

HAWAII STATE DEPARTMENT OF HEALTH

Wastewater Surveillance Report

10/31/2023

Background

Wastewater surveillance adds a useful layer of monitoring community levels of SARS-CoV-2. Due to the shift to self-testing and decreased clinical testing, reported COVID-19 case counts are lower than the *actual* COVID-19 case counts. Using wastewater surveillance data paired with the monitoring of COVID-19 case counts, hospitalizations, and fatalities, this allows for a more complete understanding of disease patterns. When trends are similar across these measures, confidence in the accuracy of those trends increases.

Advantages of monitoring wastewater concentrations of SARS-CoV-2:

- Wastewater based epidemiology:
 - Helpful when paired with clinical data since SARS-CoV-2 concentrations in sewage are positively correlated with COVID-19 case counts.
- Early warning for emerging outbreaks:
 - Infected people begin shedding 2 - 3 days before onset of symptoms.
 - SARS-CoV-2 is shed in feces by both individuals with asymptomatic and symptomatic COVID-19 infections.

Possible limitations of these data to consider:

- We cannot precisely predict case counts with the detection of concentrations of SARS-CoV-2 in wastewater.
- Wastewater surveillance might not capture low levels of infection in a community.
- Some communities and/or facilities are not connected to a Wastewater Treatment Plant (WWTP).
- Inhibitors could be present in wastewater that impacts the detection of SARS-CoV-2. Inhibition assessments are in place to ensure RNA quantification methods and viral recovery are performing as expected.

Interpretation of Trends

Not all peaks and surges in concentrations will correlate with a community-wide increase in cases. Wastewater is a highly variable mixture where concentrations of all pathogens like SARS-CoV-2 may vary based upon time of collection, or collection methods of sewage. For example, concentrations can vary on whether the sample was a grab sample (only captures at one point of time) or a 24-hour composite sample (more longitudinal variability over time). If an upward trend is observed in the data, this might represent an increase in cases that has yet to be confirmed through case-based surveillance. Additional data is required to confirm whether this trend will persist.

SARS-CoV-2 Variants in Sewage

SARS-CoV-2 is a constantly evolving virus. The detection of SARS-CoV-2 variants in wastewater is another useful layer of surveillance since some variants spread more rapidly than others. Information on dominant or new variants in a community assists in public health response. Additionally, in some cases, variants have been detected in wastewater prior to detection in clinical samples.

Wastewater Surveillance for the State of Hawaii

This report contains results for the SARS-CoV-2 surveillance of sewage in collaboration with the National Wastewater Surveillance System (NWSS). A total of 14 WWTP from the State of Hawaii are participating in this surveillance. Samples are collected weekly and analyzed by a contracted lab by NWSS (previously Biobot Analytics). Concentrations in this document are reported as SARS-CoV-2 copies per nanoliter of wastewater (unless otherwise stated).

For visualization and interpretation of trends, this report includes regression lines to help visualize possible changes in SARS-CoV-2 concentrations in sewage and COVID-19 case counts over time. For example, if the constant trend in SARS-CoV-2 concentrations is decreasing, we will likely observe a similar decrease in COVID-19 cases. Still, trends in concentrations do not always perfectly reflect community levels of SARS-CoV-2. Not all communities in Hawaii are sewered or are serviced by participating WWTP, which can disproportionately reflect more urban and often more heavily touristed areas. Tourism also frequently changes populations served by each WWTP and their travel may result in fluctuations in disease detection.

This report also includes information on the estimated composition of variants in wastewater through Next Generation Sequencing (NGS). NGS which is parallel to Whole Genome Sequencing (WGS) and allows for high-throughput and timely results. NWSS previously contracted lab (Biobot Analytics) conducted NGS with Illumina instruments through their trusted sequencing partners. They calculated the estimated proportion of variants with the Freyja tool by measuring the frequency of variations at each position in the SARS-CoV-2 genome among mapped sequence fragments from a mixed SARS-CoV-2 sample. Data are reported in relative abundance. For example, if BA.5 (parent Omicron lineage) has the highest proportion, this means that BA.5 is the dominant variant relative to all other SARS-CoV-2 variants detected in the wastewater. These sequence data do not include information on the relative abundance of other pathogens present in wastewater. Variant composition estimates should be interpreted with caution, as substantial gaps in coverage across the reference genome and/or a lack of sequencing depth can produce inaccurate variant/lineage calls.

Due to the variability of wastewater and presence of inhibitors, concentrations reported have been normalized by flow and population served for each WWTP. Excessive rainfall and changes in water use can impact concentrations of SARS-CoV-2 in sewage over time. The use of a fecal indicator control (Pepper Mild Mottle Virus - PMMoV) helps account for any changes in human waste input in wastewater over time. For more information on how wastewater surveillance works, refer to the resources at the end of the report. At the Hawaii Department of Health's State Lab, we are in the process of validating our own protocols for processing wastewater on-site. **Note: due to a contract dispute between CDC (NWSS) and its contractor, the most recent quantitative and variant SARS-CoV-2 data (for all participating WWTP across the state) included in this section of the report is from September 2023.** This report includes SARS-CoV-2 concentrations from samples collected from 07/01/2023 to 09/12/2023, and relative variant proportions from 07/01/2022 to 09/22/2023. Report print date: 10/31/2023.

Metadata for participating WWTP by county

County	Number of WWTP	Total Population Served
Honolulu	5	906,000
Maui	3	160,000
Hawaii	3	21,507
Kauai	3	11,100

SARS-CoV-2 Wastewater Surveillance Data

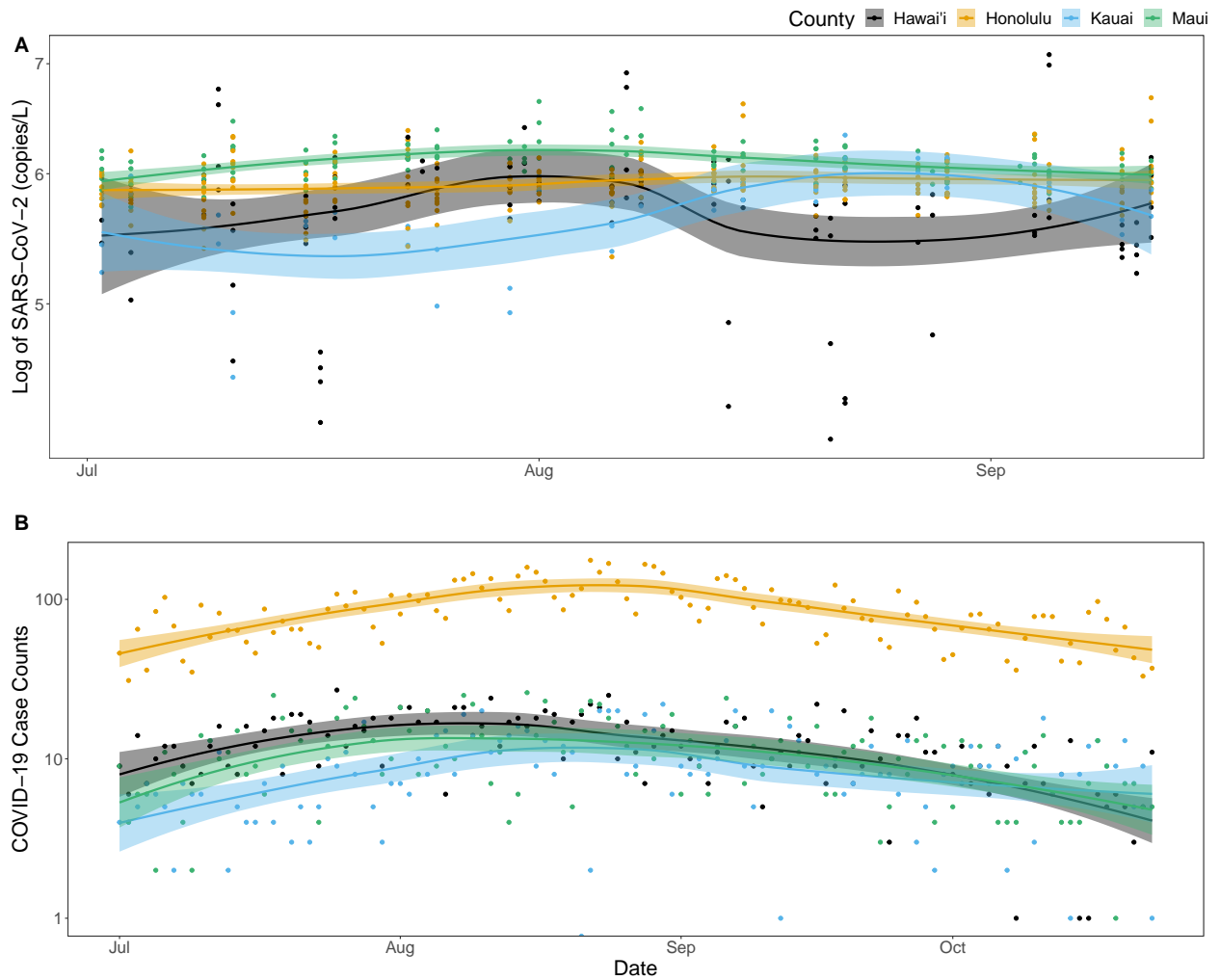


Figure 1. (A) Log transformed normalized concentrations of SARS-CoV-2 in sewage (copies/L) and (B) case counts for the state of Hawaii by each county. Regression line was created with a prediction interval from a locally weighted (LOESS) regression. Shaded region represents 95% confidence interval.

Notes: Trends in raw sewage concentrations of SARS-CoV-2 are fluctuating in all counties. **Due to a contract dispute between CDC (NWSS) and its contractor, the most recent quantitative SARS-CoV-2 data (for all participating WWTP across the state) included in this section of the report is from September 2023.**

SARS-CoV-2 Variants in Wastewater

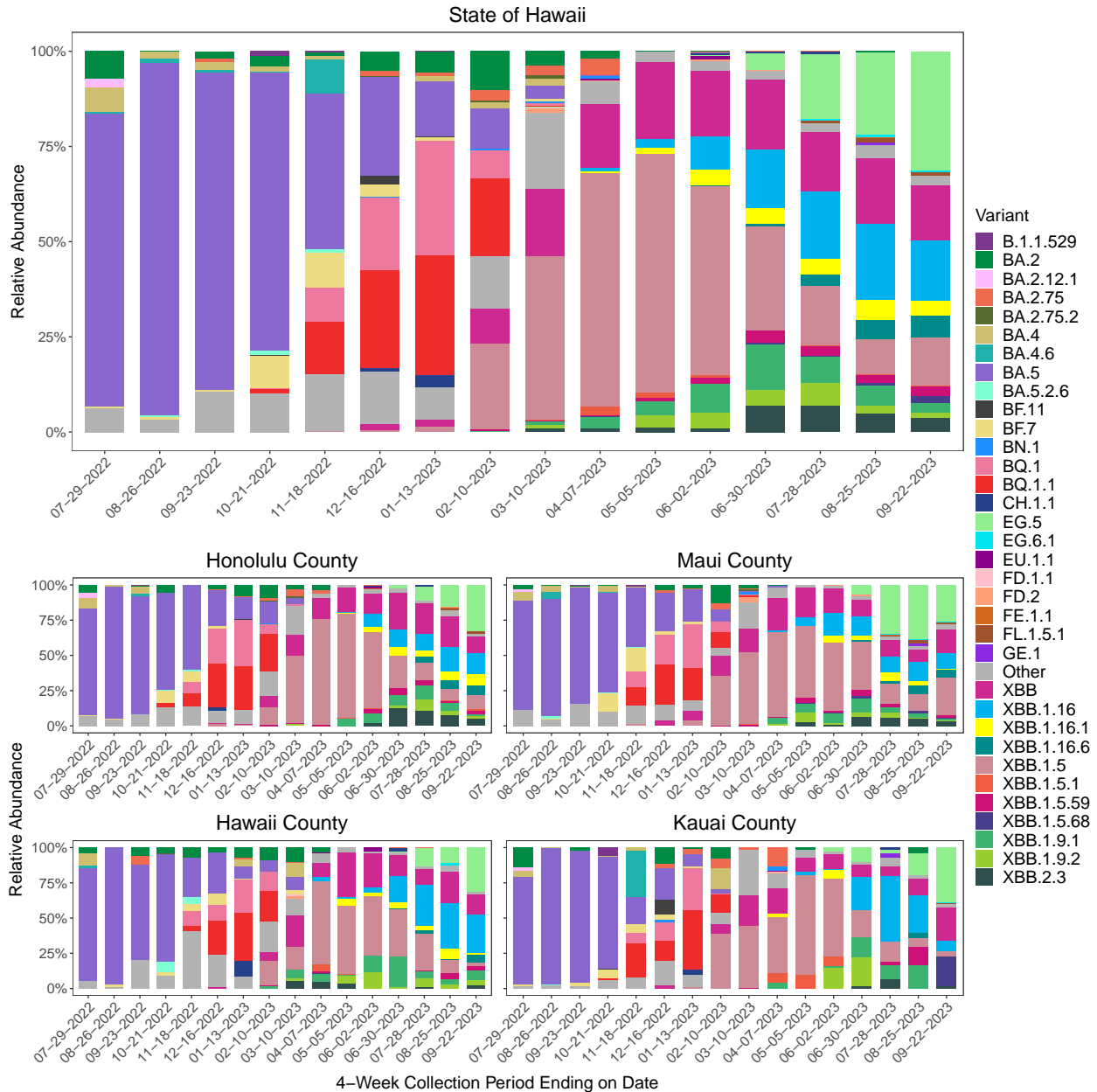


Figure 2. Stacked barplot demonstrating the relative abundance of SARS-CoV-2 aggregated lineages detected in wastewater across the State of Hawaii from 07/01/2022 to 09/22/2023.

Notes: Among the SARS-CoV-2 lineages detected in the most recent data included in this report, XBB* lineages have the highest relative abundance of estimated variants since February 2023 across the State of Hawaii. XBB* are all lineages and sublineages of Omicron. For a more detailed description of sequencing and information on clinical SARS-CoV-2 variants in the State of Hawaii, refer to the *State of Hawaii SARS-CoV-2 Sequencing and Variant Report* and the resources provided at the end of this report. These data are only a partial representation of the population from each county which might impact the abundance of certain lineages. **Due to a contract dispute between CDC (NWSS) and its contractor, the SARS-CoV-2 variant wastewater data included in this section of the report is from September 2023.**

SARS-CoV-2 and Beyond: Additional Wastewater Surveillance Data

Wastewater-based epidemiology (WBE) has emerged as an effective method for monitoring various pathogens to obtain unbiased data on disease prevalence in a community. Other pathogens, excluding SARS-CoV-2, such as fungal, bacterial, or viral pathogens are suitable candidates for wastewater surveillance. To be monitored effectively, pathogens must be excreted or shed by humans, present in detectable concentrations during an active infection, and incapable of replication in the environment outside of a host (e.g., sewage systems).

Pathogens meeting these criteria, and of public health significance, can be surveyed similarly to SARS-CoV-2 concentrations in wastewater. Notable examples of pathogens that fulfill the requirements for wastewater surveillance include Influenza (commonly known as the “flu”), Respiratory Syncytial Virus (RSV), Norovirus (NoV), MPOX (formerly known as monkeypox), and *Candida auris*.

Other Respiratory Pathogens

Influenza viruses are highly contagious enveloped RNA viruses that infect the upper respiratory tract and are always accompanied by a fever. The two common subtypes, Flu A and Flu B, are responsible for the majority of human infections during flu seasons. Infected individuals shed Influenza virus in bodily fluids like mucus and saliva for about 3 - 7 days in healthy adults, and up to 10 days or more in children depending on the viral titer. Infected individuals can also shed Influenza in their feces. Due to this viral shedding, Influenza A and B are deemed suitable for wastewater monitoring purposes.

RSV is a single-stranded enveloped RNA virus that infects the respiratory tract with symptoms ranging from congestion, dry cough, fever, to trouble breathing. While RSV typically induces mild symptoms in healthy individuals, it poses a higher risk for severe infections in infants, the immunocompromised, and the elderly. RSV primarily spreads through large droplets or through contact with contaminated objects. Notably, the virus can survive on surfaces for several hours, potentially contributing to its spread. RSV has been detected in the stool of infected individuals, and its concentrations in wastewater have shown a significant positive correlation with clinically confirmed cases of RSV, demonstrating the effectiveness to track community prevalence of RSV with wastewater surveillance.

Gastrointestinal Pathogens

Noroviruses are single-stranded RNA viruses that cause millions of cases of acute gastroenteritis annually. Gastroenteritis is characterized by symptoms such as diarrhea, vomiting, nausea, and stomach pain and is commonly referred to as the “stomach flu.” Inadequate handwashing before touching the mouth or consuming food, ingestion of contaminated food or liquids from infected individuals, and consumption of uncooked shellfish are common routes of transmission. NoV is excreted in the feces of infected individuals regardless of infection severity, and does not replicate in the environment without a zoological host, making NoV an ideal candidate for wastewater surveillance. WastewaterSCAN data focuses on the NoV GII strain, which causes 80% of norovirus infections worldwide.

Other Pathogens of Concern

MPOX is a double-stranded DNA virus closely related to the smallpox. Infected individuals experience a painful rash resembling pimples or blisters, which can appear on various body parts such as hands, feet, chest, face, mouth, and genitalia. The virus primarily spreads through direct contact with infected individuals with an active rash, contaminated objects (fomites), respiratory droplets, or vertical transmission from a parent to child. Infected individuals shed MPOX into wastewater through urine, semen, saliva, and feces. WBE of MPOX began in 2022 and has been useful in assessing the prevalence of MPOX within communities.

Candida auris (*C. auris*) is an opportunistic fungal pathogen known for its resistance to multiple antifungal agents. While *C. auris* generally poses minimal risk to healthy individuals, it significantly impacts those in long-term healthcare facilities, particularly those with underlying medical conditions, a history of exposure to antifungal agents, or patients requiring invasive medical devices. This pathogen primarily infects the skin through open wounds and the ears, often accompanied by fever and chills. However, *C. auris* may enter the body and infect the bloodstream, heart, or brain (similar to bacterial infections but do not improve with the use of antibiotics). Therefore, infections caused by *C. auris* can be severe and may lead to fatalities. While colonization with *C. auris* can occur without causing any noticeable symptoms, individuals can still transmit the pathogen to others through direct contact or contact with contaminated fomites. *C. auris* has been found in human excreta (feces and urine) as well as in wastewater. Utilizing routine wastewater surveillance to track new introductions of *C. auris* into specific jurisdiction's is vital for infection prevention and control efforts, especially in healthcare settings.

The remainder of this report contains results for wastewater surveillance of SARS-CoV-2, other respiratory pathogens (Flu A, Flu B, and RSV), and gastrointestinal pathogens (NoV GII) and other pathogens of concern (MPOX and *C. auris*) in collaboration with the National Wastewater Surveillance System (NWSS) and WastewaterSCAN. **Note: a total of six WWTP in two counties from the State of Hawaii are participating in this surveillance since WastewaterSCAN were only capable of recruiting these six.** Samples are collected three times a week and analyzed by WastewaterSCAN. WastewaterSCAN processes sludge from participating WWTP in Hawaii rather than the liquid fraction (which is what NWSS contracted lab Biobot Analytics previously utilized for processing). Concentrations in the following pages (unless otherwise stated) are reported as copies per g of dry sludge. This following includes samples collected from 08/15/2023 to 10/25/2023.

Metadata for participating WWTP by county

County	Number of WWTP	Total Population Served
Honolulu	5	906,000
Hawaii	1	16,257

SARS-CoV-2 WastewaterSCAN Surveillance Data

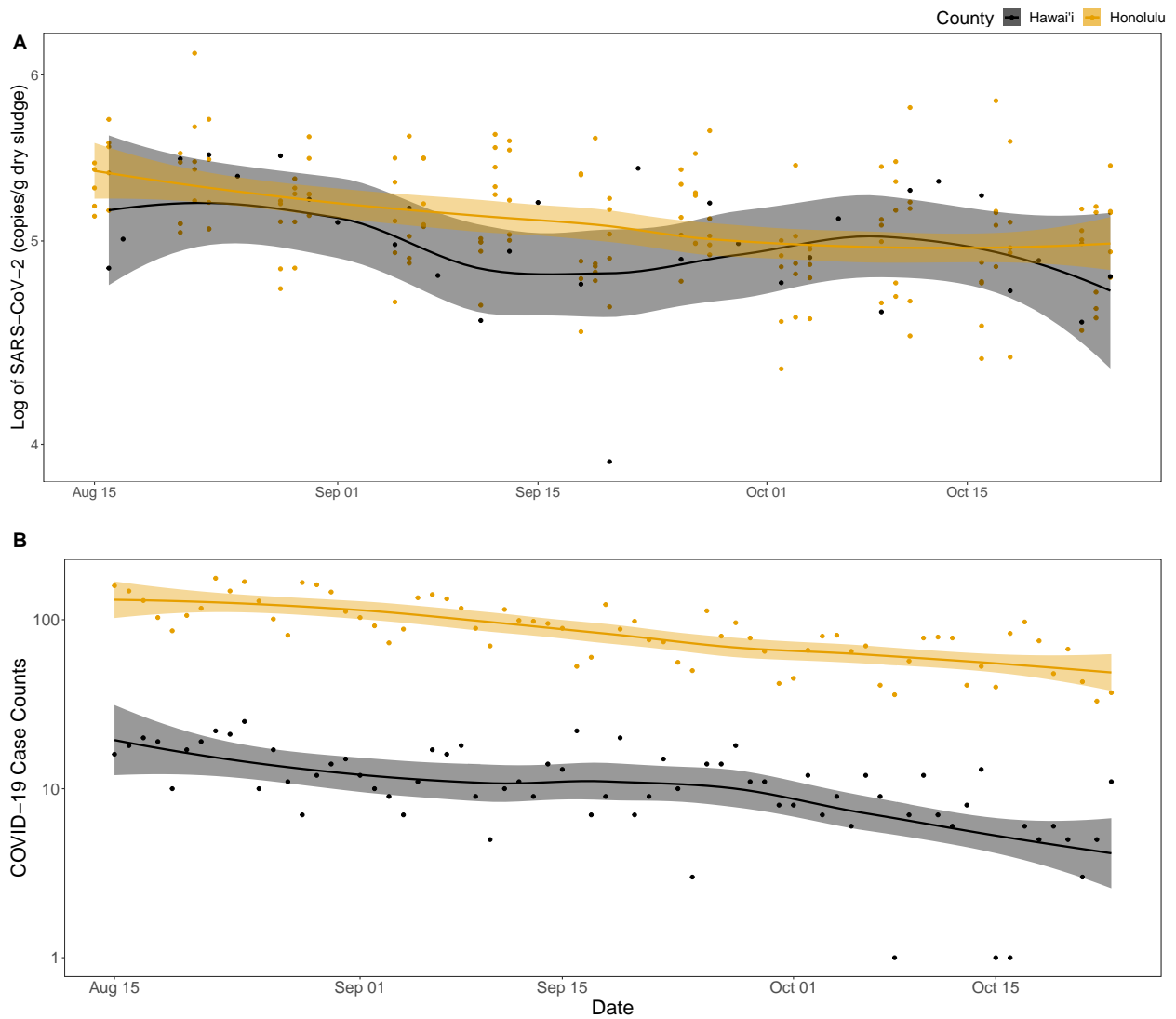


Figure 3. (A) Log transformed normalized concentrations of SARS-CoV-2 in sewage (copies/g dry sludge) quantified by WastewaterSCAN for one WWTP from Hawaii County and five from Honolulu County and (B) COVID-19 case counts for each county. These data are plotted separately since WastewaterSCAN utilizes sludge rather than the liquid fraction of raw sewage influent. Regression line was created with a prediction interval from a locally weighted (LOESS) regression. Shaded region represents 95% confidence interval.

Notes: Trends in raw sewage concentrations of SARS-CoV-2 are fluctuating in these counties.

Wastewater Surveillance Data for Respiratory Pathogens

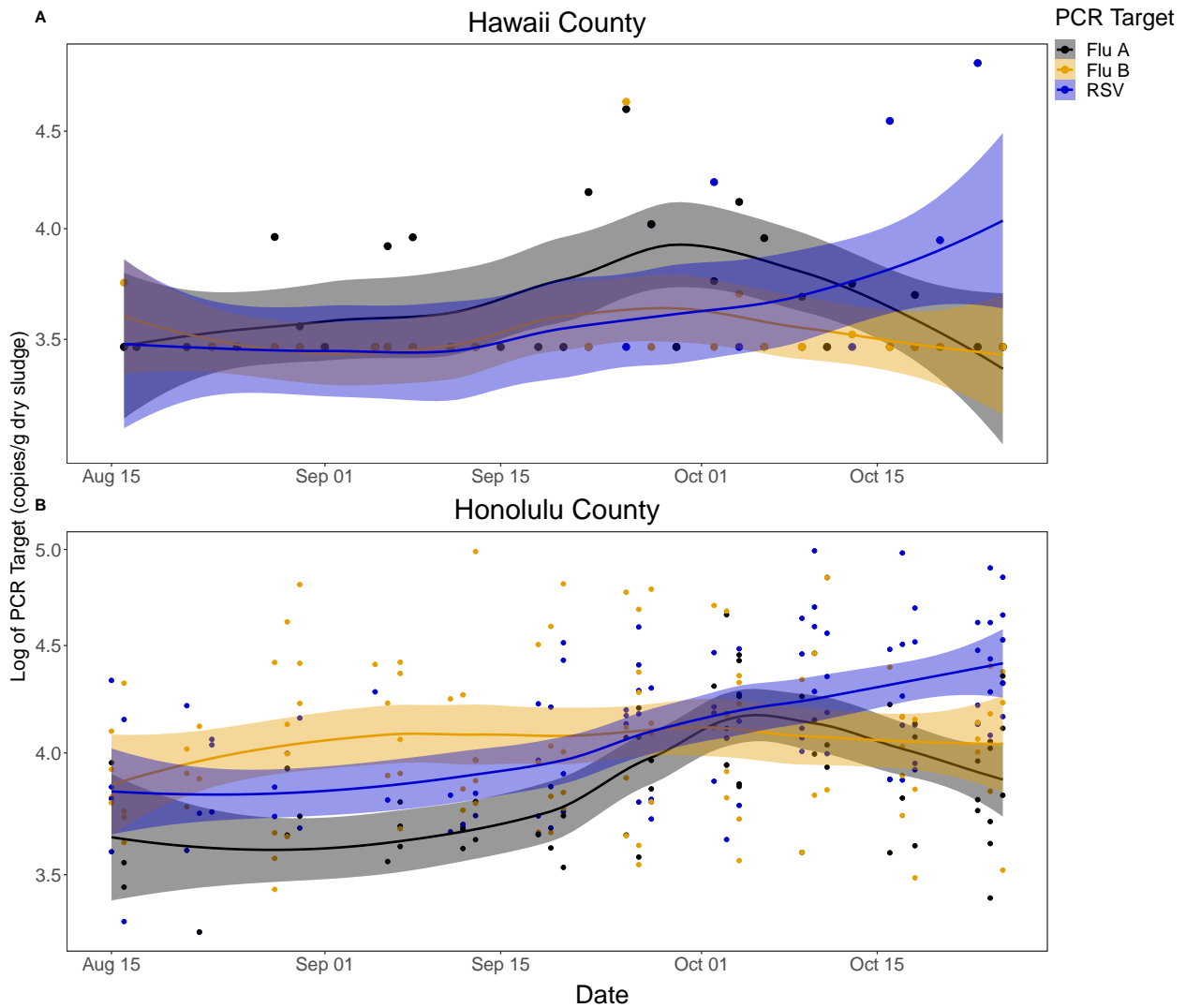


Figure 4. Log transformed normalized concentrations of Flu A, Flu B, and RSV in sewage (copies/g dry sludge) quantified by WastewaterSCAN for one WWTP from (A) Hawaii County and five from (B) Honolulu County. Regression line created with a prediction interval from a locally weighted (LOESS) regression. Shaded region represents 95% confidence interval.

Notes: Concentrations of Flu A and Flu B are very similar over time. RSV trends appear to be increasing, reflecting the typical seasonal increase of RSV from October through April.

Wastewater Surveillance Data for Gastrointestinal Pathogens

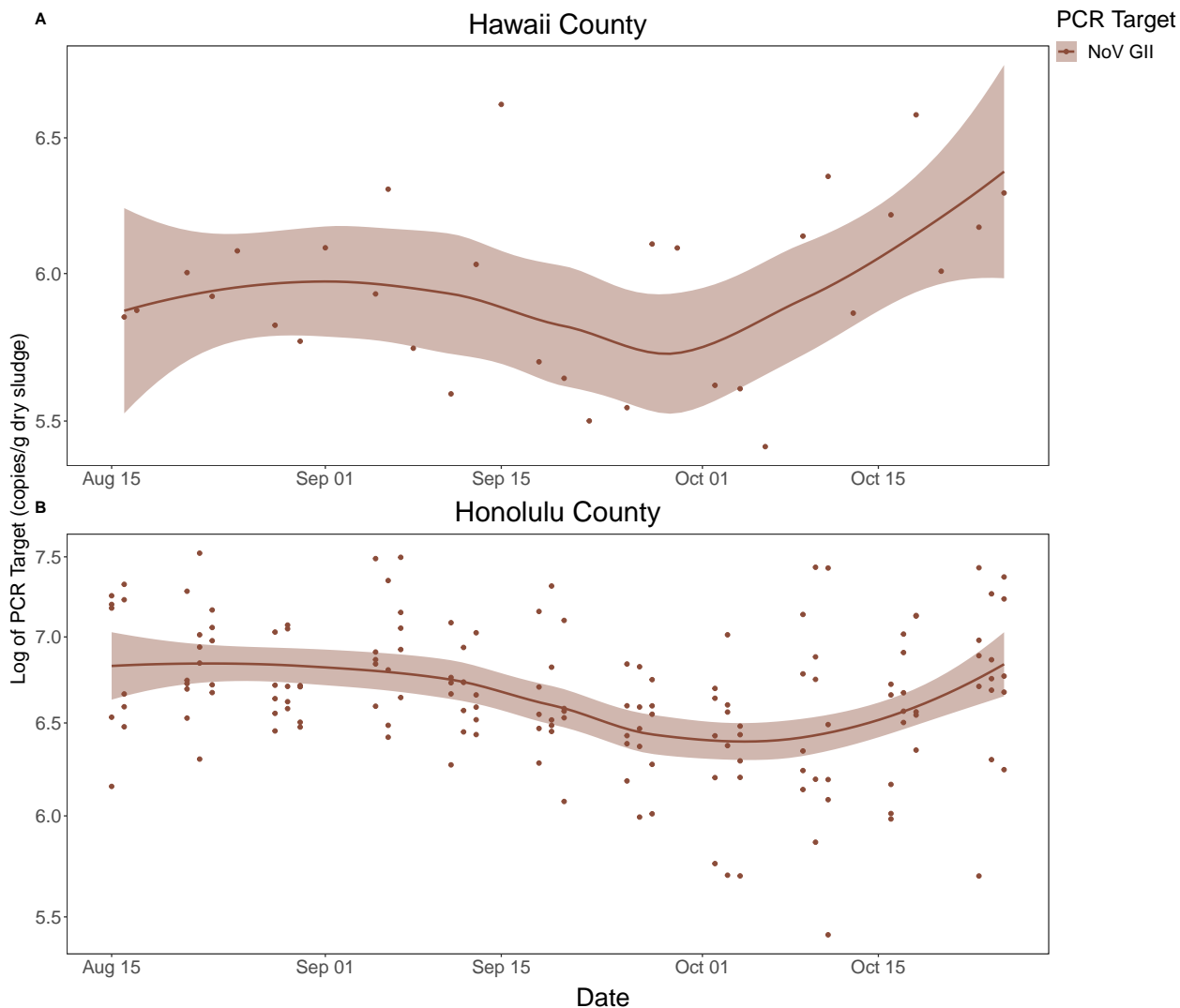


Figure 5. Log transformed normalized concentrations of NoV GII in sewage (copies/g dry sludge) quantified by WastewaterSCAN for one WWTP from (A) Hawaii County and five from (B) Honolulu County. Regression line created with a prediction interval from a locally weighted (LOESS) regression. Shaded region represents 95% confidence interval.

Notes: WastewaterSCAN has estimated that the limit of detection for targets is ~1000 copies/g. NoV GII is found at consistently higher concentrations, likely since those infected primarily shed NoV GII in feces. Still, NoV GII trends are relatively stable across time and similar across counties.

Wastewater Surveillance Data for Other Pathogens of Concern

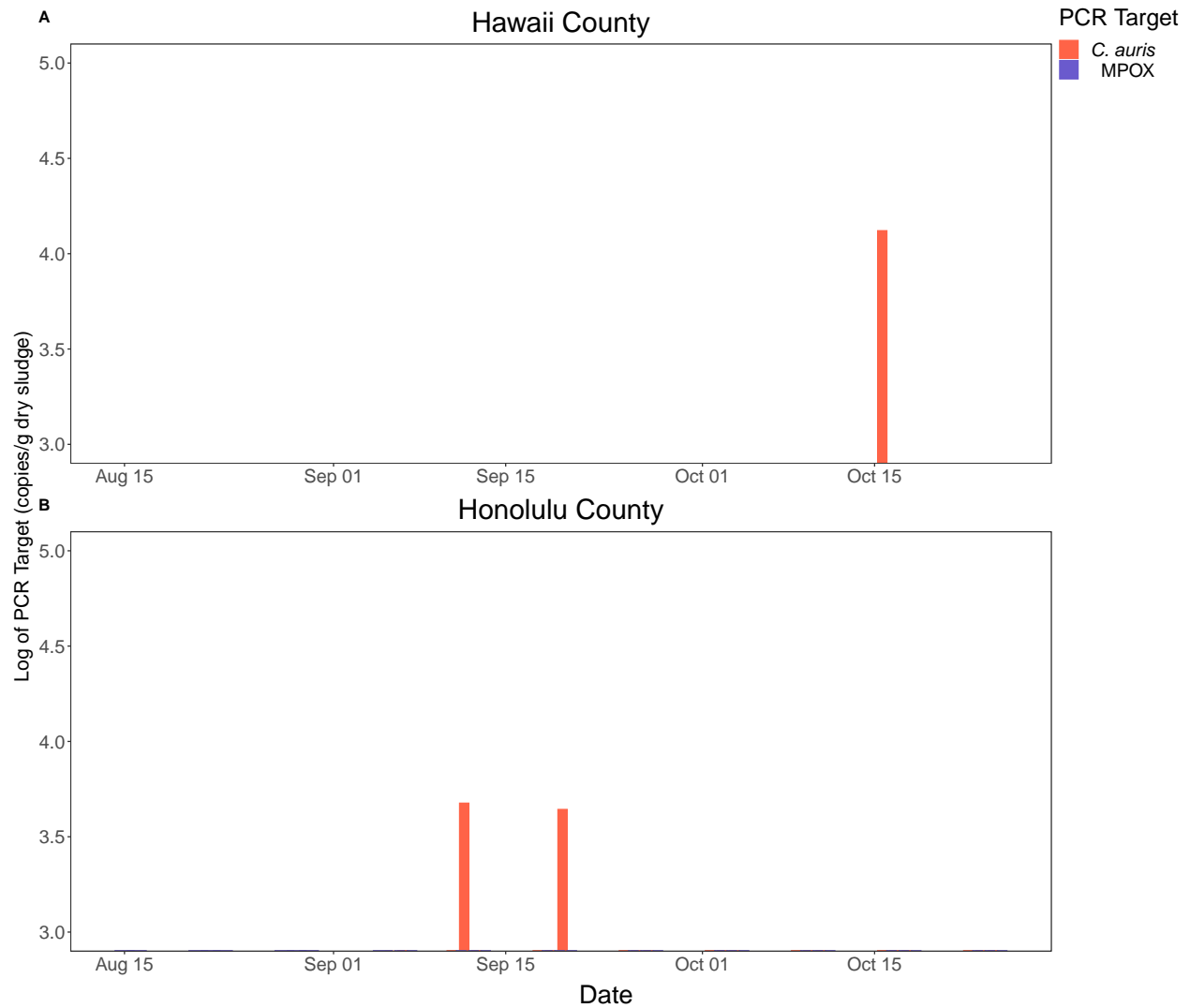


Figure 6. Bar chart of log transformed normalized concentrations of *C. auris* and MPOX in sewage (copies/g dry sludge) quantified by WastewaterSCAN for one WWTP from (A) Hawaii County and five from (B) Honolulu County.

Notes: WastewaterSCAN has estimated that the limit of detection (LOD) for targets is ~1000 copies/g. Samples that fall below the LOD for *C. auris* and MPOX do not appear on the figure. Detection of MPOX and *C. auris* in samples is rare. The majority of samples are below the LOD for both pathogens. *C. auris* detection in wastewater occurred in mid-September for Honolulu county, and in mid-October for Hawaii County.

Resources

- National Wastewater Surveillance System (NWSS): <https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/wastewater-surveillance.html>
 - How it works: <https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/resources/how-wws-works.html>
 - Data Reporting: <https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/data-reporting-analytics.html>
 - Data: <https://covid.cdc.gov/covid-data-tracker/#wastewater-surveillance>
 - Testing Method: <https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance/testing-methods.html>
- Biobot Analytics: <https://biobot.io/>
 - Data: <https://biobot.io/data/>
 - Methodology and Protocol: <https://biobot.io/covid19-community-plus-report-notes/>
 - Sequencing: <https://biobot.io/covid19-variants-report-notes/>
- WastewaterSCAN: <https://wastewaterscan.org/>
 - Data: <https://data.wastewaterscan.org/>
 - Methodology and Protocol: <https://data.wastewaterscan.org/about>
 - <https://www.protocols.io/view/high-throughput-pre-analytical-processing-of-waste-kxygxpod4l8j/v2>
 - <https://www.protocols.io/view/high-throughput-rna-extraction-and-pcr-inhibitor-r-81wgb72bovpk/v2>
 - <https://www.protocols.io/view/high-throughput-sars-cov-2-pmmov-and-bcov-quantifi-e6nvw5orwvmk/v5>
 - <https://www.protocols.io/view/quantification-of-various-sars-cov-2-variant-mutat-14egnzrrzg5d/v11>
 - <https://www.protocols.io/view/quantification-of-various-sars-cov-2-variant-mutat-14egnzrrzg5d/v11>
- SARS-CoV-2 Variant Classifications:
 - <https://www.cdc.gov/coronavirus/2019-ncov/variants/variant-classifications.html#:~:text=SARS%2DCoV%2D2%20has%20many,contain%20one%20or%20more%20mutations.>
- Information on other pathogens surveyed by wastewater:
 - Influenza: <https://www.cdc.gov/flu/about/index.html>
 - <https://www.cdc.gov/flu/about/viruses/types.htm>
 - RSV: <https://www.cdc.gov/rsv/index.html>
 - <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3461981/>
 - Norovirus: <https://www.cdc.gov/hai/organisms/norovirus.html>
 - <https://www.cdc.gov/norovirus/lab/virus-classification.html>
 - <https://journals.asm.org/doi/10.1128/jvi.01364-10>
 - MPOX: <https://www.cdc.gov/poxvirus/mpox/symptoms/index.html>
 - <https://www.cdc.gov/poxvirus/mpox/index.html>

- *C. auris*: <https://www.cdc.gov/fungal/candida-auris/index.html>
- <https://www.cdc.gov/drugresistance/pdf/threats-report/candida-auris-508.pdf>
- <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7211321/>
- <https://www.ncbi.nlm.nih.gov/books/NBK563297/>
- More about wastewater surveillance for SARS-CoV-2 and other pathogens:
 - <https://www.sciencedirect.com/science/article/pii/S2590049822000078>
 - <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8416286/>
 - <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7583624/>
 - <https://www.nature.com/articles/s41586-022-04980-y>
 - <https://www.nature.com/articles/s41586-022-05049-6>
 - <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10256456/>
 - <https://pubmed.ncbi.nlm.nih.gov/34153546/>
 - <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9858235/>
 - <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8769679/>
 - <https://pubs.acs.org/doi/10.1021/acs.estlett.1c00963>
 - <https://pubs.acs.org/doi/10.1021/acs.est.2c07763>