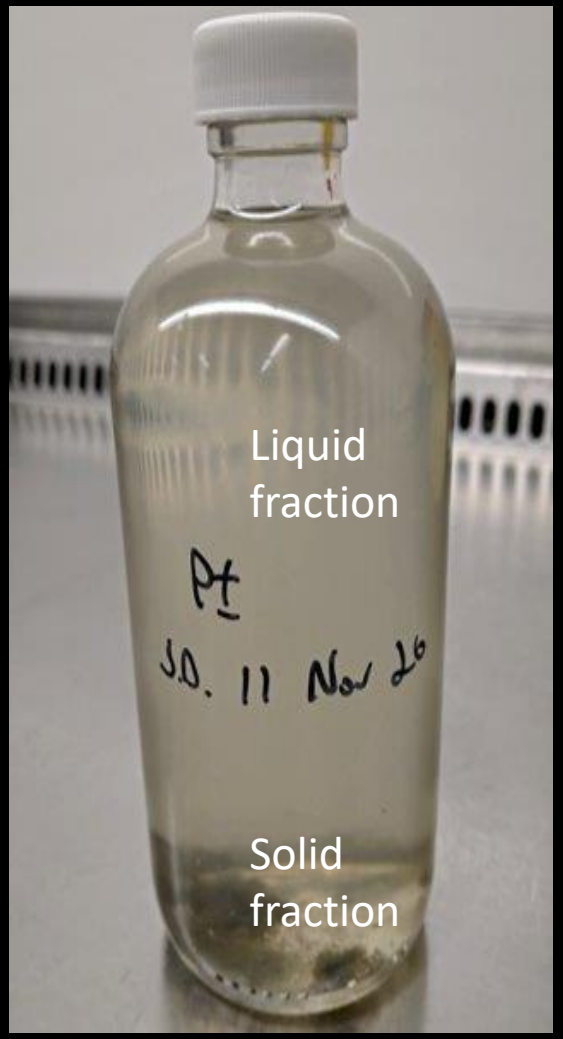
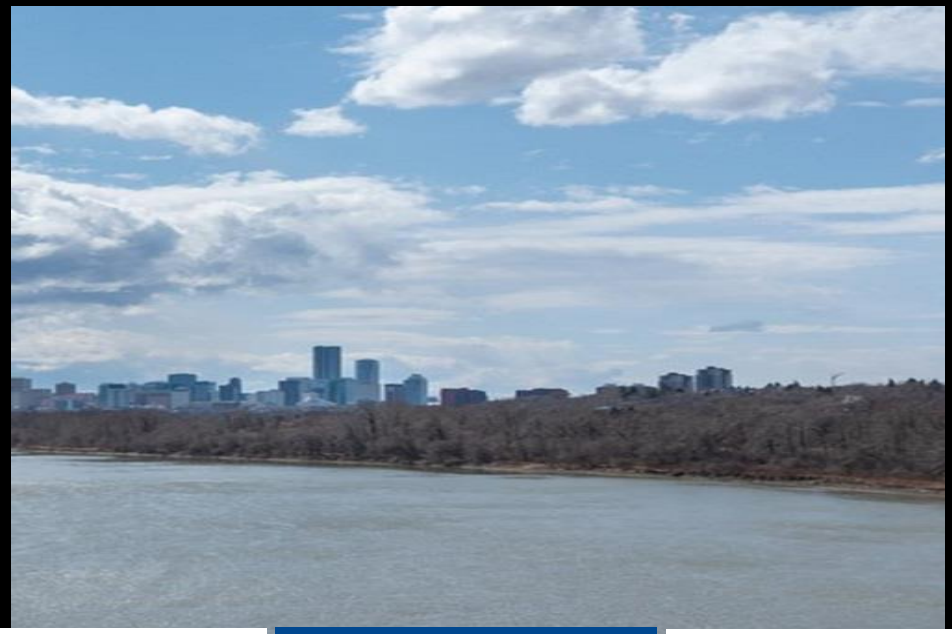


Figure from: Scorza et al 2022, Nature Scientific Data 9, 713

A review of the pandemic – a WBS perspective

- Partners since 2020:
  - SHA (Drs. Hennink and Medu)
  - EPCOR (Operator wastewater treatment plant)
  - City of Regina (Shelley Wellman/ Joy Yu)

- Since 2021:
  - Support from Public Health Agency Canada and Health Canada
  - Sequencing by National Microbiology Lab in Winnipeg
  - Additional cities



Saskatchewan Health Authority

EPCOR

REGINA

NSERC CRSNG

Public Health Agency of Canada

Agence de la santé publique du Canada

MOOSE JAW SASKATCHEWAN

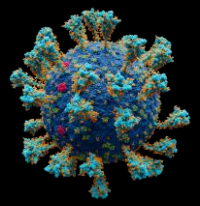
City of Yorkton

Weyburn

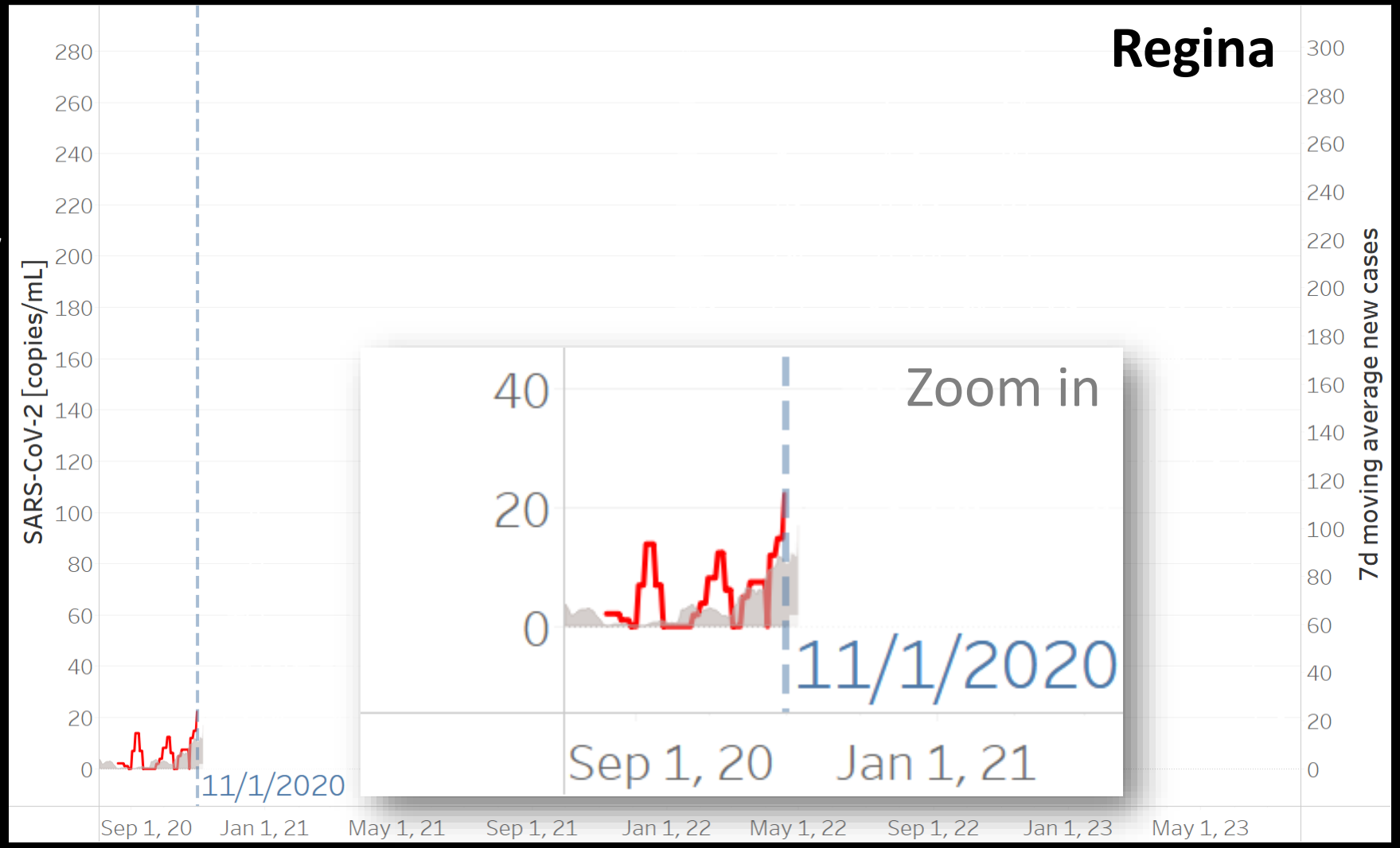
SWIFT CURRENT where life makes sense

LUMSDEN

Regina – WBS in summer/fall 2020



- Positive signal: average of ~3 new cases
- What is the expected relationship between wastewater signal and clinical case numbers?



What do we know about SARS-CoV-2 fecal shedding rates?

- Answer: not much
- No stool data before symptom onset

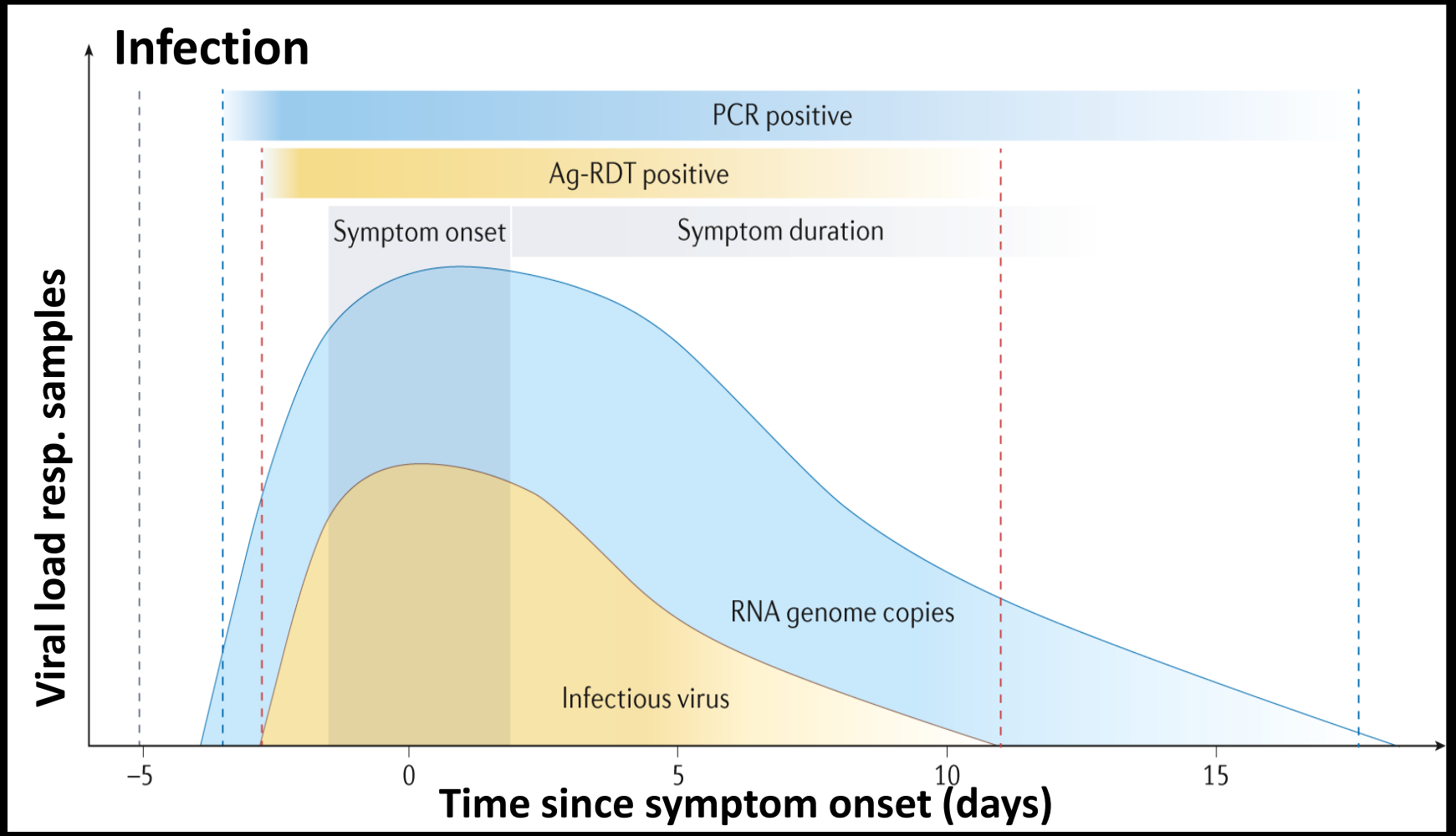


Figure from: Puhach et al 2023, Nature Reviews Microbiology 21, 147-161

Clinical testing vs. fecal shedding

- Lead or lag time highly dependent on clinical testing regimen
- Max 5-10 days?
- Lead realistically <10 days

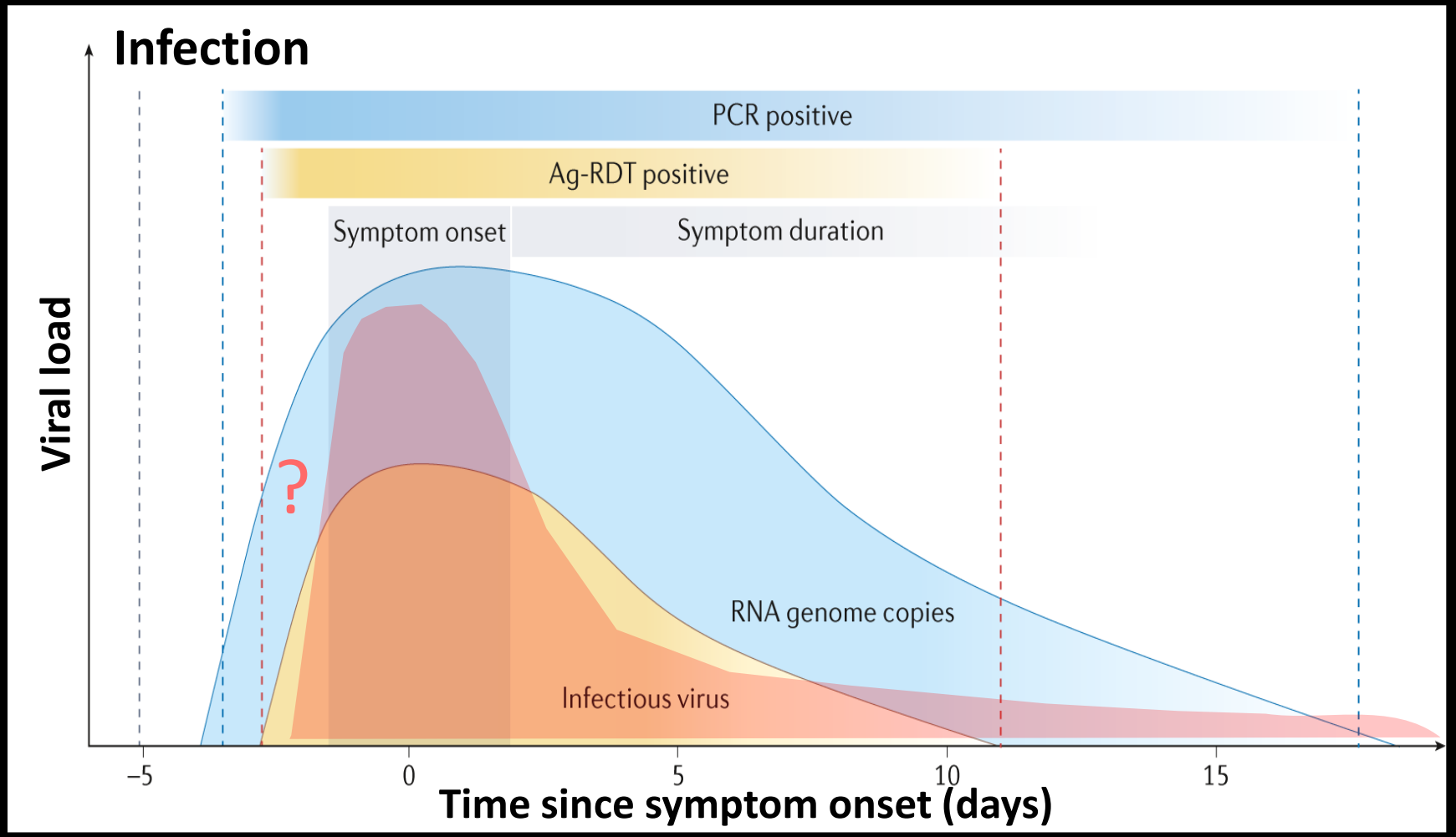
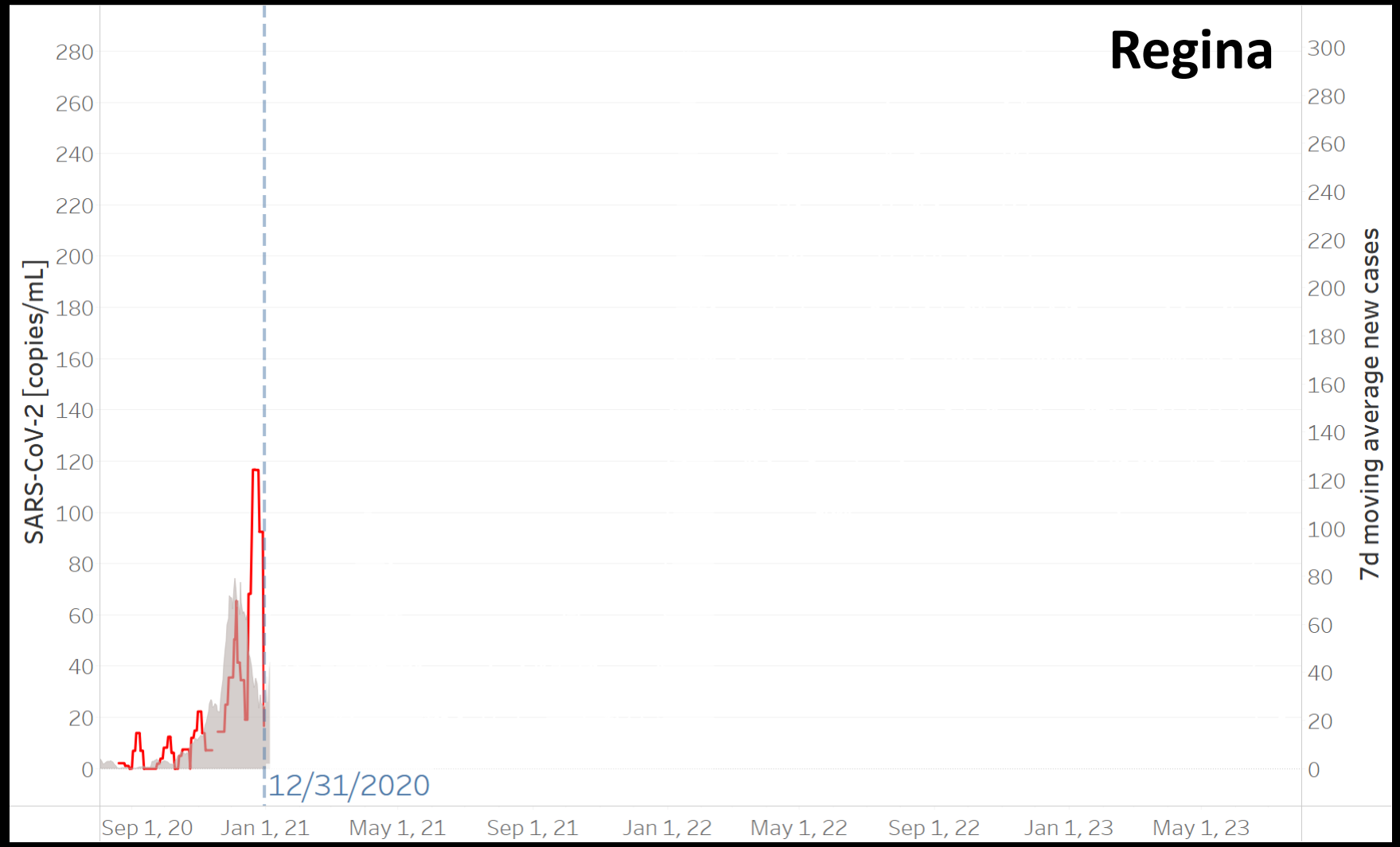
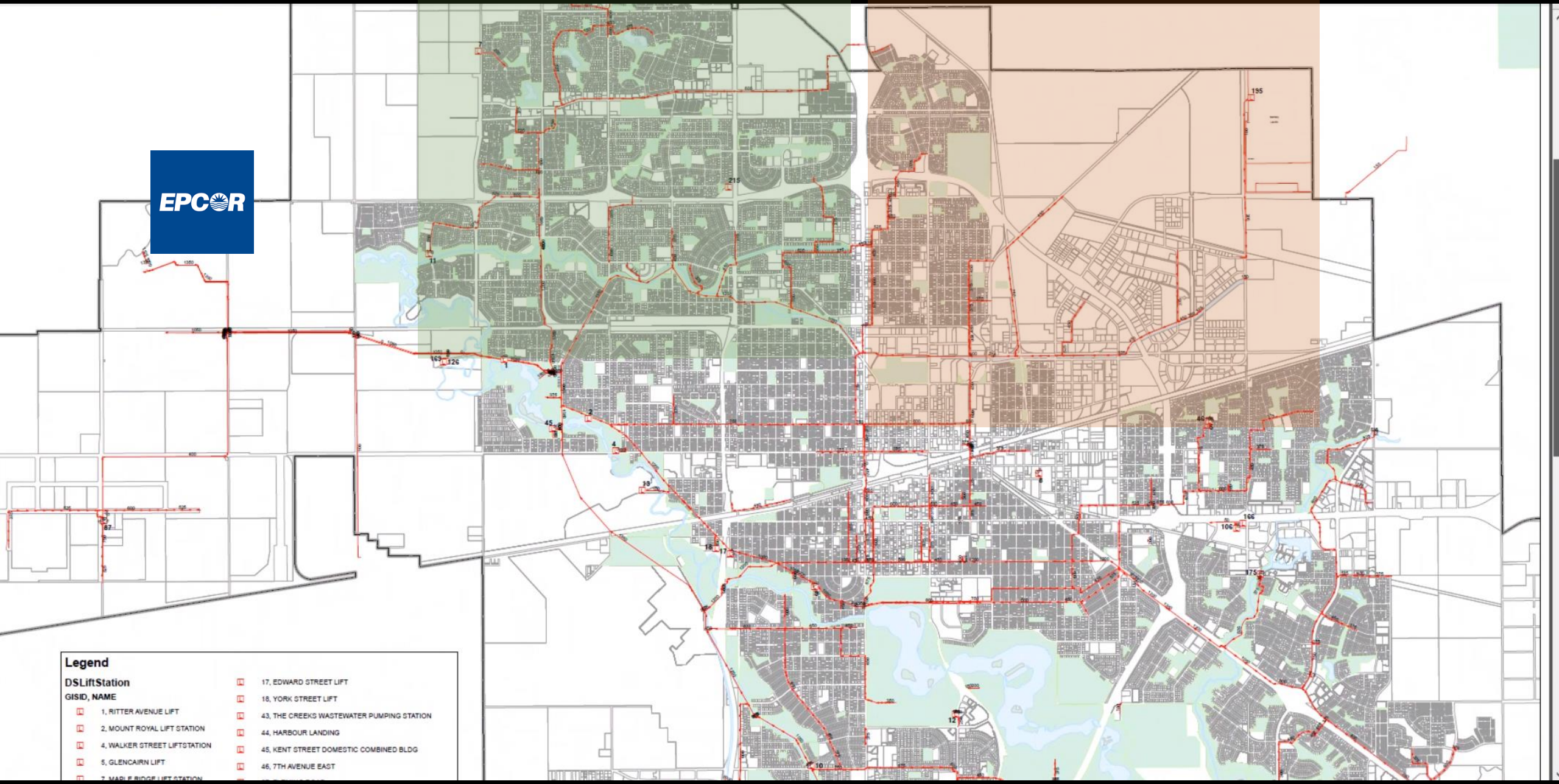


Figure from: Puhach et al 2023, Nature Reviews Microbiology 21, 147-161

Regina – WBS in fall/winter 2020

- Sustained increase after Thanksgiving
- Surprisingly strong signal around Christmas




EPCOR
Legend
DSLiftStation
GISID, NAME
1, RITTER AVENUE LIFT
2, MOUNT ROYAL LIFT STATION
4, WALKER STREET LIFTSTATION
5, GLENCAIRN LIFT
17, EDWARD STREET LIFT
18, YORK STREET LIFT
43, THE CREEKS WASTEWATER PUMPING STATION
44, HARBOUR LANDING
45, KENT STREET DOMESTIC COMBINED BLDG
46, 7TH AVENUE EAST

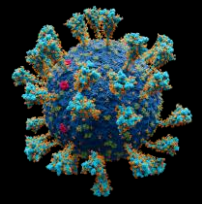
Impact of sewer parameters

- Size of sewer system, residence time
- Changes in flow rate (e.g. rain, snow melt, population size, industrial use)
- Contamination of sewer system (e.g. cleaners, solvents etc.)

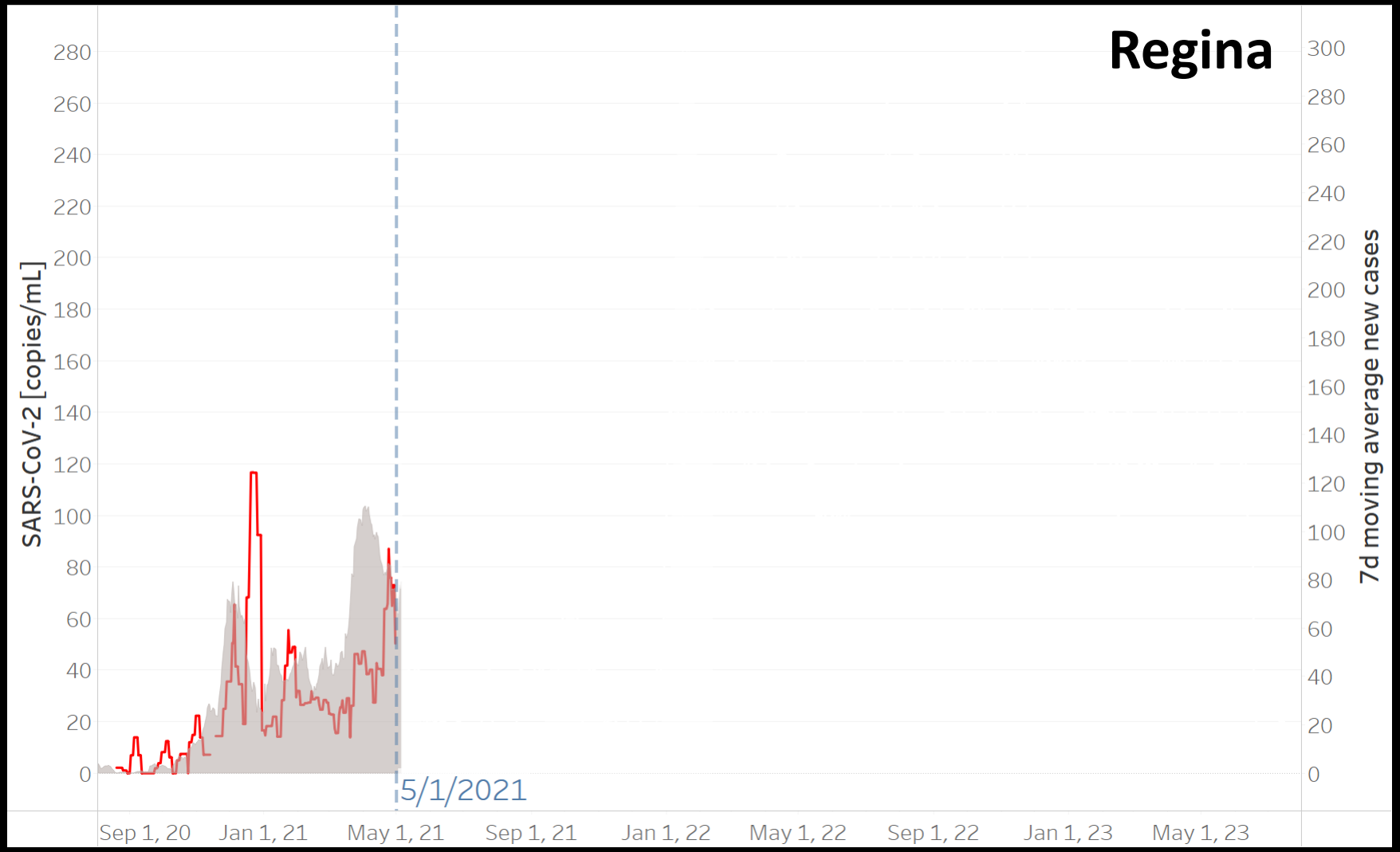
➢Viral signal is highly dependent on sampling location/sewer system

➢But robust for larger trends

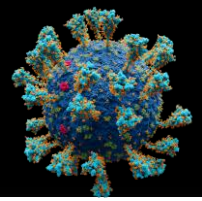
Regina – WBS in spring 2021



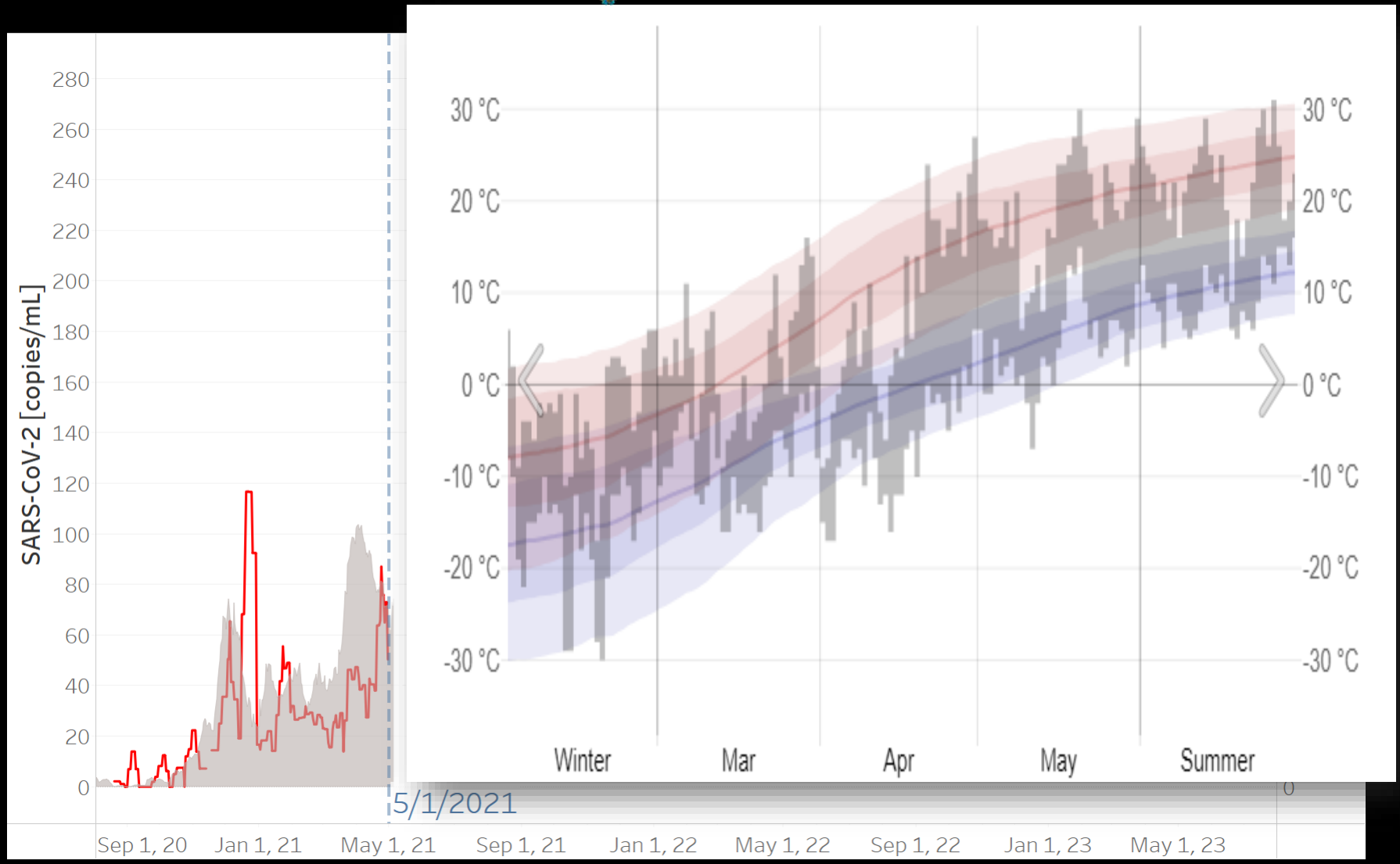
- Alpha wave: March/April 2021
- Presence of Delta variant: since 4/25/2021
- Drop of SARS-CoV-2 signal: March/May 2021



Regina – WBS in spring 2021



- High temperature increases in Regina between March - May
- Snow melt might dilute wastewater samples



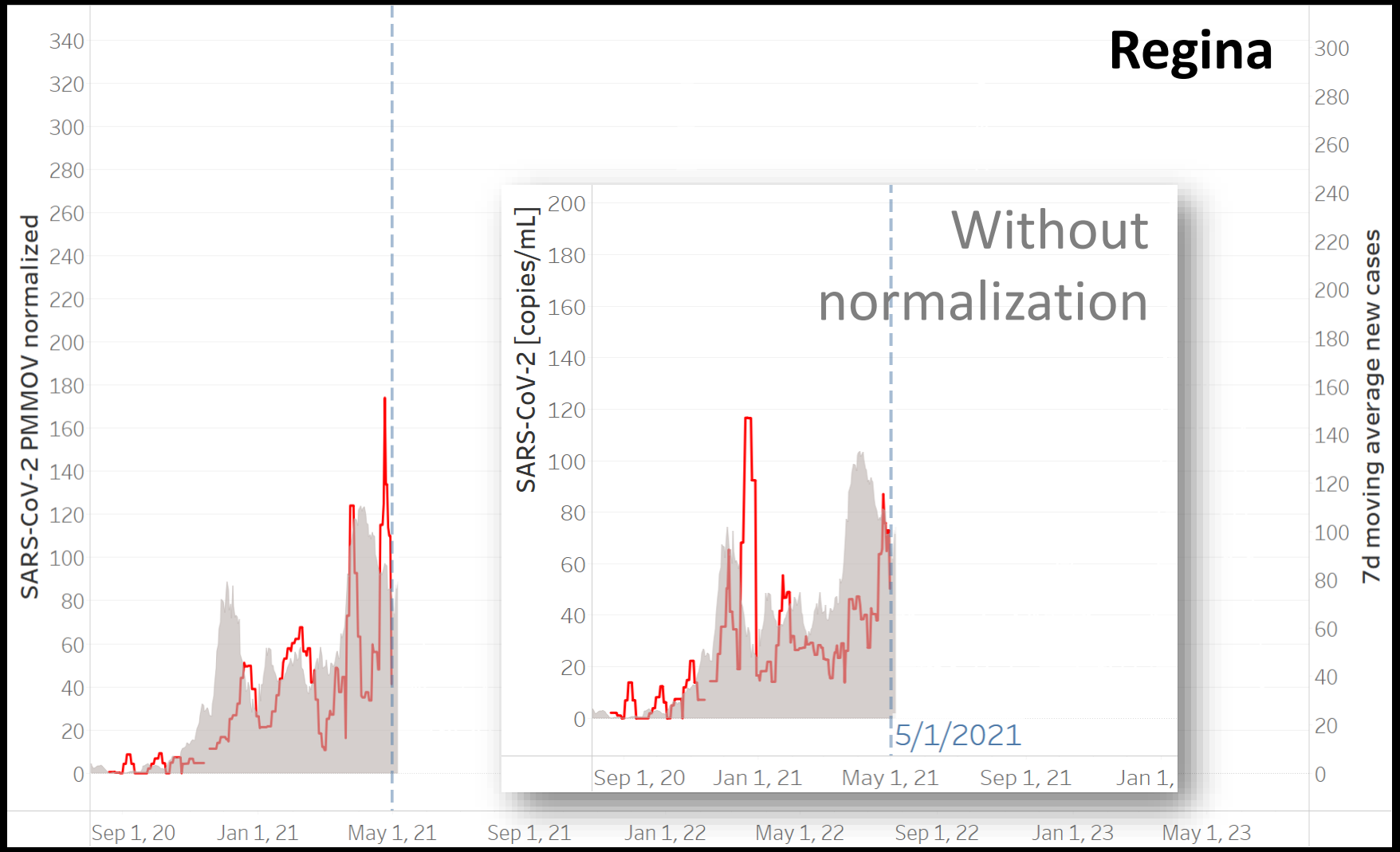
Data normalization

- Markers in wastewater to account for population size, dilution, extraction efficiency, etc.
  - Other viruses (e.g. pepper mild mottle virus, PMMoV)
  - Human biomarkers (5-hydroxyindoleacetic acid, cortisol, creatinine, ammonia etc.)
  - Food (aspartame, caffeine, etc.)

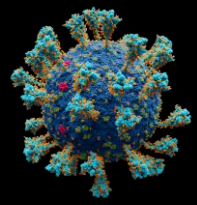
- **Problem**: “True” infection number is unknown

Impact of PMMoV normalization during snow melt

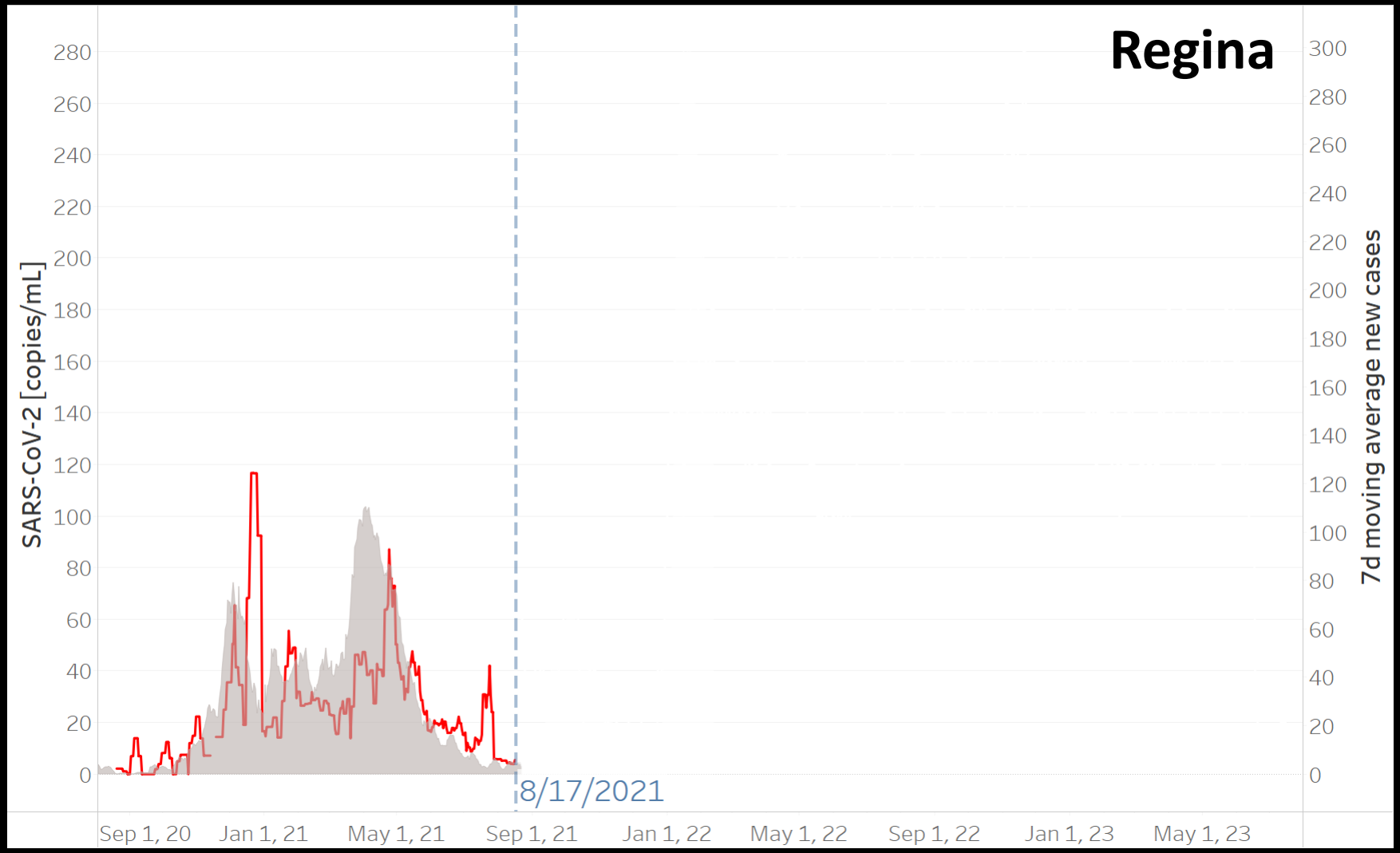
- Normalization increased viral signal during melt



Regina – WBS in summer 2021

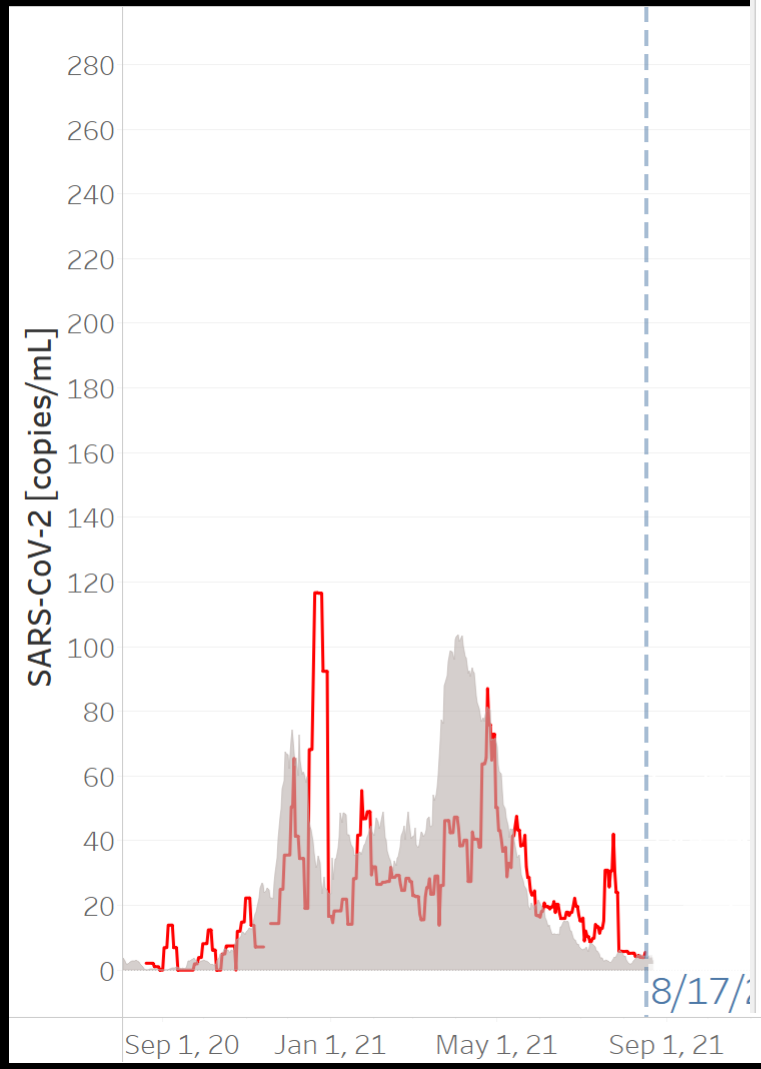


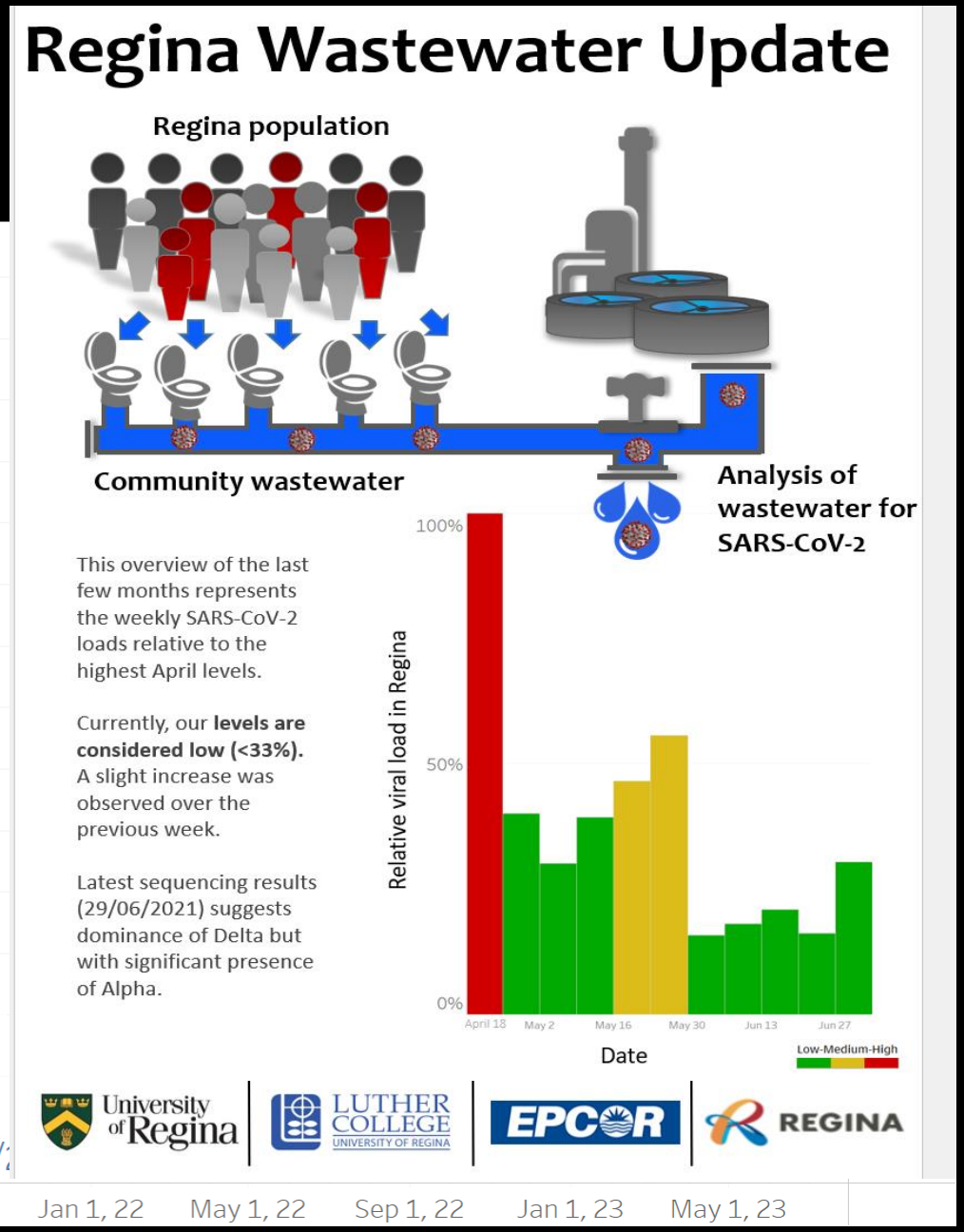
- Delta variant: dominant in July 2021
- Expansion to over 11 sites to monitor decline of SARS-CoV-2



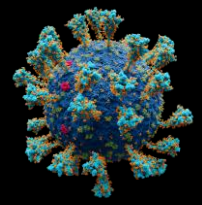
Regina – WBS in summer 2021

- Delta variant: dominant in July 2021
- Expansion to over 11 sites to monitor decline of SARS-CoV-2
- Public release of data

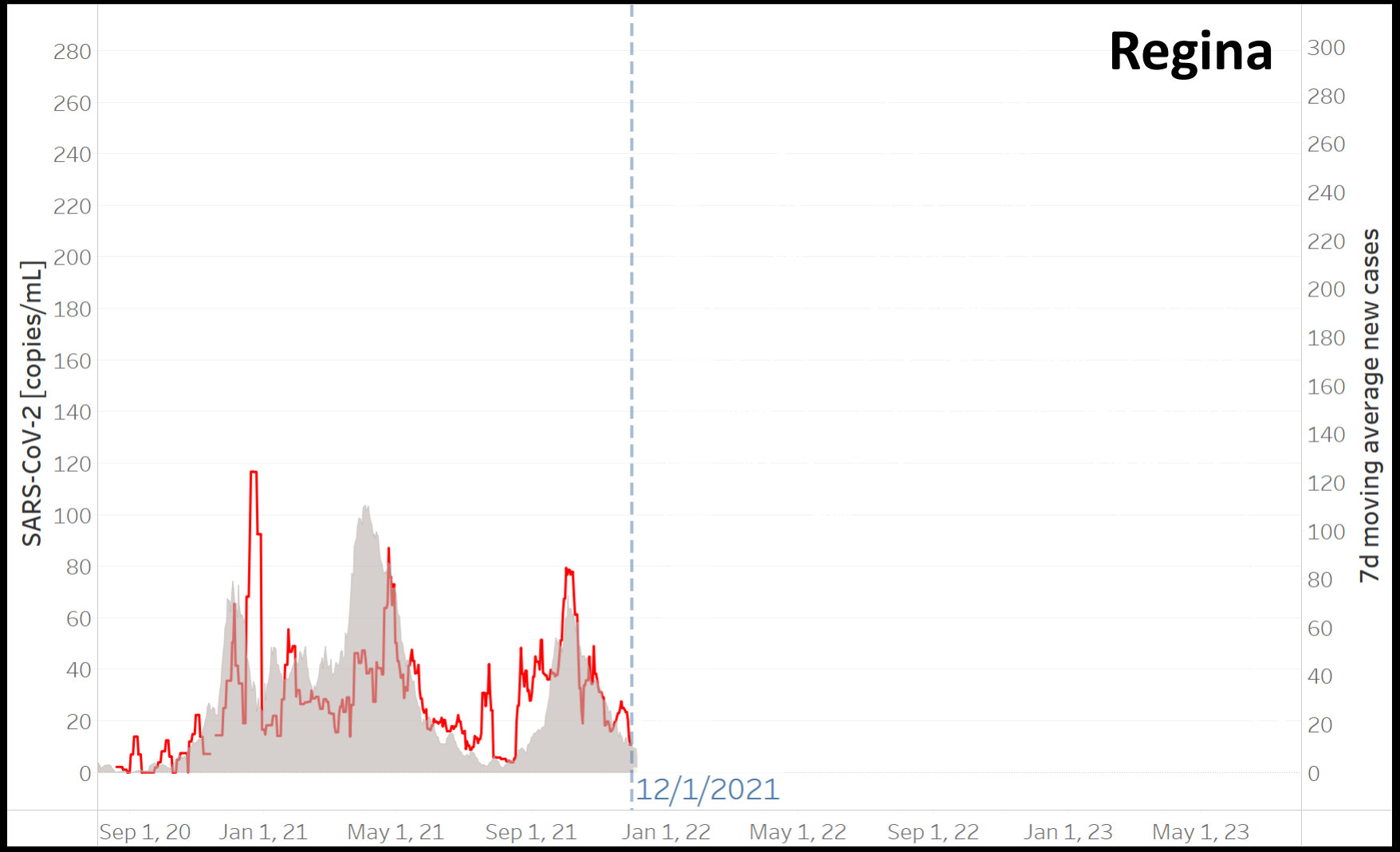




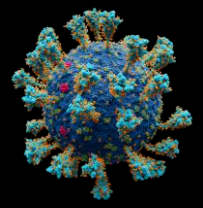
Regina – WBS in fall/winter 2021



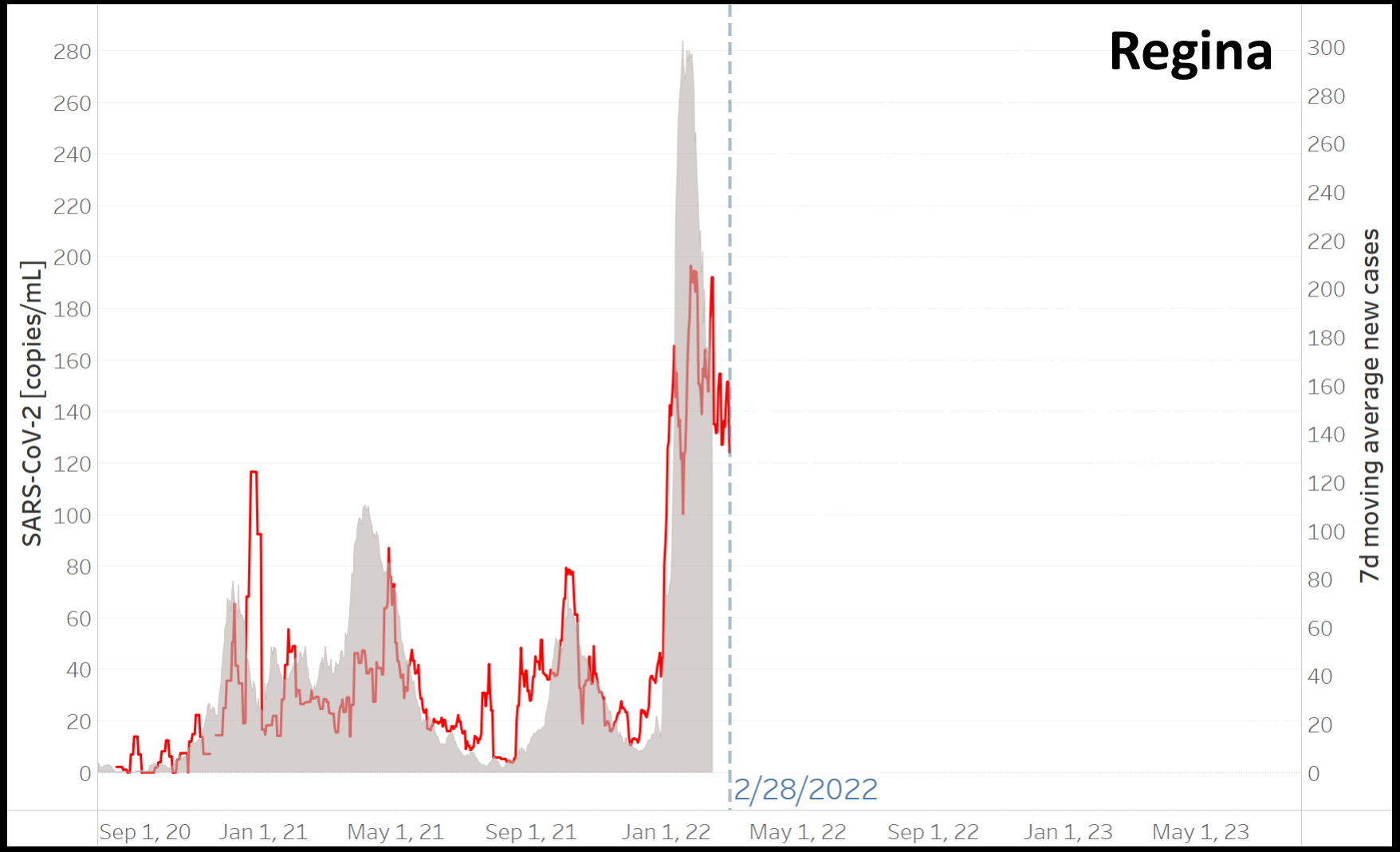
- Delta variant drives new wave 2021
- End of asymptomatic testing
- Reduction by December 2021



Regina – WBS early 2022

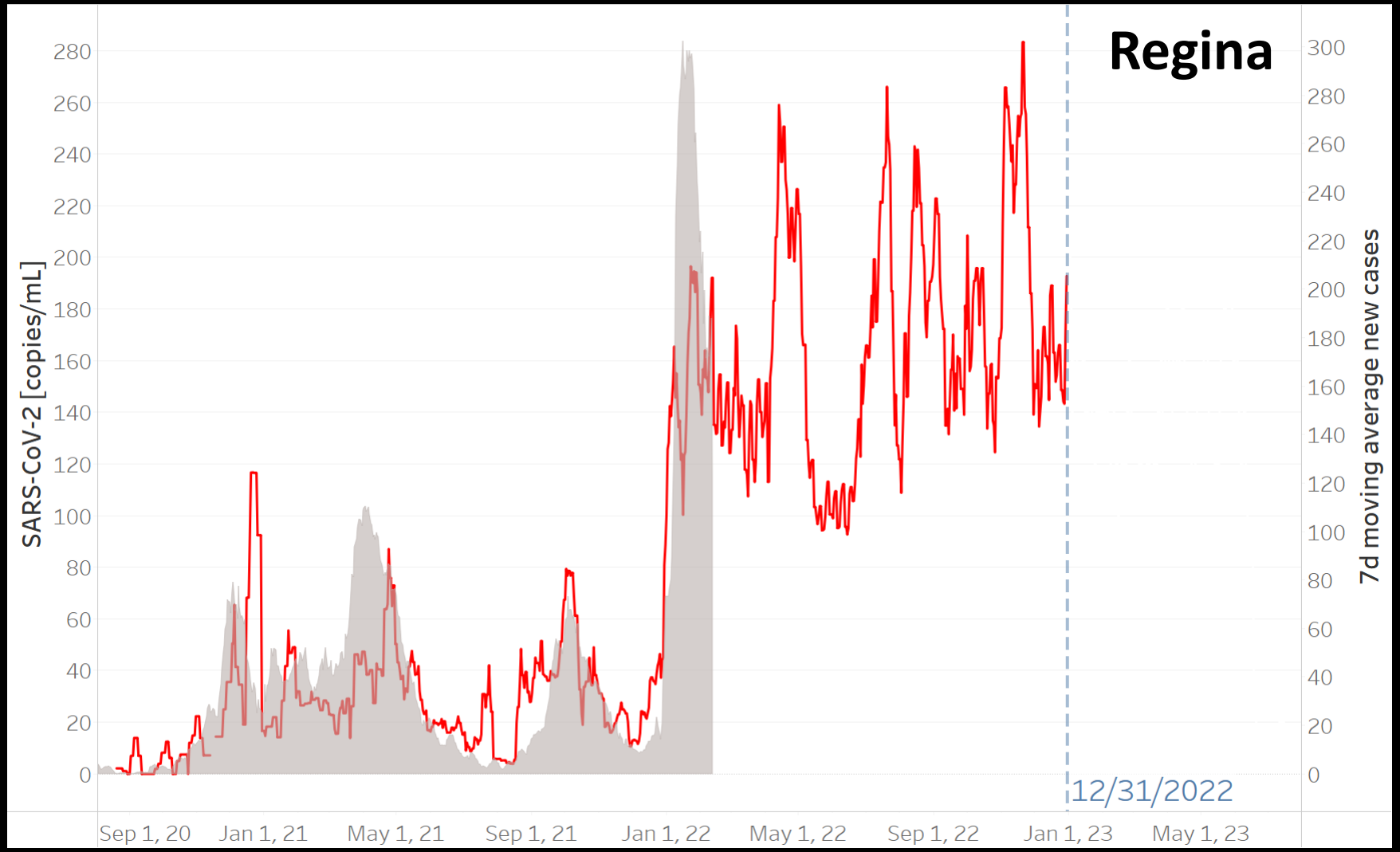


- January 2022: Omicron variant became dominant
- February 2022: End of public testing



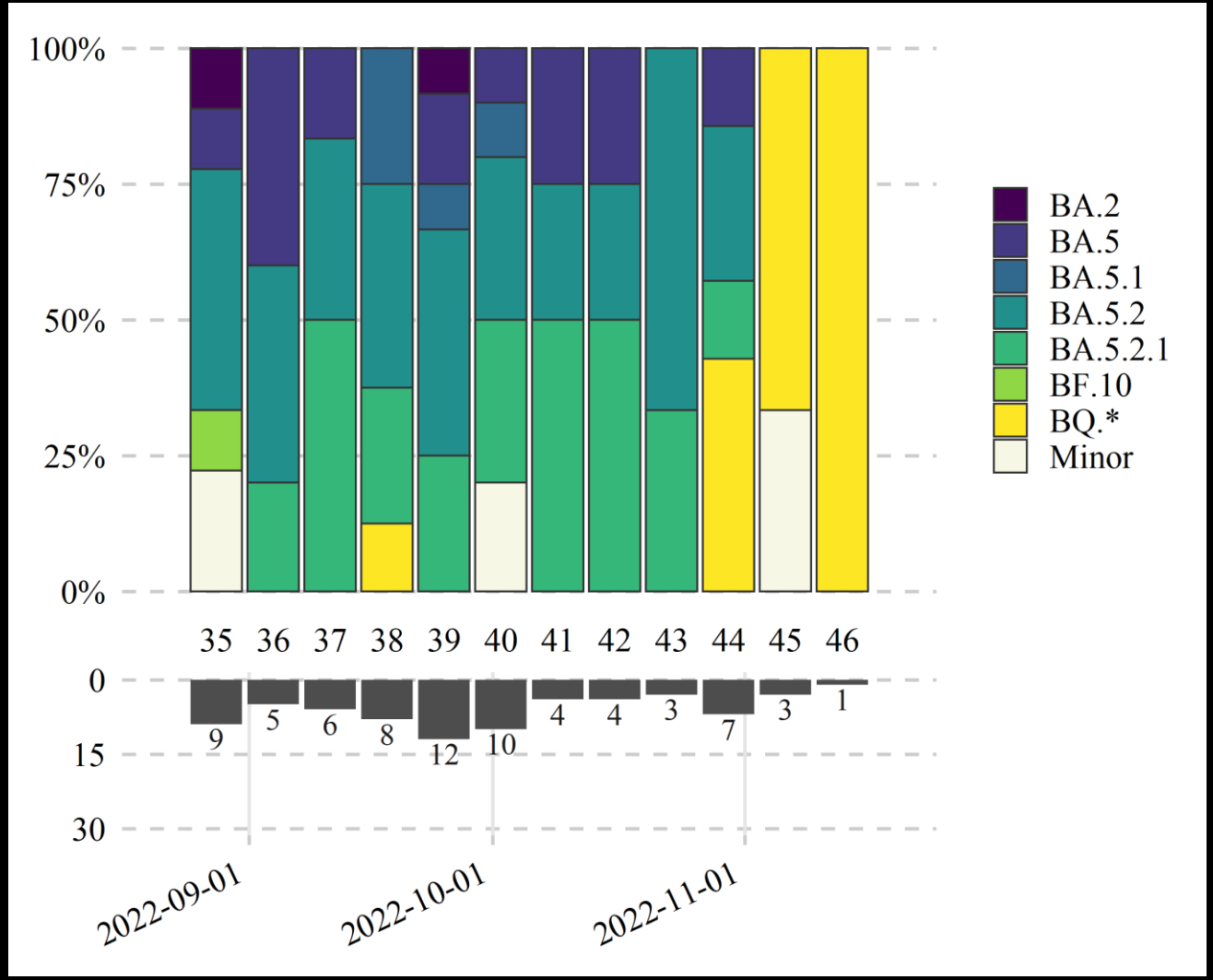
Regina – WBS 2022 “The year of Omicron and its sub-variants”

- January 2022: Omicron variant became dominant
- February 2022: End of public testing
- Consistent high levels, driven by sub-variants



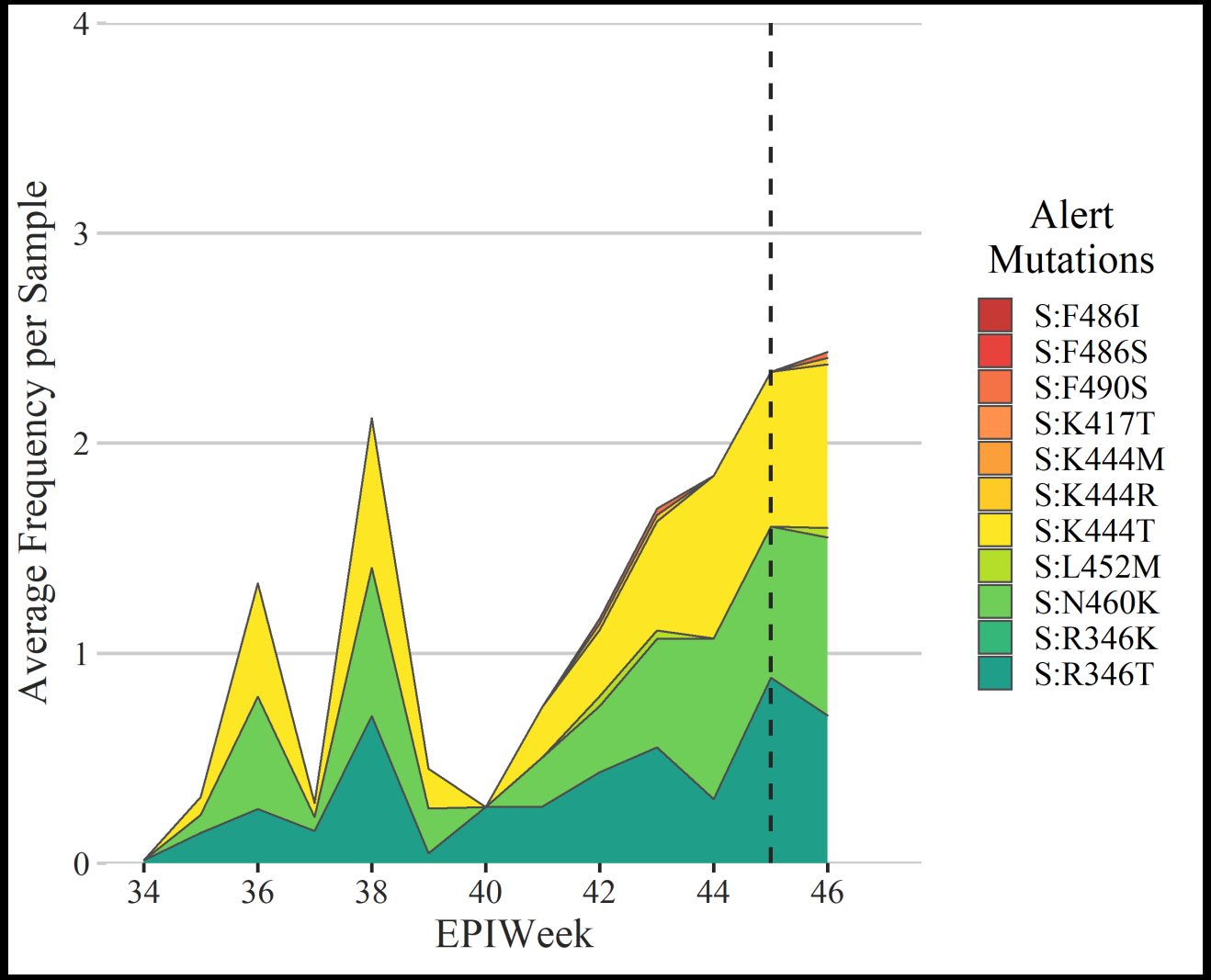
Regina – WBS variant monitoring in 2022

- Identification of Omicron variants in wastewater
  - Sequencing at NML (Dr. Landgraff's lab)
- BQ.* first detected in Regina
  - BQ.* dominant within two weeks



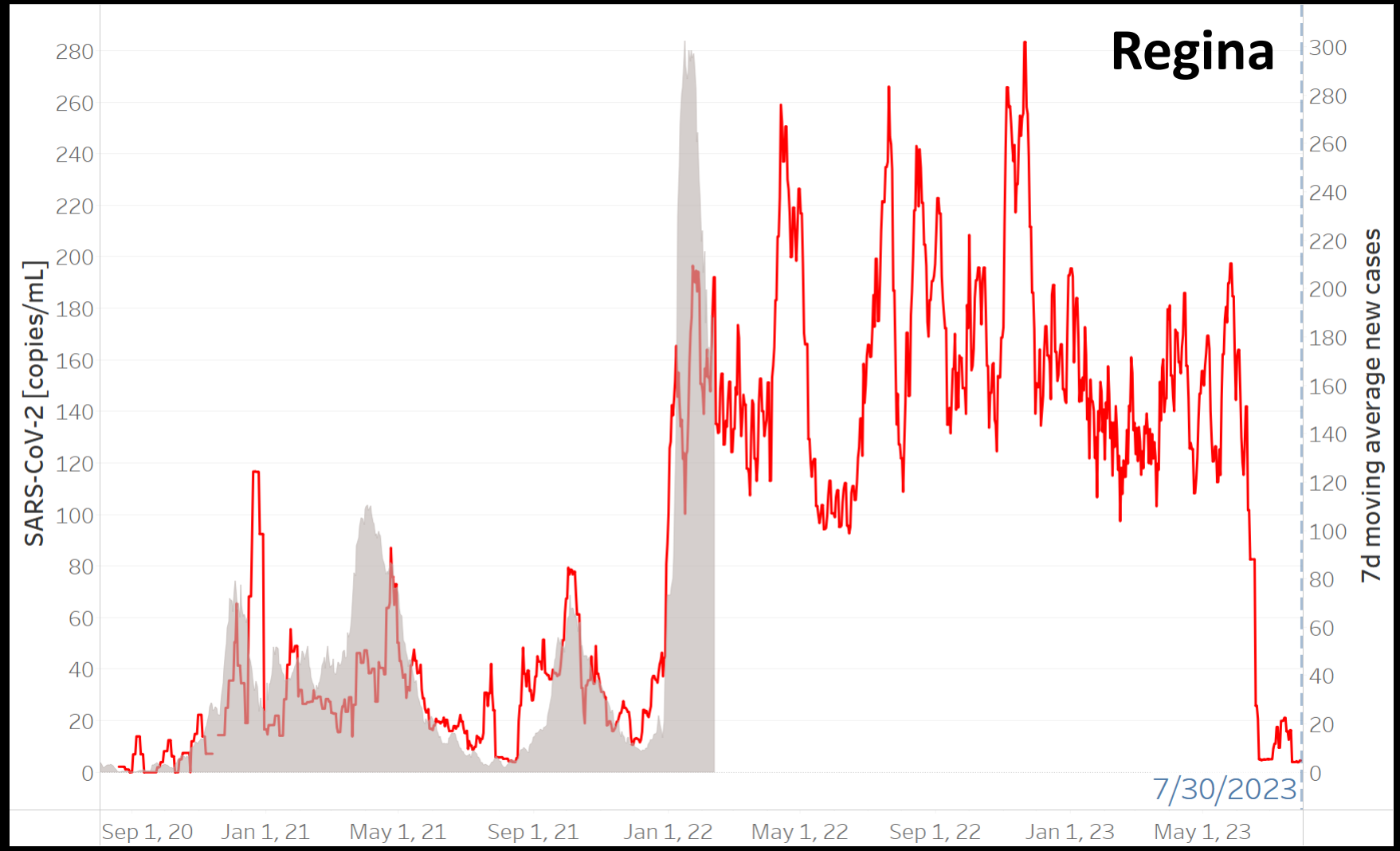
Regina – WBS mutation monitoring

- Wastewater sequencing allows the identification of point mutants
  - Sequencing at NML (Dr. Landgraff's lab)



Regina – WBS until July 2023

- First summer drop since Omicron
- RRPL continues testing (since July 2023)

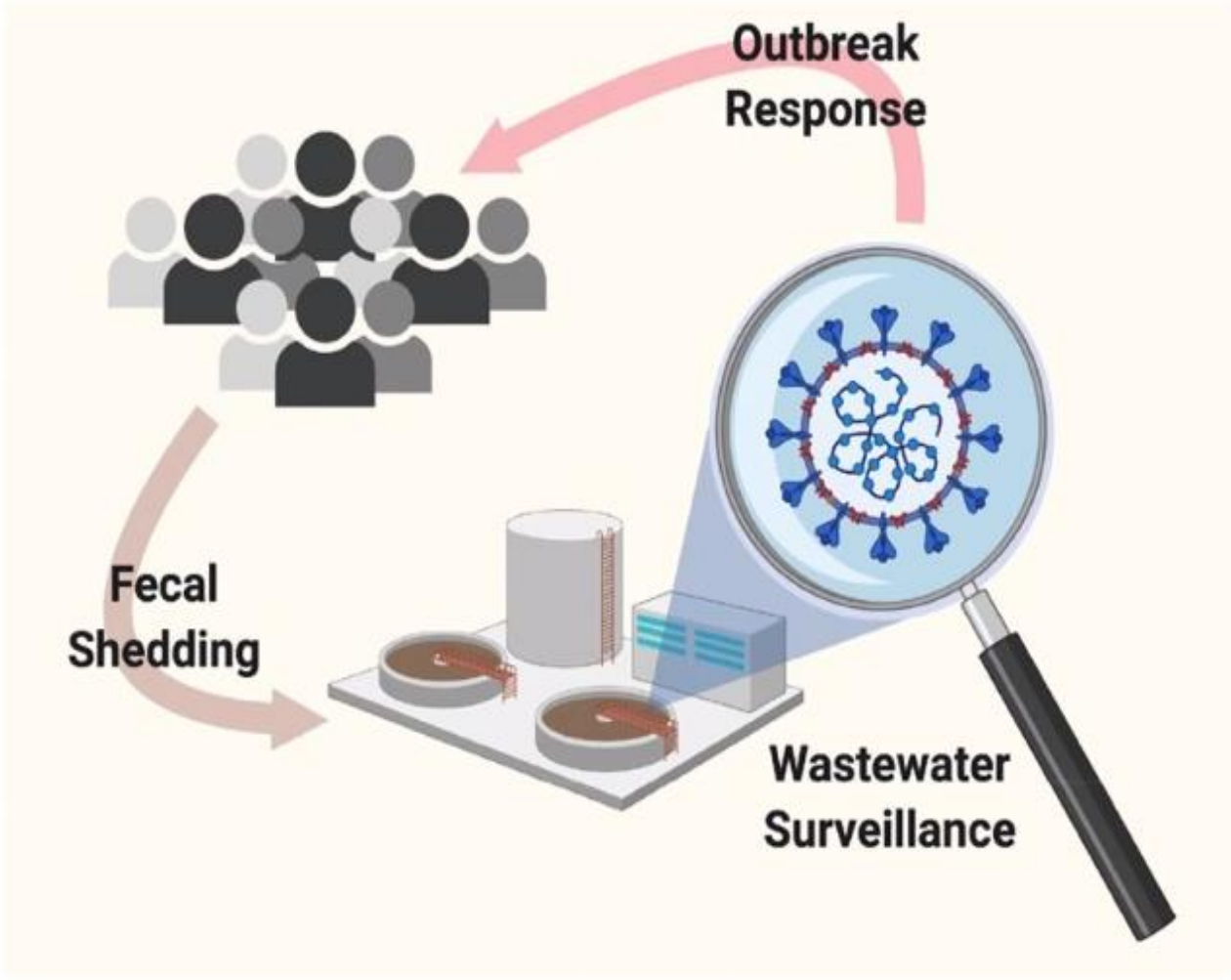


Wastewater-Based Surveillance (WBS)

- ✓Testing at scale
- ✓Low bias
- ✓Low cost, fast

Open questions for SARS-CoV-2:

- ✓Sensitivity (early warning for outbreaks)
- ✓Trend monitoring
- ✓(Sub-)variant monitoring



Bivens et.al. (2020) *Environ. Sci. Technol.*

Future goals

- Expansion of targets
  - Other diseases (already implemented: influenza, mpox, RSV)
  - Drugs of abuse
  - Biomarkers?

- Sites
  - Vulnerable facilities (e.g., long-term care homes)
  - “Interesting” facilities (e.g., airports, hospitals)

Ethical concerns

- Privacy concerns
- Balancing equity with risk of marginalization/stigmatization
- Trust in health authority/science
- Potential abuse of data

Thank you!

Want to learn more about wastewater surveillance in our lab?

https://www.youtube.com/watch?v=4mR4Kp14zfA

Wastewater surveillance - dominant variants in Regina