Interim roadmap assessment: prior to Step 2

Rosanna Barnard, Nick Davies, Mark Jit, John Edmunds
London School of Hygiene & Tropical Medicine
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Summary

We model the stages of the UK Government's "Roadmap" for reopening in terms of increases to population mobility that may be expected to result at each stage; increases to population mobility are based upon previously-observed mobility patterns during comparable periods of movement restrictions from 2020. Our projections suggest that Step 2 alone may lead to a small surge of cases and deaths, and that Step 4 may lead to a larger surge of cases and deaths comparable to that seen during the first wave. However, we caution that this work is preliminary and makes pessimistic assumptions about the impact of Step 4 which require further work to refine.

Assumptions and results at a glance

31 March 2021
Scenarios, not forecasts; subject to reassessment

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Reproduction numbers (medium mobility scenario)

Stage	Excluding immunity: R_0		Including immunity: R_t	
	schools open	schools closed	schools open	schools closed
1	2.09 (2.07-2.11)	1.60 (1.58-1.61)	1.19 (1.18-1.19)	0.77 (0.77-0.78)
2	2.37 (2.35-2.39)	1.91 (1.9-1.93)	1.25 (1.25-1.26)	0.86 (0.85-0.86)
3	2.54 (2.52-2.56)	2.12 (2.1-2.13)	1.23 (1.22-1.23)	0.89 (0.89-0.90)
4	4.11 (4.07-4.14)	3.79 (3.76-3.82)	1.59 (1.57-1.60)	1.08 (1.06-1.10)

Vaccine efficacy

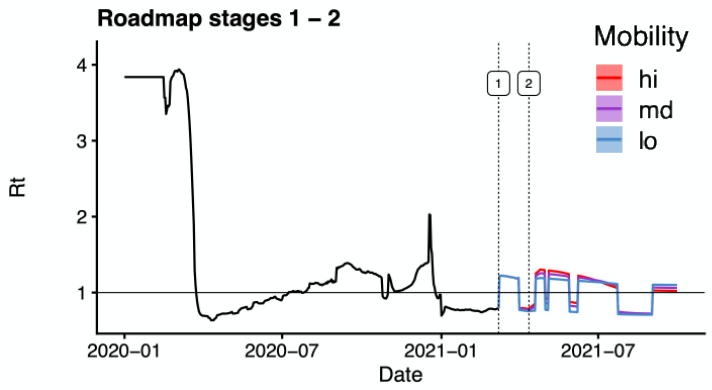
Efficacy against	AstraZeneca		Pfizer	
	1st +28d	2nd +14d	1st +28d	2nd +14d
Infection	31%	31%	70%	85%
Hospitalization	72.5%	85%	91%	98%
ICU admission	72.5%	85%	91%	98%
Death	72.5%	85%	91%	98%

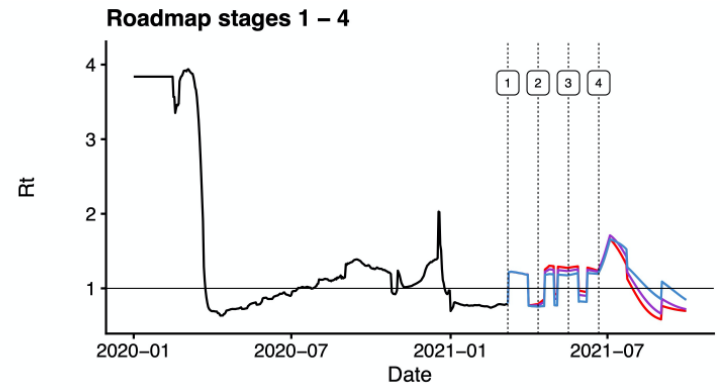
Uptake

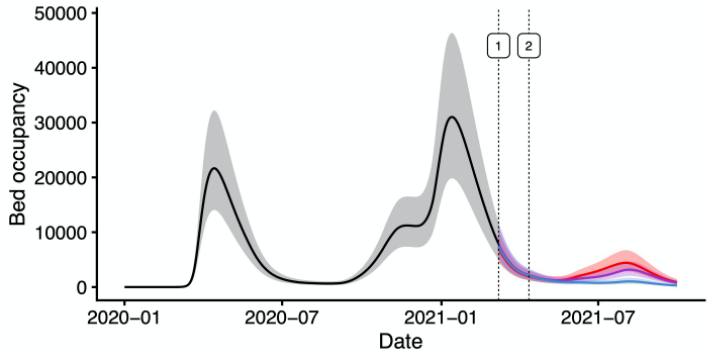
Age	Low	High
0-17	0%	0%
18-29	75%	82%
30-49	75%	86%
50-69	85%	94%
70+	95%	99%

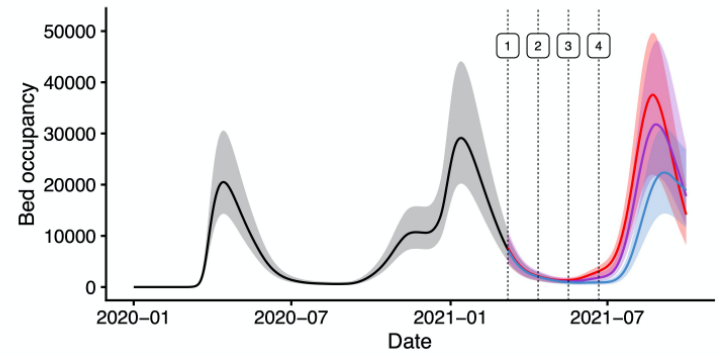
Further assumptions

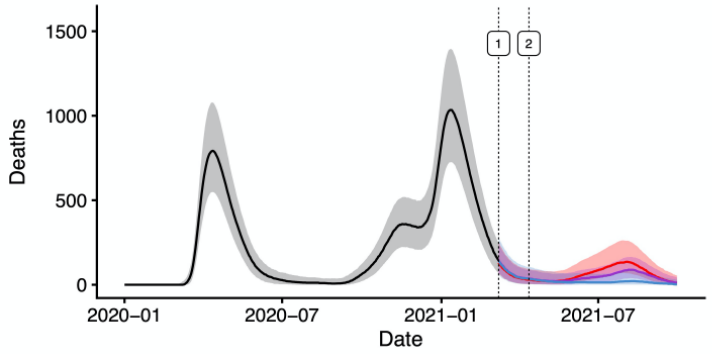
Assumption	Shown at right	Sensitivity analyses
Waning of immunity	None	15% per six months
Vaccine supply	Low scenario	High scenario
Vaccine uptake	Low scenario	High scenario
Seasonality of transmission	Due to school holidays only	—
Vaccine escape variants	None	—

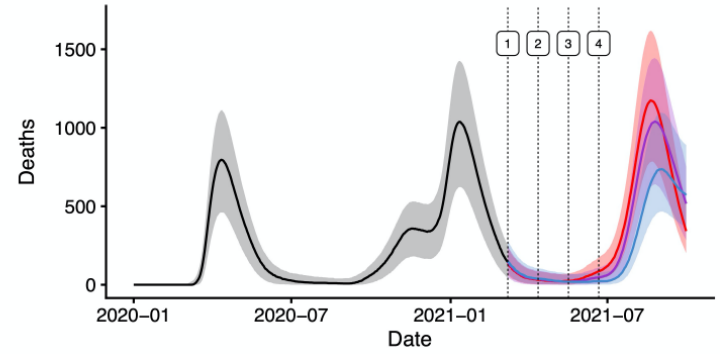












Basic model assumptions

The LSHTM model is an age- and geographically-structured deterministic compartmental model. Geographic structure is by NHS England region and age groups are 5-year age bands from 0–4 to 75+. The model uses Google Community Mobility data to track mobility to workplaces, retail & recreation venues, transit stations, and grocery & pharmacy locations. School openings and closings are accounted for in contacts among school-aged children, university-aged young adults and school/university staff. The relationship between mobility indices and social contact rates is derived from the historical relationship between Google Community Mobility indices and social contact rates as measured by the CoMix study in 2020. The model tracks two variants (for B.1.1.7 versus pre-existing variants) or three variants (for additional illustrative modelling of the potential future impact of vaccine escape variants such as B.1.351).

The model is fitted to PCR prevalence as measured by the ONS; seroprevalence as measured by REACT-2, UK Biobank, and the ONS; daily incidence of COVID-19 deaths, hospital admissions, hospital bed occupancy, and ICU admissions as provided by PHE and the NHS; and the frequency of *S* gene target failure over time to capture the spread of B.1.1.7. The AstraZeneca and Pfizer vaccines are distributed according to recorded vaccine uptake by age group and projected forward according to assumptions delineated by SPI-M. Vaccine efficacies assumed for each vaccine are given in Table 1, and vaccine uptake scenarios are given in Table 2.

The age-specific probability of clinical symptoms is adopted from Davies et al (Nature Medicine, 2020) using data from 6 countries. The age-specific probability of hospital admission, ICU admission, and death given infection are fitted to data from England, with the relative rates by age group based on data collected by a large meta-analysis of the COVID-19 infection fatality rate (Levin et al., Eur J Epi 2020) and based on data collected by ISARIC (the CO-CIN study) for England (Davies et al., Lancet Inf Dis 2020). Each of these age-specific probabilities of severe outcomes is allowed to vary over the course of the epidemic in England and vary between pre-existing strains and B.1.1.7. In scenarios with a vaccine escape strain (such as B.1.351), the probability of severe outcomes is assumed to be the same as for B.1.1.7. We do not yet have good data on the probability of severe outcomes for infection with B.1.351, but there are early indications of potentially increased severity (Pearson et al, 2021).

The model is described in more detail in Davies et al. 2020 (Lancet Inf Dis) and Davies et al. 2021 (Science).

Assumptions for roadmap

We base our assumptions on how social contact rates might be expected to change at each stage of the Roadmap by using historical data on mobility for 2020. For each stage of the roadmap, “low”, “medium”, and “high” estimates for the change in mobility are derived from periods in 2020 when restrictions were at levels deemed to be similar for each stage of the roadmap. These are illustrated in Fig. 1 below. As policies for Stage 4 have yet to be decided, we assume that Stage 4 will return mobility levels to the pre-pandemic baseline (Fig. 1A), while maintaining a level of social distancing (i.e. physical distancing, mask wearing, hand hygiene) of 30-40% as fitted for each NHS England region during the summer of 2020.

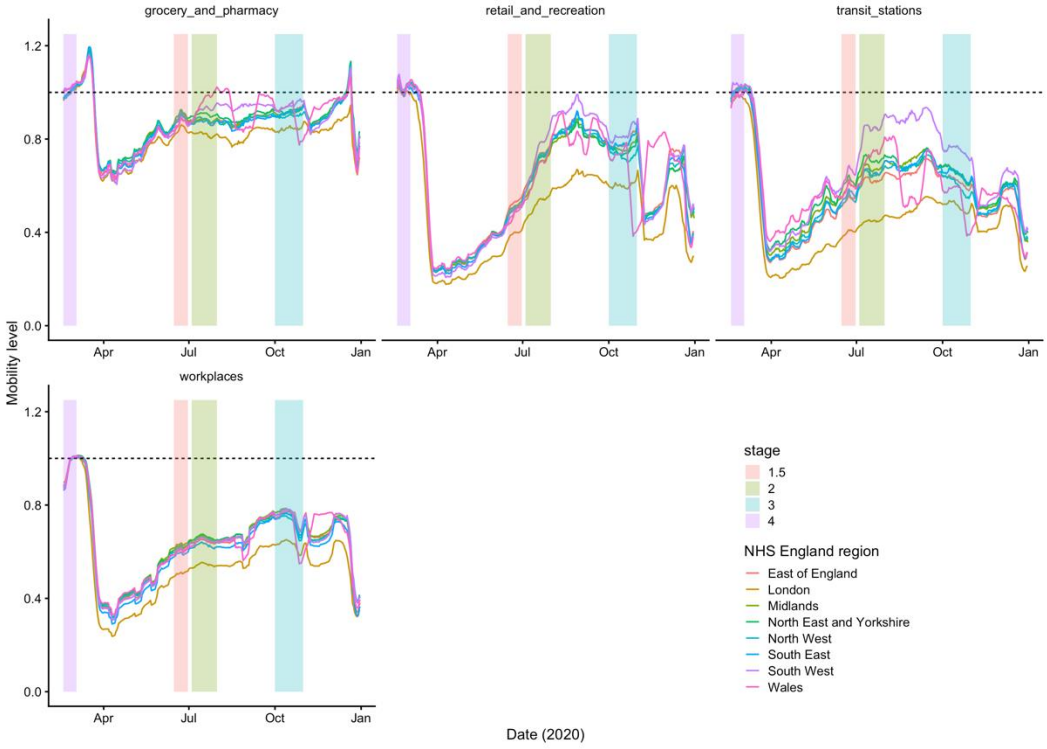
Table 1. Assumptions for vaccine efficacy.

Parameter	Description	Previous (SPI-M)	Current	Evidence
ei_va1, ei2_va1	Efficacy against infection (strain 1, 2) for AstraZeneca dose 1	0.48, +14 days	0.3135, +28 days	Using Voysey et al. randomised controlled trial for ChAdOx1 nCoV-19 vaccine AZD1222, Table 2, average of vaccine efficacies for 'Asymptomatic or symptoms unknown' LD/SD and SD/SD recipients -> (58.9% + 3.8%) / 2 = 31.35%
ed_va1i, ed_va1i2	Efficacy against disease (given infection with strain 1,2) for AstraZeneca dose 1	0.7, +14 days	0.6, +28 days	Using Lopez Bernal et al., Table 3, adjusted odds ratio for ChAdOx1 vaccine against unvaccinated individuals, first dose +28-34 days is 0.4 -> efficacy is 100% - 40% = 60%
ei_va2, ei2_va2	Efficacy against infection (strain 1,2) for AstraZeneca dose 2	0.6, +7 days	0.3135, +14 days	Using Voysey et al. randomised controlled trial for ChAdOx1 nCoV-19 vaccine AZD1222, Table 2, average of vaccine efficacies for 'Asymptomatic or symptoms unknown' LD/SD and SD/SD recipients -> (58.9% + 3.8%) / 2 = 31.35%
ed_va2i, ed_va2i2	Efficacy against disease (given infection with strain 1,2) for AstraZeneca dose 2	0.82, +7 days	0.778, +14 days	Using Voysey et al. randomised controlled trial for ChAdOx1 nCoV-19 vaccine AZD1222, Table 3, average of efficacies for LD/SD and SD/SD in 'COV002 (UK), age 18–55 years with >8 weeks' interval between vaccine doses*' row -> 77.8% = (90% + 65.6%)/2
ei_vb1, ei2_vb1	Efficacy against infection (strain 1,2) for Pfizer dose 1	0.48, +14 days	0.7, +28 days	Using Hall et al., Table 2, adjusted hazard ratio for full cohort, dose 1 >=21 days is 0.3 -> efficacy = 100% - 30% = 70%
ed_vb1i, ed_vb1i2	Efficacy against disease (given infection with strain 1,2) for Pfizer dose 1	0.88, +14 days	0.7, +28 days	Using Lopez Bernal et al., Table 2, adjusted odds ratio vs. days 4-9 post first dose, for Pfizer dose 1, +28-34 days is 0.3 -> efficacy = 100% - 30% = 70%
ei_vb2, ei2_vb2	Efficacy against infection (strain 1,2) for Pfizer dose 2	0.6, +7 days	0.85, +14 days	Using Hall et al., Table 2, adjusted hazard ratio for full cohort, dose 2 >=7 days is 0.15 -> efficacy = 100% - 15% = 85%
ed_vb2i, ed_vb2i2	Efficacy against disease (given infection with strain 1,2) for Pfizer dose 2	0.94, +7 days	0.89, +14 days	Using Lopez Bernal et al., Table 2, adjusted odds ratio vs. days 4-9 post first dose, for Pfizer dose 2, +14 days is 0.11 -> efficacy = 100% - 11% = 89%

Table 2. Assumptions for vaccine uptake.

Age group	Current uptake limit (SPI-M)	Proposed (low)	Proposed (high)	
0-4	75%	0%	0%	
5-9	75%	0%	0%	
10-14	75%	0%	0%	
15-19	75%	75%, 18+	82.5%, 18+	:= mean of 82% (Ansell et al.), 83% (ONS)
20-24	75%	75%	82.5%	:= mean of 82% (Ansell et al.), 83% (ONS)
25-29	75%	75%	82.5%	:= mean of 82% (Ansell et al.), 83% (ONS)
30-34	75%	75%	85.8%	:= mean of 84.6% (Ansell et al.), 87% (ONS)
35-39	75%	75%	85.8%	:= mean of 84.6% (Ansell et al.), 87% (ONS)
40-44	75%	75%	85.4%	:= mean of 83.8% (Ansell et al.), 87% (ONS)
45-49	75%	75%	85.4%	:= mean of 83.8% (Ansell et al.), 87% (ONS)
50-54	85%	85%	93.55%	:= mean of 92.1% (Ansell et al.), 95% (ONS)
55-59	85%	85%	94.05%	:= mean of 92.1% (Ansell et al.), 96% (ONS)
60-64	85%	85%	94%	:= mean of 93% (Ansell et al.), 95% (ONS)
65-69	85%	85%	95%	:= mean of 93% (Ansell et al.), 97% (ONS)
70-74	95%	95%	98.85%	:= mean of 98.7% (Ansell et al.), 99% (ONS)
75+	95%	95%	98.85%	:= mean of 98.7% (Ansell et al.), 99% (ONS)

(A) Mobility assumptions: periods from 2020 used as reference periods



(B) Mobility assumptions: median-scenario mobility levels for each roadmap stage

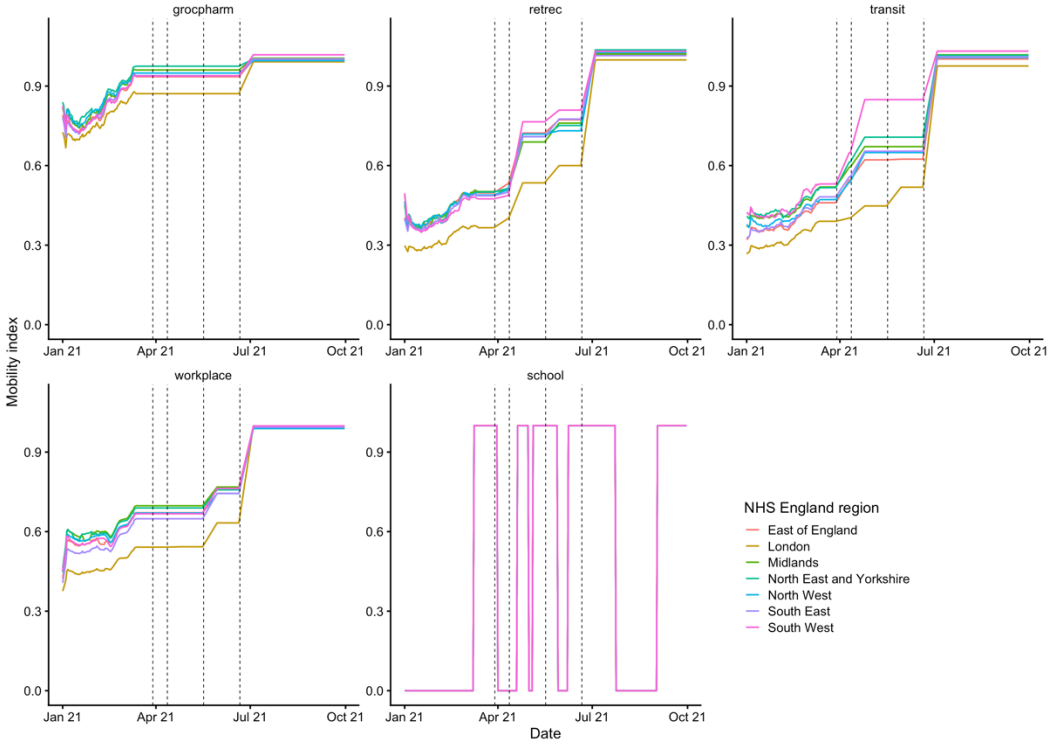


Fig. 1. (A) Shaded areas show reference periods for each stage of the Roadmap assumed by the LSHTM model. (B) Median mobility scenario for each stage of the Roadmap. Dashed vertical lines show roadmap stages 1.5 (i.e. 29 March), 2 (12 April), 3 (17 May), and 4 (21 June). Mobility changes are assumed to phase in over a 2-week period, and are constrained to not decrease from earlier to later stages of the roadmap.

Results and discussion

Our modelling scenarios suggest that, regardless of the level of mobility assumed to obtain after each roadmap step from among the scenarios considered, enacting Step 2 is likely to lead to a small resurgence of cases and hospitalisations, regardless of whether no waning immunity (**Fig. 2**) or exponentially waning immunity of 15% per six months (**Fig. 3**) is assumed. In particular, with Step 2 enacted, whether R is greater than 1 depends upon whether schools are open or closed, with $R > 1$ when schools are open and $R < 1$ when schools are closed. Two phases of epidemic growth between the Easter holiday and the Summer half term, and between the Summer half term and the Summer holiday, are observed. Due to lags between infection and severe outcomes, this leads to an increase in hospital admissions and deaths beginning around mid-May, regardless of whether Step 3 is taken on 17 May. This illustrates that the full impact of Step 2 may be difficult to observe from admissions and deaths until after Step 3 is enacted.

When Steps 3 and 4 are enacted, in all scenarios modelled, a resurgence in admissions and deaths comparable to the magnitude of the second wave in January 2021 is observed. This third wave peaks in late July to early August 2021.

The near-threshold behaviour in the reproduction number associated with schools opening and closing suggests that effective infection control measures in schools may substantially assist with avoiding epidemic growth during Steps 1–3. As there has not been enough time since Step 1 to fully assess the impact of existing infection control measures in schools, it is possible that the modelled impact of school openings on R is less than assumed here. Alternatively, lower than expected mobility in non-school sectors, or improvements in testing, isolation, and contact tracing may prevent school openings during Steps 1–3 from bringing R above 1.

These scenarios assume no growth of an immune escape variant or a more rapidly spreading variant. The effective reproduction number during Steps 1–3 is projected to lie between 0.77 and 0.90 during school holidays for the median mobility scenario. Accordingly, even a small increase in R owing to a new variant has the potential to bring R above 1 even during periods of school closure. This emphasizes that careful monitoring of variants, and actions to control the spread of any new variants remains crucial to reopening.

We have made more pessimistic assumptions for the impact of vaccines on infection and transmission than other groups, as well as for the impact of vaccines on severe outcomes. Reevaluating these assumptions as more data on the real-world effectiveness of the Pfizer and AstraZeneca vaccine on infection and transmission come in will help to clarify the potential impact of Steps 1–4.

Our modelling suggests that R will oscillate around 1 during Steps 1–3 of the roadmap. While this leads to relative stability in severe outcomes associated with COVID-19 over the summer of 2021, we emphasize that it is much preferable, from an epidemiological standpoint, to keep R below 1. Our modelling suggests that the rollout of vaccines alone does not achieve this. Accordingly, further infection control measures in schools, workplaces, and retail and recreation venues, or improvements to the efficacy of mass testing, isolation, and contact tracing, would be highly valuable in achieving control and enabling reopening of society and the economy.

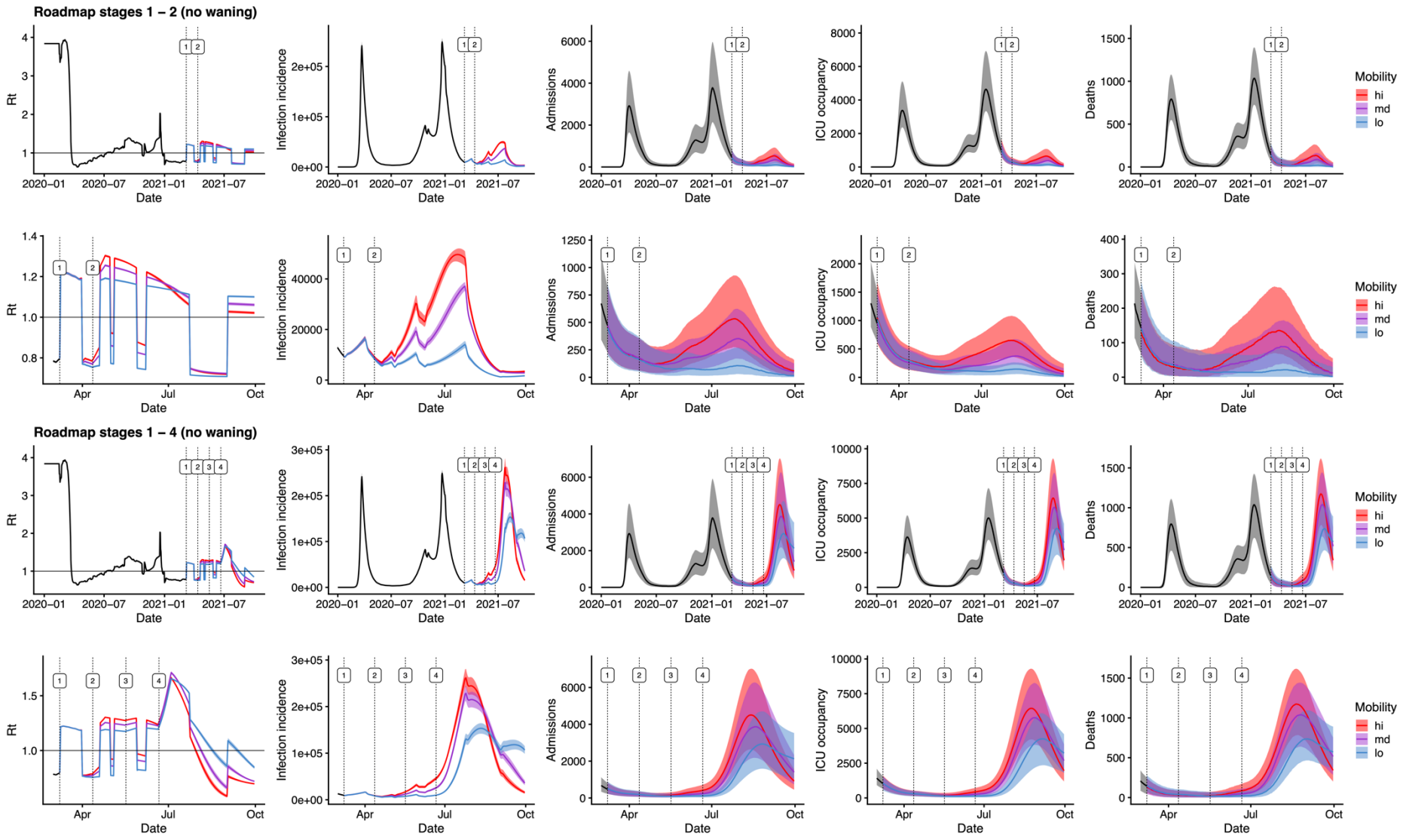


Fig. 2. Roadmap stages without waning immunity. Impact of roadmap stages 1–2 (top two rows) in isolation and complete stages 1–4 (bottom two rows) under high, medium, and low mobility scenarios. Rows 1 and 3 show the time period from 1 January 2020 to 30 September 2021, while rows 2 and 4 show 1 March to 30 September 2021. The beginning of each step is marked with a vertical dashed line.

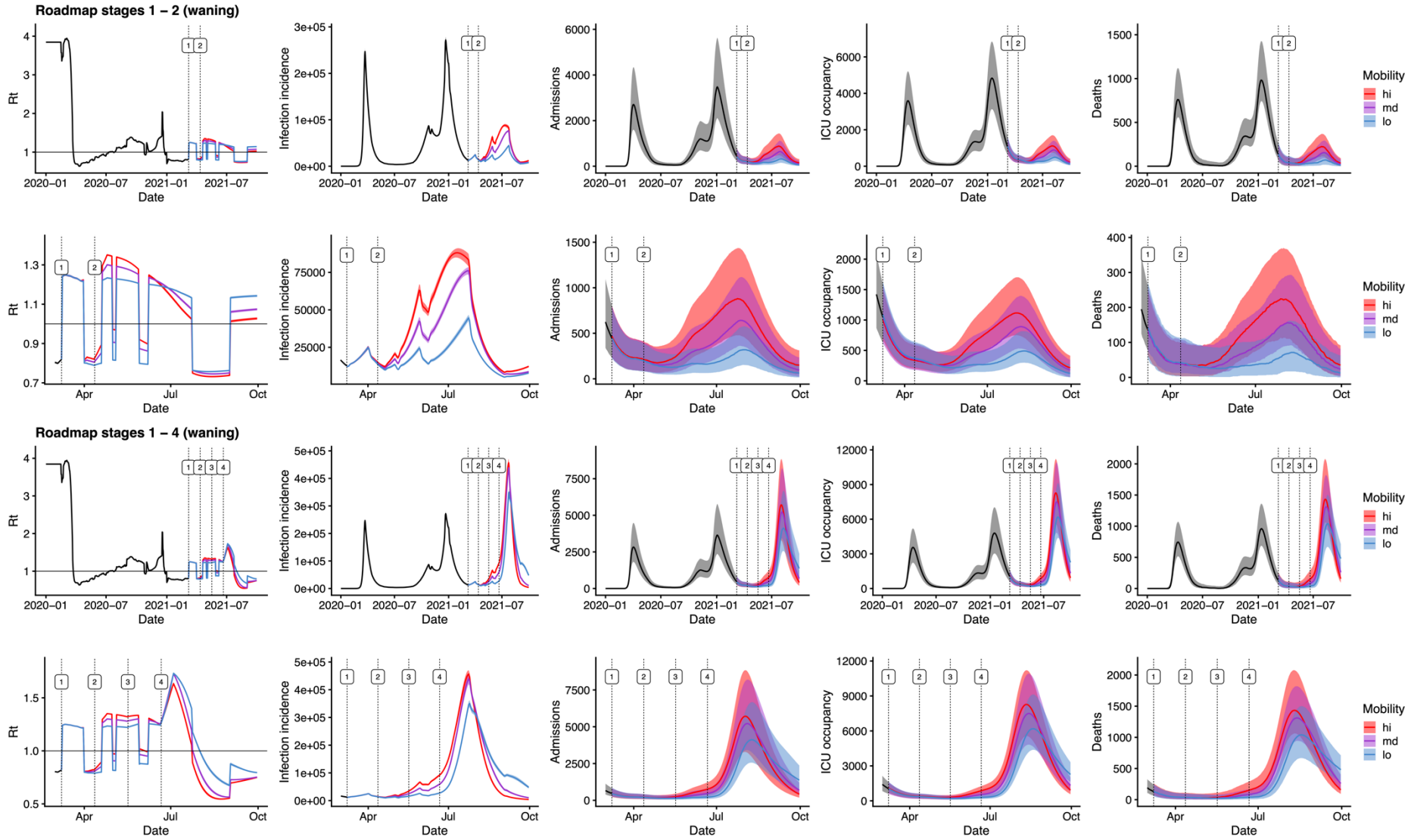


Fig. 3. Roadmap stages with waning immunity (loss of 15% natural protection per six months). Impact of roadmap stages 1–2 (top two rows) in isolation and complete stages 1–4 (bottom two rows) under high, medium, and low mobility scenarios. Rows 1 and 3 show the time period from 1 January 2020 to 30 September 2021, while rows 2 and 4 show 1 March to 30 September 2021. The beginning of each step is marked with a vertical dashed line.