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Retrospective Assessment Of The Accuracy Of Mpox Case Projections In New York City

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BACKGROUND

- In mid-2022, New York City (NYC) became the epicenter of the US mpox epidemic. Health authorities needed forecasts to anticipate the timing and magnitude of the outbreak.
- We performed mathematical model-based projections with methodologies that evolved alongside the epidemic.

Objective: To retrospectively evaluate our mpox case projections and reflect on potential reasons for accuracies and inaccuracies.

METHODS

- Early in the outbreak (July 1 – 15, 2022), we performed short-term (2-week) forecasting using exponential regression.
- Once the epidemic was no longer exponentially growing (July 15 – Aug. 9), we developed a Susceptible-Exposed-Infected-Recovered (SEIR) model, taking into account immunity accrued through vaccination and prior exposure.
- To also estimate case detection rate, we consulted with the NYC Department of Health and Mental Hygiene regarding populations most-at-risk of mpox based on available epidemiological data. Modelers and epidemiologists collaboratively developed an estimate of **70,180 people at risk**, informed by estimates of LGBTQ adults with male sex at birth who had 2+ partners in the last 3 months.
- SEIR model parameters were calibrated using the OPTUNA optimization framework.
- Model code can be found at: https://github.com/BershteynLab/NYCMonkeypox_model

Table 1: SEIR model parameters calibrated to fit case count data using constrained optimization.

Parameter	Value	Calibration Bounds
R_0	3.8	1.0 – 4.0
Incubation period	7.5 days	6.6 – 10.9 days
Infectious period	14 days	14 – 28 days
Case ascertainment	6%	5% – 100%
First vaccine dose efficacy	77%	50% – 100%

Once the NYC mpox epidemic slowed from exponential to linear growth, an SEIR model could accurately forecast case counts for the rest of the epidemic.

RESULTS

- Initial exponential forecasts of the NYC mpox outbreak were only accurate for very short-term predictions (< 2 weeks) (Figure 1, left panel). Forecasts were more accurate after 1 week (mean absolute error: **83.0 cases/week**) than after 2 weeks (mean absolute error: **351.4 cases/week**).
- In contrast, the SEIR model accurately predicted the decline in cases through the end of Sept. 2022, when cases fell to < 70/wk. Over the period from Aug. 10 to Sept. 24 2022, the mean absolute error of the SEIR-based projection was **8.2 cases per week** (Figure 1, right panel).
- Assuming 70,180 people at risk, the model fit optimization **estimated a case ascertainment rate of 6%.**

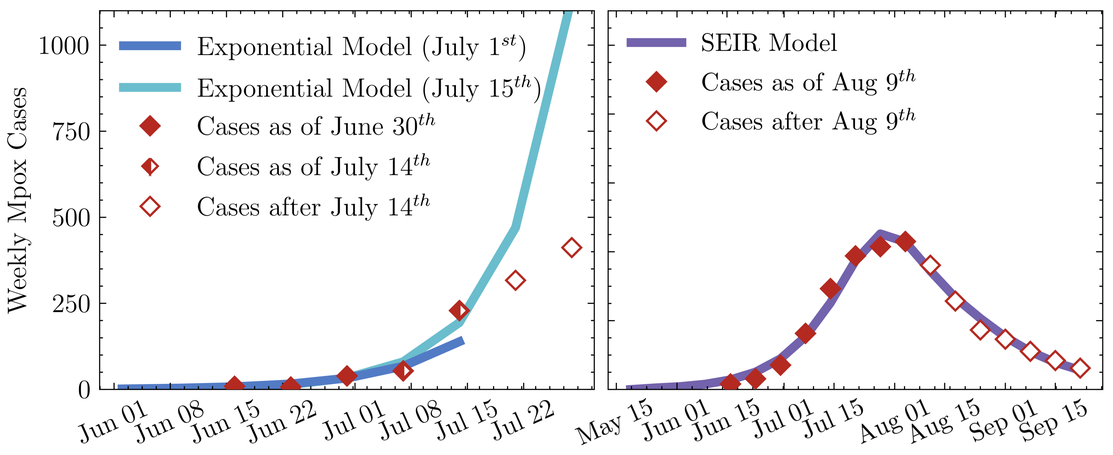


Figure 1: Weekly case count and model fits for the exponential (left) and SEIR (right) models. The July 1st exponential model was trained on ◆ to predict ◆ . The July 15th exponential model was trained on ◆ & ◆ to predict ◇. The outbreak exited exponential growth around July 15th, explaining the large prediction error by the July 15th model. The SEIR model (right) was trained on ◆ to predict ◇ .

CONCLUSIONS

- Model-based mpox projections provided only short-term accuracy in the early epidemic, but long-term accuracy once the epidemic exited exponential growth and an SEIR model was developed.
- Cumulative cases and vaccinations when exiting exponential growth, and the epidemiology of those most-at-risk, provided evidence for the product of case ascertainment rate and size of the most-at-risk population – a crucial input for an accurate SEIR model.
- The ability of the SEIR model to accurately forecast mpox cases was in part attributable to lack of vaccine or immune escape by mpox, in contrast to more rapidly-evolving viruses such as SARS-CoV-2.

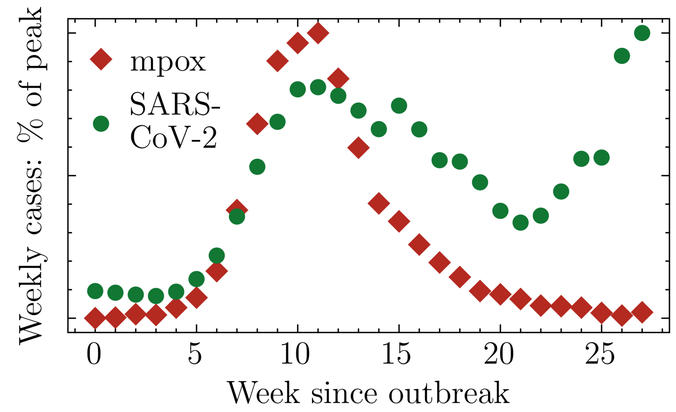


Figure 2: Weekly case count for SARS-CoV-2 (Delta + Omicron wave) and mpox. Mpox follows a canonical SEIR curve, while SARS-CoV-2 is more difficult to forecast due to vaccine and immune escape.

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