Real-time use of a dynamic model to measure the impact of public health interventions on measles outbreak size and duration — Chicago, Illinois, 2024

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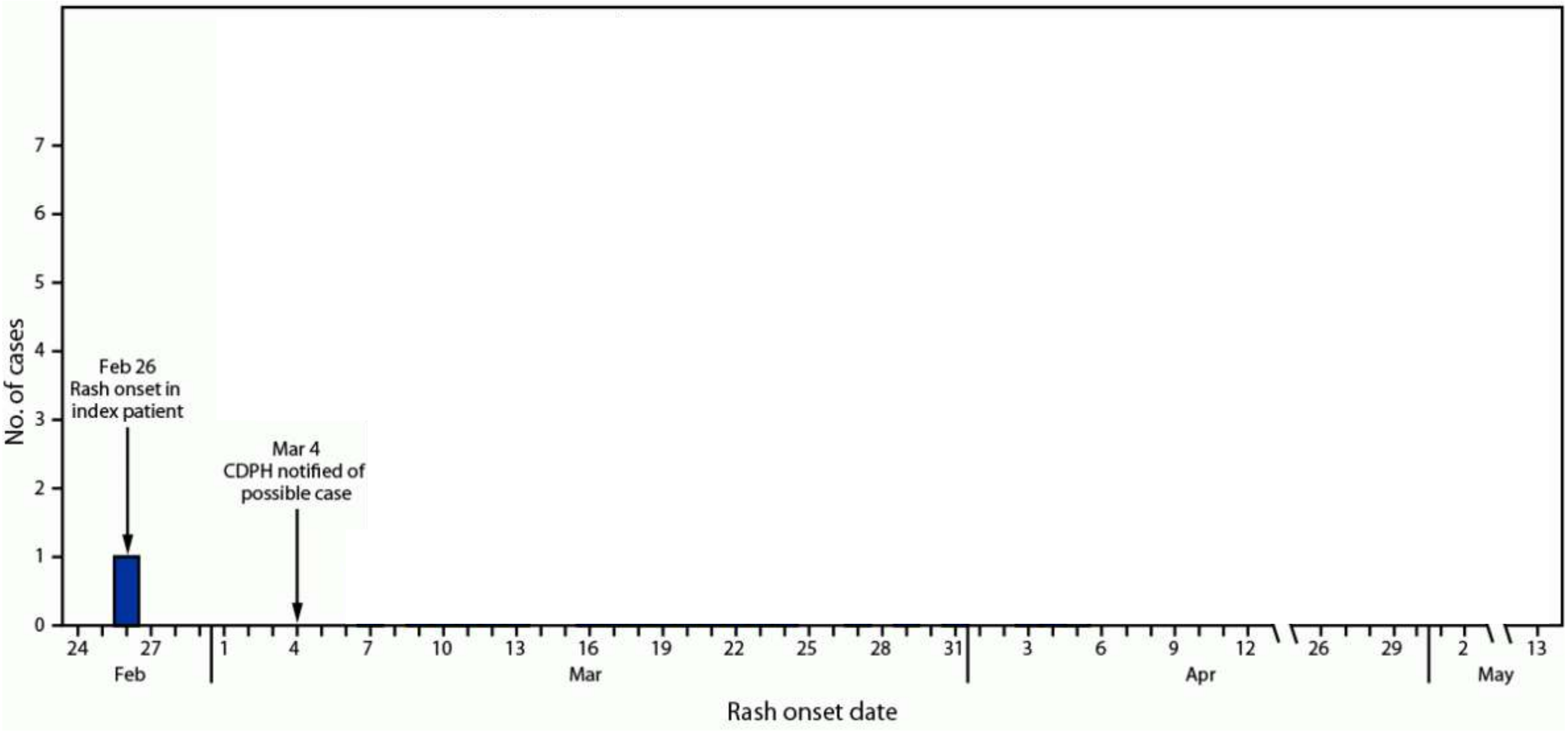
In 2024, a measles outbreak was possible among new arrivals in Chicago

- Around this time, there were 12,000 people in 27 temporary migrant shelters in Chicago
- ~90% were from Venezuela
- Venezuela has had declining measles immunization coverage among children

Source: www.chicagotribune.com/2024/05/30/citys-public-health-department-declares-measle-outbreak-over-according-to-report/

In March 2024, a measles case was reported at a new arrivals shelter in Chicago



Shelter conditions were crowded and well-mixed

https://www.nbcnews.com/nightly-news/video/growing-concern-over-chicago-measles-outbreak-206564421700

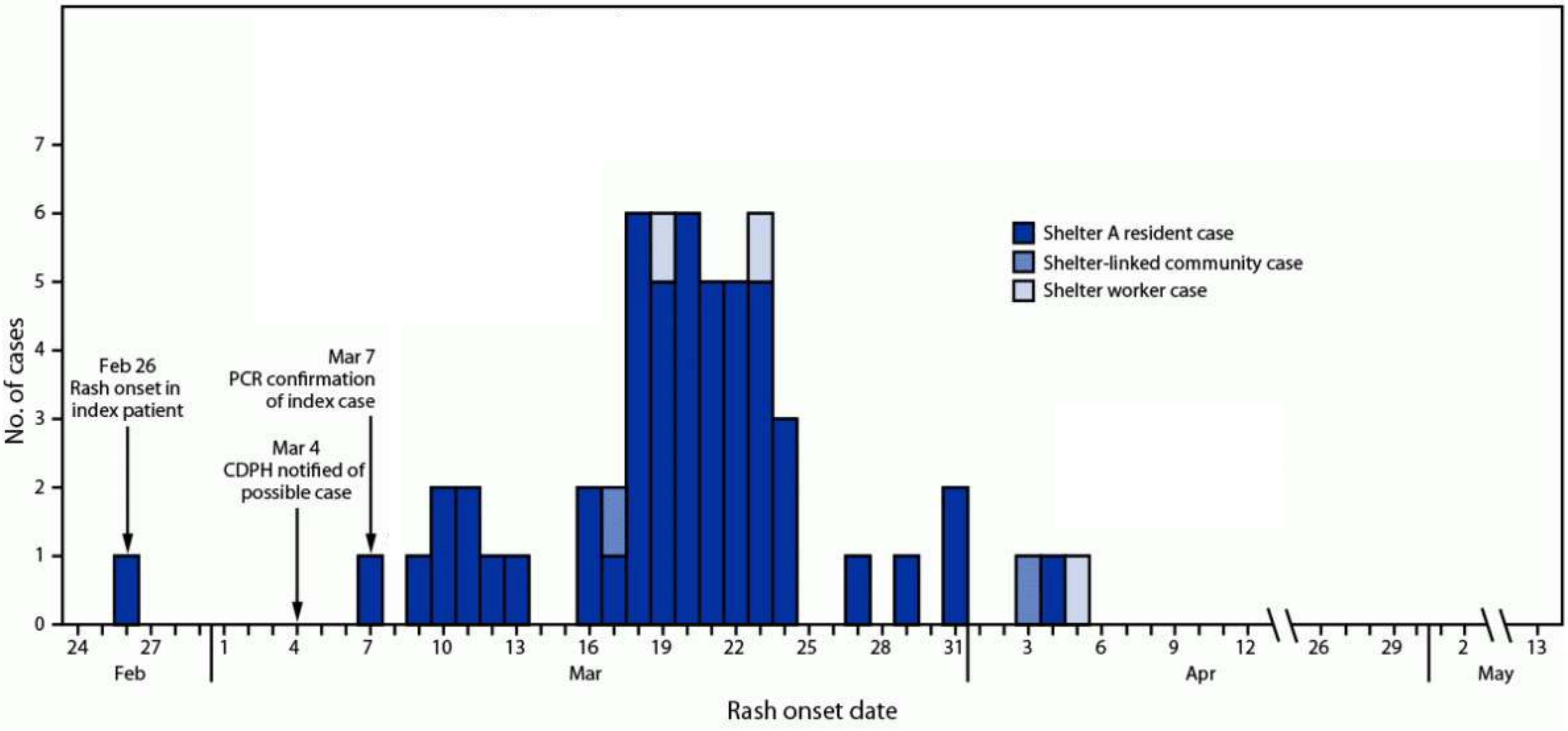
Shelter conditions were crowded and well-mixed

2,100 people in this shelter

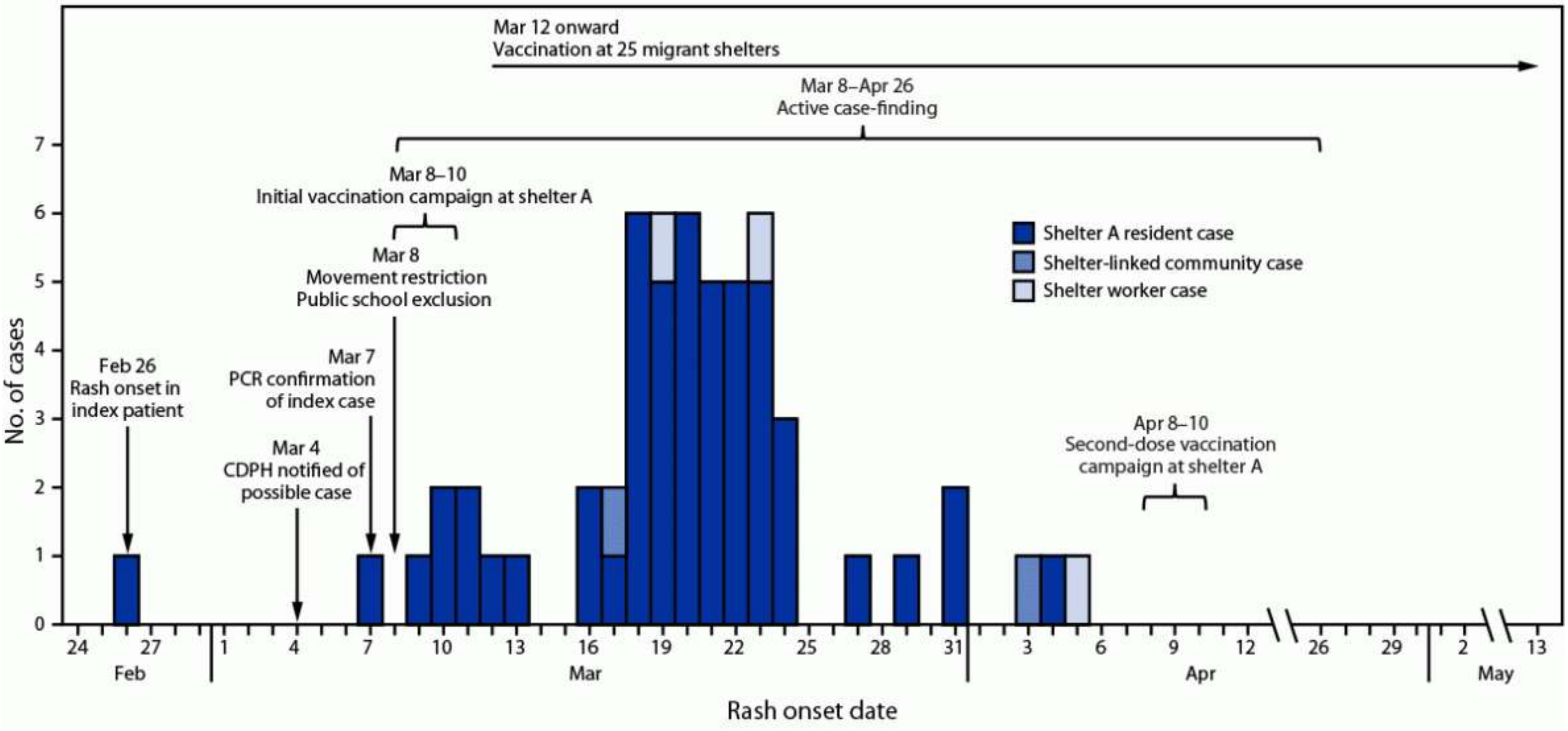
>500 people in certain rooms in the shelter

https://www.nbcnews.com/nightly-news/video/growing-concern-over-chicago-measles-outbreak-206564421700

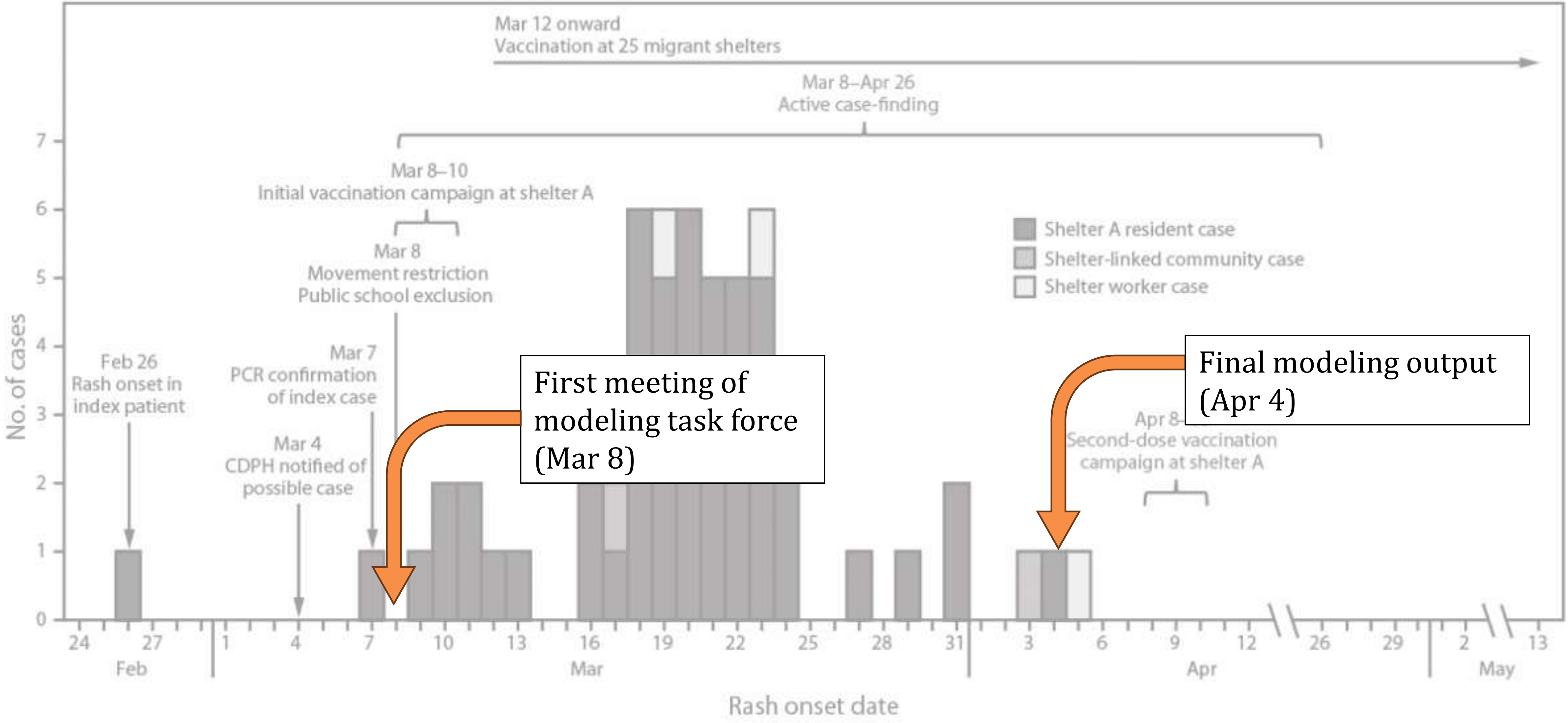
The resulting measles outbreak had 57 total cases



Public health interventions reduced the size of the outbreak



A modeling task force was assembled early in the outbreak



Modelers were tasked with multiple types of questions

Real-time situational awareness about the shelter outbreak:

- Is the case series data consistent with the single, known introduction?
- What is the final expected **outbreak size**?
- When is the outbreak expected to **end**?

***Post hoc* evaluation of the interventions** in the shelter outbreak:

- To what degree did **mass vaccination** reduce the outbreak size?
- To what degree did **active case-finding** reduce transmission?

Other questions, not about the shelter itself:

- What is the chance of an outbreak in shelters with similar conditions?
- What is the probability of spillover into the larger community?
- How does this outbreak relate to nationwide trends in measles cases?

The task force had access to, and expertise with, an existing modeling framework

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Operation Allies Welcome Completes Vaccination Campaign for Measles and Varicella for Afghan Evacuees

Release Date: October 4, 2021

OAW flights from abroad will resume this week

WASHINGTON – Operation Allies Welcome (OAW) has completed a historic and nationwide vaccination campaign for measles, mumps, rubella (MMR), and varicella (chickenpox) to Afghan evacuees who are temporarily staying at eight military installations in the United States. As a result of this effort, more than 49,000 Afghan evacuees nationwide are now vaccinated. Evacuees are also receiving vaccinations at staging areas in Europe and the Middle East. OAW flights from staging areas will resume this week. Arriving eligible Afghans receive the MMR, varicella, polio, COVID-19, and other age appropriate vaccinations, as well as medical exams and health screenings, as a condition of their humanitarian parole.

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ARTICLES · Volume 8, Issue 8, E618-E628, August 2023 · *Open Access*

Measles virus transmission patterns and public health responses during Operation Allies Welcome: a descriptive epidemiological study

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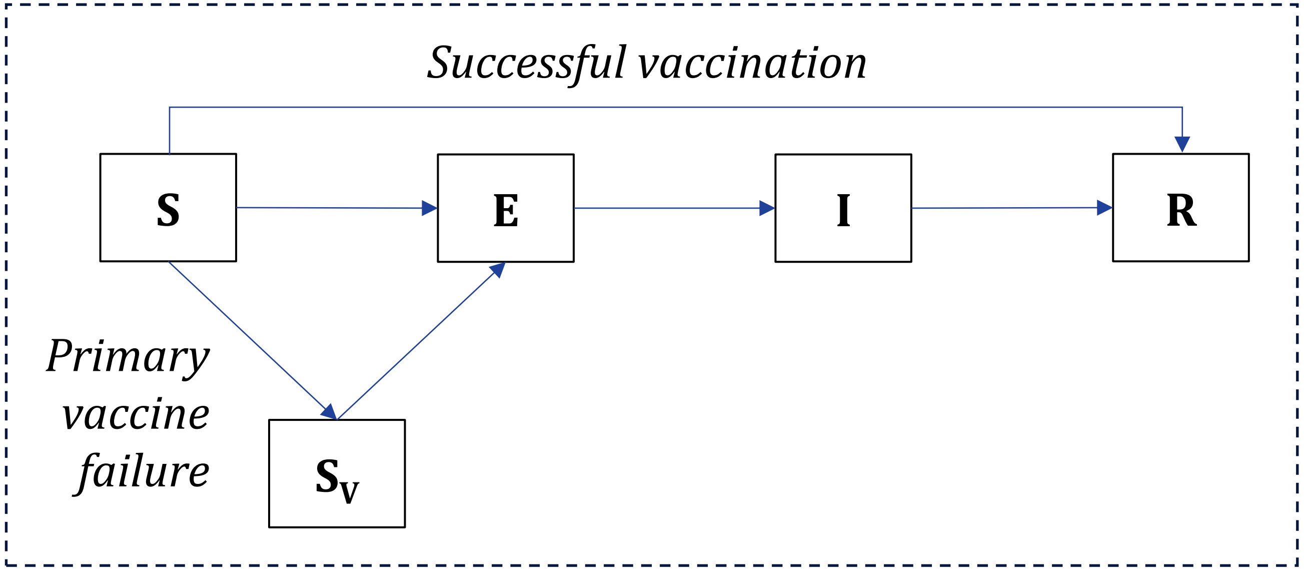
Compartmental, stochastic model

Age group: <6 months

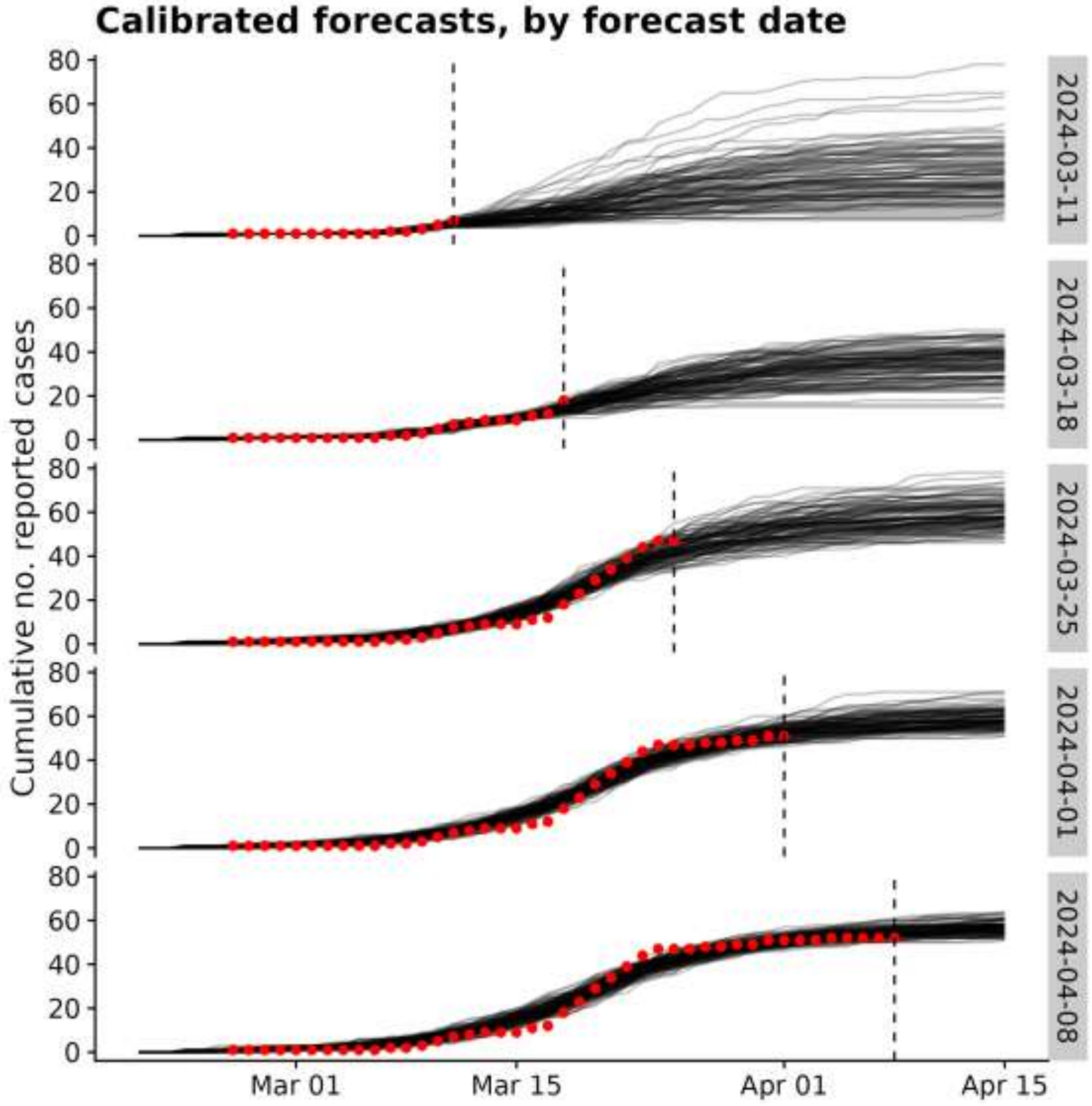


Other age groups:
- 6-11 months
- 1-11 years
- >11 years, not pregnant
- >11 years, pregnant

- Assume well-mixed population
- Use age-structured estimates of measles immunity among Venezuelans for starting *S* and *R* compartment sizes
- Account for *R* individuals who do not have vaccination records
- Move individuals from *S* to *R* or S_V based on empirical vaccination effort
- Move individuals between other compartments using Gillespie algorithm and typical mass action ODEs
- Change recovery (I→R) rate constant after active case finding begins

https://github.com/CDCgov/measles-model-chicago-2024

Calibrated forecasts were used to estimate outbreak duration and size



- As expected, forecast accuracy improved with time
- Outbreaks are highly stochastic, but stochasticity in this model formulation likely did not capture true variability in reproductive number across individuals
- First-pass compartmental model did not reproduce observed generations of infections, because of overdispersion of latent (E) and infectious (I) periods.

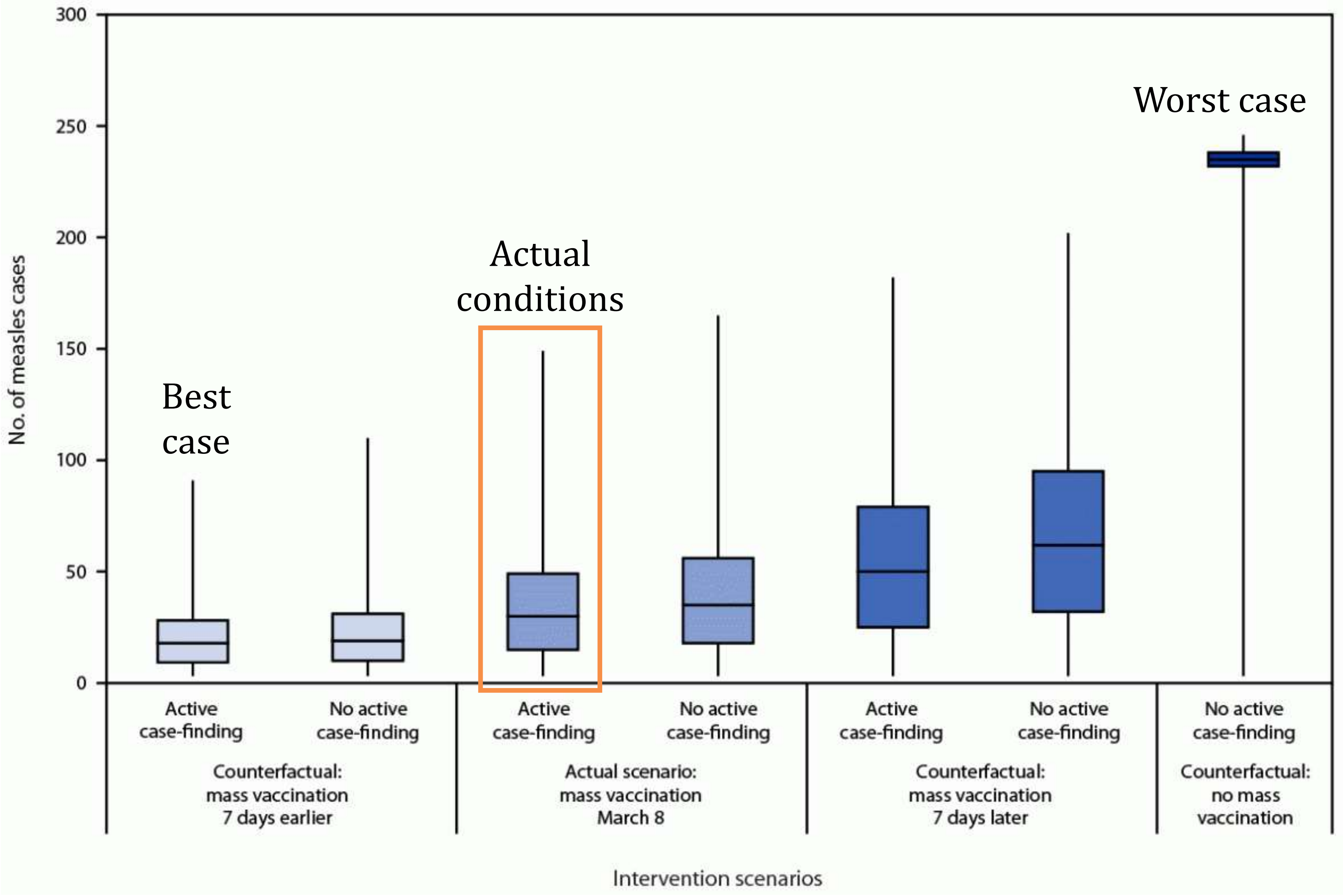
Calibrated forecasts were used to estimate outbreak duration and size

Forecast date	No. of observed measles cases among shelter residents	Median model-predicted final outbreak size (IQR)	Median model-predicted final rash onset date
Mar 11	7	29 (20–39)	Apr 16
Mar 18	18	38 (31–41)	Apr 18
Mar 25	47	60 (57–65)	Apr 20
Apr 1	51	60 (58–63)	Apr 20
Apr 8	52	58 (56–60)	Apr 18

Model stabilized to a ~10% overestimate of final outbreak size (52)

Estimates of the outbreak duration were consistent, ~10-day overestimates

Counterfactual simulations gave *post hoc* estimates of interventions' effects



Counterfactual simulations gave *post hoc* estimates of interventions' effects

Worst case

Intervention start dates		Chance of additional measles cases among shelter residents,* %					Duration
Mass vaccination	Active case-finding	Zero cases	1–9 cases	10–49 cases	50–99 cases	≥100 cases	Last rash onset in outbreak (median)
Never	Never	24	7	—	—	69	May 26
Mar 15	Never	24	10	23	28	15	Apr 21
	Mar 8	23	13	28	27	8	Apr 17
Mar 8	Never	24	15	40	21	1	Apr 14
	Mar 8	23	17	43	17	1	Apr 9
Mar 1	Never	24	24	49	3	—	Apr 3
	Mar 8	23	26	49	2	—	Mar 30

Best case

Actual conditions

Reflections on the modeling experience

- **Real-time support**, both forecasts and counterfactuals, were very useful to on-the-ground team.
- We benefited from having a **tool on the shelf**, with plausible parameters already specified.
- We benefited from a **strong team**:
  - The task force lead was a highly experienced measles modeler.
  - We had ~5 modelers with some modeling and software development experience.
- The compartmental model was useful, up to a point.
  - Compartmental models make **implicit assumptions** about compartmental dwell time distributions.
  - Incremental increases in conceptual model complexity (e.g., explicitly tracking vaccination documentation status) led to exponential increases in **implementation complexity**.
- We would have benefited from **standardized tooling**:
  - Turn-key calibration and inference methods
  - High-performance individual-level simulations

The team, disclaimer, links to products

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https://github.com/CDCgov/measles-model-chicago-2024

DOI: 10.15585/mmwr.mm7319a2

Dr. Borah's NIC presentation on this outbreak: https://drive.google.com/file/d/1jPJppKjGu_qtklDZ6d49-UJghA7K_eK5/view?pli=1

CFA is hiring!

Contact Scott Olesen <ULP7@CDC.GOV> for guidance on navigating federal hiring system