

Background and Motivation

Timeline:

- Late March 2020: "Stay Home, Stay Healthy" order was issued in Washington State in response to the COVID-19 pandemic.
- May 1: A 4-phase reopening plan was announced.
- July 15: If implemented without interruptions, all types of public interactions will resume.

Goals:

- 1) Develop a model capable of fitting to **age-specific case numbers and deaths, as well as the timing of the peak of the epidemic outbreak.**
- 2) Assess the impact of interventions such as **early test and isolate, early test and treat, post exposure prophylaxis and inpatient treatment** to understand whether such measures will allow less restrictive social distancing during and after reopening.

Methods

- We used age structured mathematical model (Figure 1) with contact matrix, stratifying the population and interactions by:
 - Age (0-19 years, 20-49 years, 50-69 years, and 70+ years)
 - Infection status (susceptible, exposed, asymptomatic, pre-symptomatic, symptomatic, recovered)
 - Treatment status (undiagnosed, diagnosed, hospitalized)
- The **forces of infection**, representing the risk of the susceptible individuals to acquire infection (transition from S to E), are differentiated by susceptible individuals' age, the proportion of contacts with each age group (contact matrix), infected contacts' age, infection and treatment status, and simulated intervention impact on transmission (see Table)

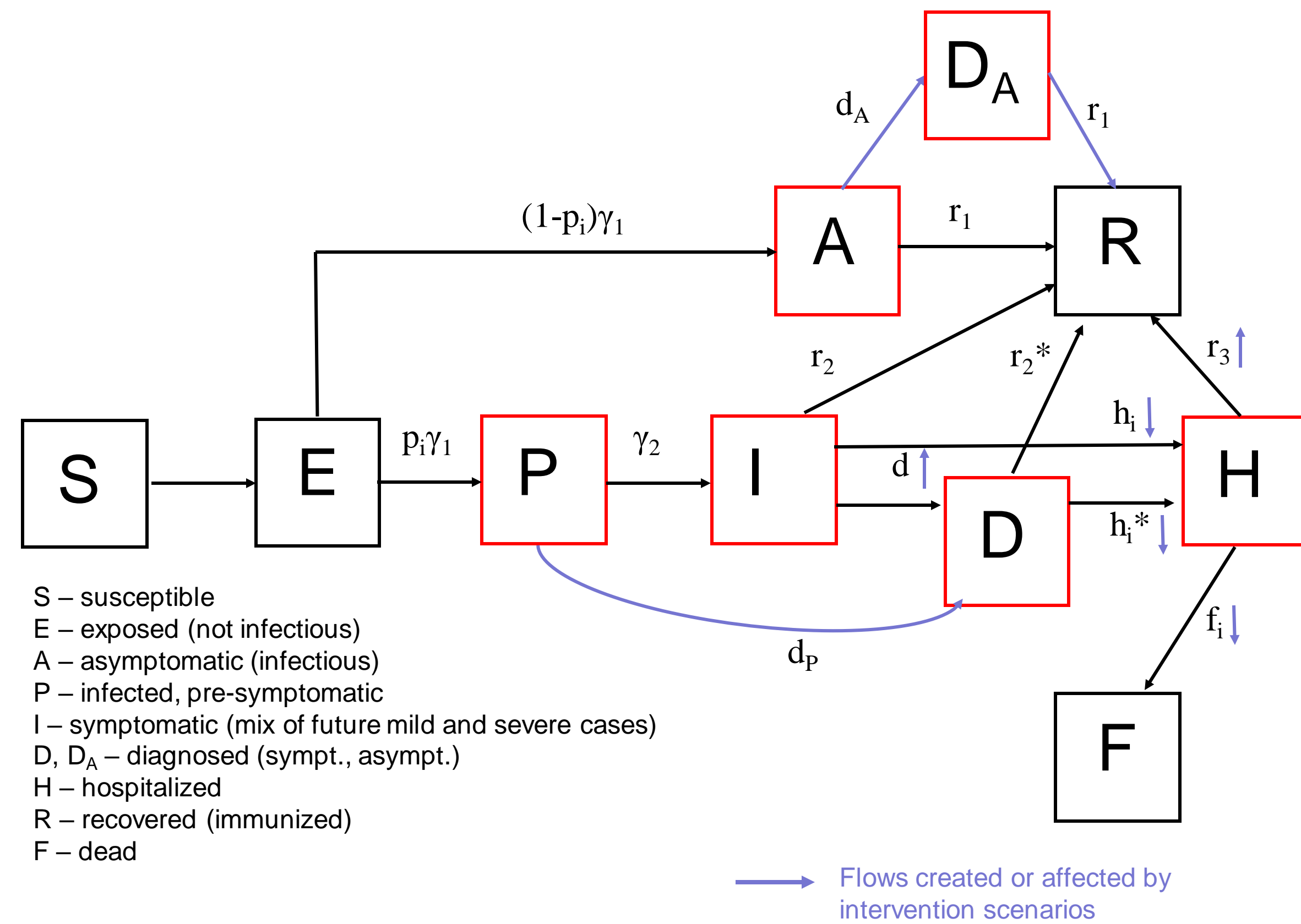


Figure 1. Model diagram. Infectious states are presented in red. Stratification by age (4 groups) is not shown.

Model Calibration

The model was calibrated to 5 local data sources (Figure 2):

- 1) cumulative number of confirmed cases and
- 2) deaths reported in King County over time since the start of the epidemic outbreak;
- 3) age-distribution of the cumulative confirmed cases and
- 4) deaths reported in King County at 3 time points after the start of the epidemic outbreak;
- 5) timing of the peak of daily confirmed cases estimated as April 1.

Best fit and other 100 acceptable parameter sets which fit data reasonably well are selected.

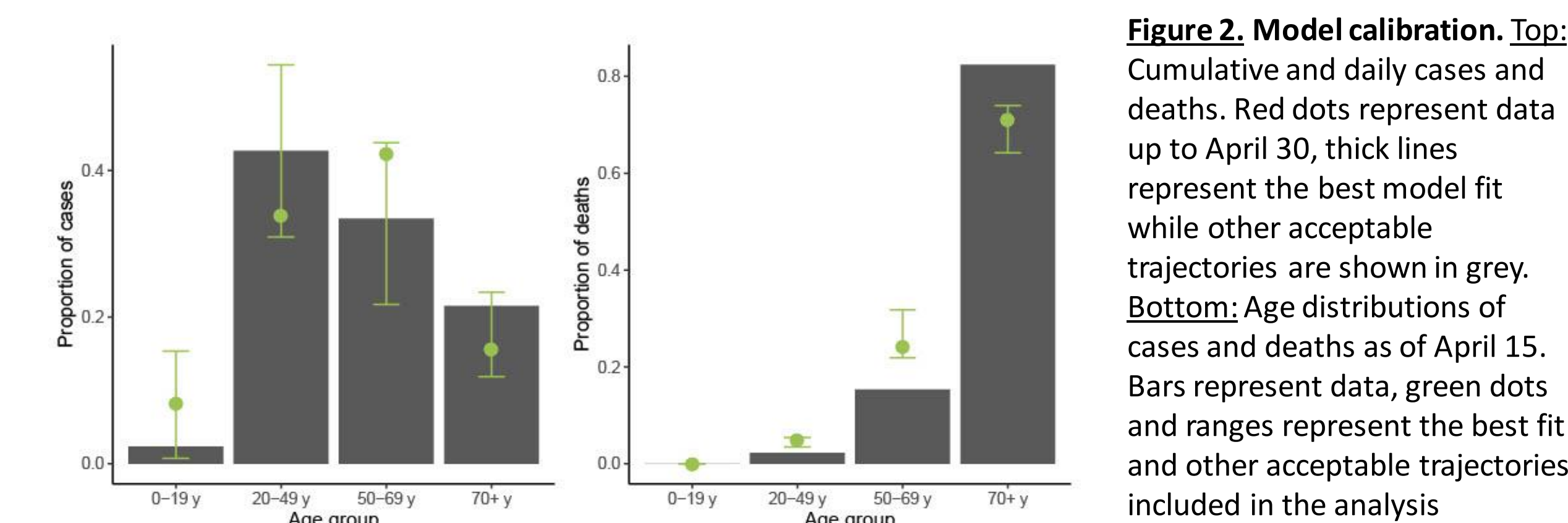
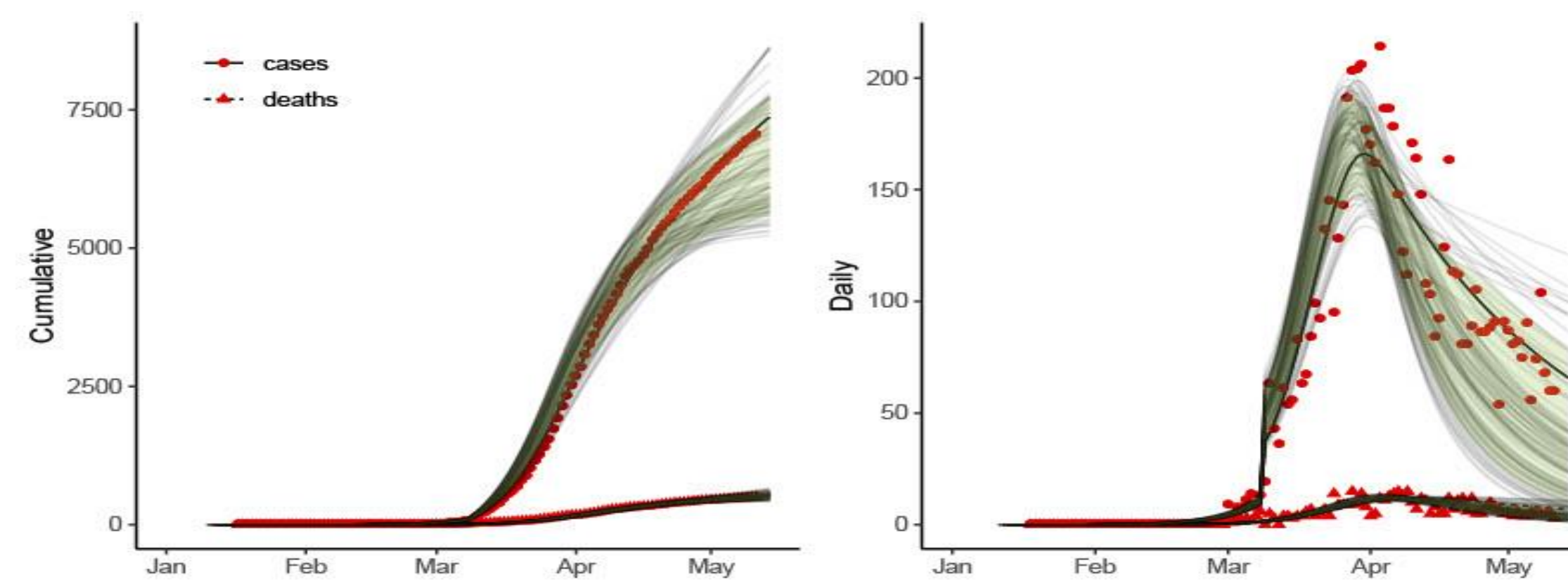


Figure 2. Model calibration. **Top:** Cumulative and daily cases and deaths. Red dots represent data up to April 30, thick lines represent the best model fit while other acceptable trajectories are shown in grey. **Bottom:** Age distributions of cases and deaths as of April 15. Bars represent data, green dots and ranges represent the best fit and other acceptable trajectories included in the analysis

Reopening and intervention scenarios

| Scenario (Name) | Simulated effects in the model |
|---|---|
| Uniform expansion of physical contacts across age groups (Baseline) | • Gradually increase physical interactions to predefined (up to 75%) pre-COVID levels between May 15 and July 15 for all age groups. |
| Extended physical distancing for seniors (Protect seniors) | • Gradually increase physical interactions to predefined (up to 75%) of pre-COVID levels between May 15 and July 15 for age groups 1, 2 and 3 only (<70). |
| Schools reopening in fall (Reopen schools) | • Additional increase of the physical interactions of the youngest group to 80% of the pre-COVID on Sept.1 |
| Effective inpatient treatment | • Reduce mortality rate among hospitalized by 50% • Improve recovery rate among hospitalized by 20% |
| Rapid test and isolate symptomatic | • Increase diagnostic rates among symptomatic to 10% daily • Reduce transmission from diagnosed by 50% |
| Rapid test, isolate and treat symptomatic | • Increase diagnostic rates among symptomatic to 10% daily • Reduce transmission from diagnosed by 75% • Reduce hospitalization rate from diagnosed by 50% |
| Rapid test and isolate symptomatic + trace, test and isolate contacts | • Increase diagnostic rates among symptomatic to 10% daily • Reduce transmission from diagnosed by 50% • Increases diagnostic rates among asymptomatic and pre-symptomatic to 5% daily |
| Rapid test, isolate and treat symptomatic + trace, test and treat contacts | • Increase diagnostic rates among symptomatic to 10% daily • Reduce transmission from diagnosed by 75% • Reduce hospitalization rate from diagnosed by 50% • Increases diagnostic rates among asymptomatic and pre-symptomatic to 5% daily |

Results

Our best fit suggests that:

- Social distancing reduced contact rates and SARS-CoV-2 transmission by **~65% (35% pre-COVID physical interactions, pC-PI)** when fully implemented in King County.
- **R_t** decreased from **2.43** at the start of the epidemic to **0.81** by the end of April.
- Approximately **2%** of the population in King County have been infected with SARS-CoV-2 by May 15 (cumulative incidence) with approximately **17%** of the symptomatic cases being diagnosed.

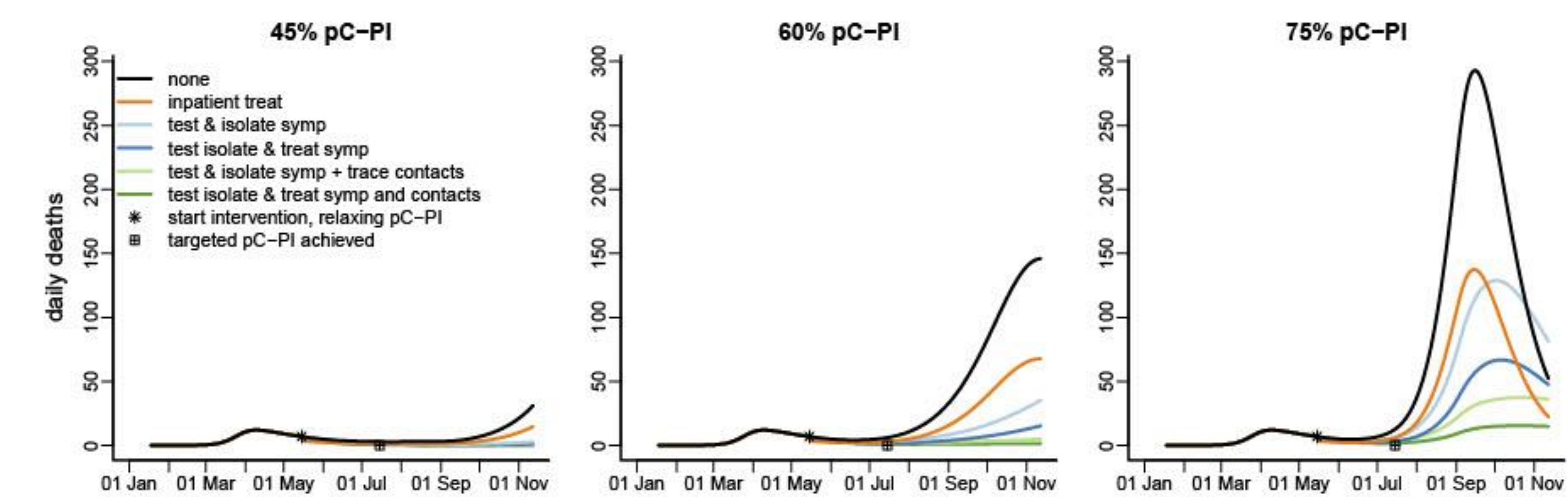


Figure 3. Model projections of daily deaths under different levels of pre-COVID physical interactions restored suggest that:

- Daily deaths will remain low at a threshold of **45% pC-PI**
- Comprehensive test and trace would allow restoration to **60% pC-PI** without significant increases in daily deaths
- When applied at **75% pC-PI**, test and trace is unlikely to prevent a massive surge in cases

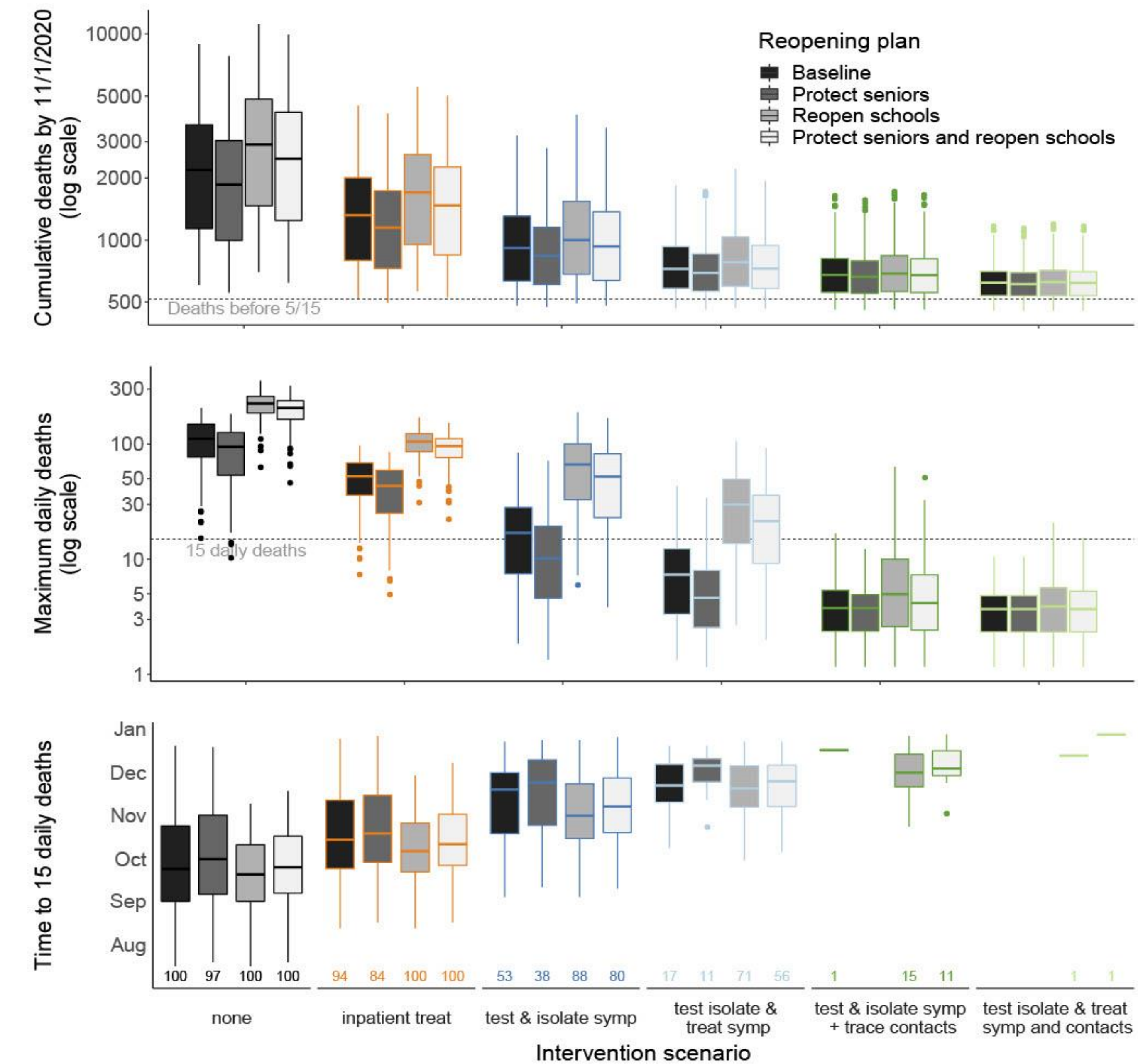


Figure 4. Model projections under different combinations of reopening scenarios and adjunctive interventions. **Top:** Cumulative deaths by Nov 1. **Middle:** Maximum daily deaths by Nov 1; **Bottom:** Time from reopening start to reach 15 deaths daily only for parameterizations which reach 15 deaths (numbers at the bottom). In all simulations reopening plan is implemented between May 15 and July 15 **restoring 60% of pC-PI** in all age groups (Baseline) or age groups 1-3 only (Protect seniors). Reopening schools further restores 80% of pC-PI in the youngest age group.

Conclusions

We predict that implementation of "test and isolate" alone is insufficient to prevent the rapid re-emergence of SARS CoV-2 without moderate physical distancing. However, widespread testing, case isolation and contact tracing may allow for safe schools reopening without a significant surge in local cases and deaths.