NIPH
Norwegian Institute of Public Health

Situational awareness and forecasting for Norway

FHI COVID-19 modelling team

Week 12, 31 March 2021

Highlights:

- **National epidemiological situation:** Our models indicate that the reproduction number has decreased significantly, being 1.03 (median, 95% CI 0.92-1.13) from March 9 until 29 March. The estimated probability that R is larger than 1 is 75%. The estimated reproduction number between February 8 and March 8 is estimated 1.41 [1.34-1.51] which shows the decrease due to the interventions of week 9 and possibly also of week 11. The SMC model estimates the 7-days averaged effective reproduction number during week 11, to be 0.8 (mean, 95% CI 0.58-1.05). In the SMC model, the estimated probability that the daily reproduction number one week ago was above 1 is 6%. The SMC model by construction captures more recent changes in the data than the change-point model and now shows a clear decrease of the 7-days averaged effective reproduction number starting from March 9. in the present situation, the number of new cases is expected to remain rather stable in the next three weeks, while the hospital admissions will continue to slowly increase in the next three weeks, because of the time gap between infection and hospitalisation. Our estimates are not yet influenced in full by the local interventions from week 11 and not at all by the national interventions introduced march 23, which are likely to lead to a further improvement of the situation.

  Since the start of the epidemic, we estimate that in total, 169.000 (95% CI 149.000- 194.000) persons in Norway have been infected. The current estimate of the detection probability is slightly increasing around ∼64%.

- **Changes introduced this week: further updated risk of hospitalisation.** We have sharpened the effect of the B.1.1.7 variant on the probability to hospitalisation for infected symptomatic individuals. We use a factor of 1.09 in January and 1.5 in February and March. Predictions use a factor 1.6. Correcting hospitalisation probabilities in this way may explain some of the decrease of estimated reproduction numbers. In the regional model, the correction of the probability of hopitalisation is done differently, as we here assume one hospitalisation risk per region per day. Hence here we can include the daily increased hospitalisation risk due to an increase of B.1.1.7. We multiply the hospitalisation risk by a gradually increasing exponential function from 1.0 to 1.5.

- **Changed this week: Long term predictions also include future intervention strategies.** Since last week, we use the individual-based model for long-term predictions to have alternative vaccination and intervention strategies. This week, we include two scenarios: a Constant Scenario assuming no changes to the current interventions; a Controlled Scenario, where the government actively control the epidemic based on the hospital prevalence. We assume that the government will introduce new interventions if the hospital prevalence exceeds 200 patients, reducing the reproduction number to 0.8. If fewer than 50 occupied hospital beds are occupied, interventions are eased, leading to a reproduction number of 1.2. The model shows that a gradual reopening will be possible from late summer.

- **National forecasting:** In one week, on April 4, we estimate ca 1500 new cases per day (median; 95% CI 1000-2000), and a prevalence (total number of presently infected individuals in Norway) of 9.000 (median; 95% CI 7.000-12.000). Compared to our estimates for April 4 made one week ago,

these numbers markedly smaller. The number of COVID-19 patients in hospital (daily prevalence) on April 4 is estimated to be 270 (median 95% CI 217-336), and the number of patients on ventilator treatment is estimated to be 49 (median 95% CI 34-66); the corresponding predictions in three weeks (April 18) are 300 (95% CI 214 - 411) and 55 (95% CI 34 - 79). Predictions in three weeks are lower than predicted last week, because of the reduced estimated reproduction number. Long term predictions show a peak in late May/June under the "nøktern" vaccination plan. The probability that the surge capacity will exceed 500 ventilator beds is now estimated to be 0% because of vaccinations.

- **Regional epidemiological situation and forecasting:** In this last week trends in transmission seem to be changing in many counties; we have moved changepoints closer to today in a try to capture such recent situations, but there is still not enough data to inform our model, and uncertainty is large for some counties. The estimated reproduction number in Oslo since March 14 is 0.73 (CI 0.48-0.97). Between February 5 and March 13 it is estimated to be 1.57 (1.47-1.65), which indicates a strong reduction of transmissibility in Oslo after the interventions were introduced on March 2 and March 12. In Viken we estimate the reproduction number since March 9 to be 1.17 (1-1.35). Reproduction number in Viken between February 22 and March 8 was 1.49 (1.28-1.77). In the other counties we estimate effective reproduction numbers since March 9. In Rogaland the estimate is 1.42 with very large uncertainty (0.71-2.11). In Vestland the estimate is 1.86, also with large uncertainty [0.93-2.75]. For Møre og Romsdal, Agder and Trøndelag uncertainty is so large that results cannot be interpreted. Vestland and Møre og Romsdal have low infection levels and therefore local outbreaks will generate strong volatility in the reproduction numbers. In the other counties, the effective reproduction number appears likely to be around or below 1. Our models will not able to able to capture the effects of the decisions taken by the government on March 23 before April 13.

  Oslo: The number of new cases per day is estimated to be 147 (mean, 95% CI 78 -241) on April 2 and on April 18 to be to 136 be 95% CI 63-268). Hospital prevalence in one week is estimated to be 50 (median; 95% CI 28-82), and in three weeks 36 (median; 95% CI 17-61). The situation is improving.

- **Telenor mobility data, local mobility and foreign visitors:** Inter-municipality mobility, measured as outgoing mobility of mobile phones from each municipality, is stable. The number of foreign visitors to Norway has stabilised to a high level.

What this report contains:

This report presents results based on a mathematical infectious disease model describing the geographical spread of COVID-19 in Norway. The model consists of three layers:

- Population structure in each municipality.
- Mobility data for inter-municipality movements (Telenor mobile phone data).
- Infection transmission model (SEIR-model)

The model produces estimates of the current epidemiological situation at the municipality, county (fylke), and national levels, a forecast of the situation for the next three weeks, and a long term prediction. We run three different models built on the same structure indicated above: (1) a national changepoint model, (2) a regional changepoint model and (3) a national Sequential Monte Carlo model, named SMC model.

How we calibrate the model: The national changepoint model is fitted to Norwegian COVID-19 hospital incidence data from March 10 until yesterday, and data on the laboratory-confirmed cases from May 1 until yesterday. We do not use data before May 1, as the testing capacity and testing criteria were significantly different in the early period.
Note that the results of the national changepoint model are not a simple average or aggregation of the results of the regional changepoint model because they use different data. The estimates and predictions of the regional model are more uncertain than those of the national model. The regional model has more parameters to be estimated and less data in each county; lack of data limits the number of changepoints we can introduce in that model. In the regional changepoint model, each county has its own changepoints and therefore a varying number of reproduction numbers. Counties where the data indicate more variability, have more changepoints.
The national SMC model is also calibrated both to the hospitalisation incidence data (same data as described above) and the laboratory-confirmed cases.

Telenor mobility data: The mobility data account for the changes in the movement patterns between municipalities that have occurred since the start of the epidemic.

How you should interpret the results: The model is stochastic. To predict the probability of various outcomes, we run the model many times in order to represent the inherent randomness.
We present the results in terms of mean values, 95% confidence intervals, medians, and interquartile ranges. We emphasise that the confidence bands might be broader than what we display, because there are several sources of additional uncertainty which we currently do not fully explore: firstly, there are uncertainties related to the natural history of SARS-CoV-2, including the importance of asymptomatic and presymptomatic infection. Secondly, there are uncertainties related to the timing of hospitalisation relative to symptom onset, the severity of the COVID-19 infections by age, and the duration of hospitalisation and ventilator treatment in ICU. We continue to update the model assumptions and parameters in accordance with new evidence and local data as they become available. A full list of all updates can be fount at the end of this report.
Estimates of all reproductive numbers are uncertain, and we use their distribution to assure appropriate uncertainty of our predictions. Uncertainties related to the model parameters imply that the reported effective reproductive numbers should be interpreted with caution.

When we forecast beyond today, we use the most recent reproduction number for the whole future, if not explicitly stated otherwise.

In this report, the term patient in ventilator treatment includes only those patients that require either invasive mechanical ventilation or ECMO (Extracorporeal membrane oxygenation).

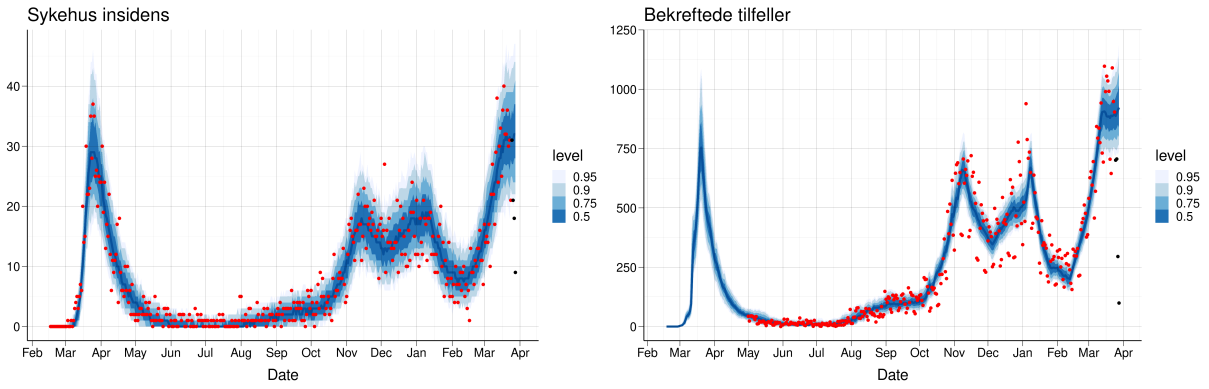
1 Estimated national reproduction numbers

Calibration of our national changepoint model to hospitalisation incidence data and test data leads to the following estimates provided in table 1. Figure 1 shows the estimated daily number of COVID-19 patients admitted to hospital (1a) and the estimated daily number of laboratory-confirmed SARS-CoV-2 cases (1b), with blue medians and interquantile bands, which are compared to the actual true data, provided in red. The uncertainty captures the uncertainty in the calibrated parameters in addition to the stochastic elements of our model and the variability of other model parameters.

Table 1: Calibration results

Reff	Period
3.15/3.14(2.44-3.9)	From Feb 17 to Mar 14
0.5/0.5(0.4-0.6)	From Mar 15 to Apr 19
0.67/0.66(0.32-1.02)	From Apr 20 to May 10
0.63/0.62(0.19-1.01)	From May 11 to Jun 30
1.03/1(0.3-1.66)	From Jul 01 to Jul 31
1.03/1.04(0.75-1.31)	From Aug 01 to Aug 31
0.95/0.94(0.75-1.08)	From Sep 01 to Sep 30
1.26/1.26(1.12-1.43)	From Oct 01 to Oct 25
1.26/1.27(1.04-1.54)	From Oct 26 to Nov 04
0.8/0.8(0.73-0.85)	From Nov 05 to Nov 30
1.07/1.07(1.03-1.12)	From Dec 01 to Jan 03
0.59/0.59(0.49-0.69)	From Jan 04 to Jan 21
0.83/0.83(0.7-0.95)	From Jan 22 to Feb 07
1.41/1.41(1.34-1.51)	From Feb 08 to Mar 08
1.03/1.04(0.92-1.13)	From Mar 09

Median/Mean (95% credible intervals)

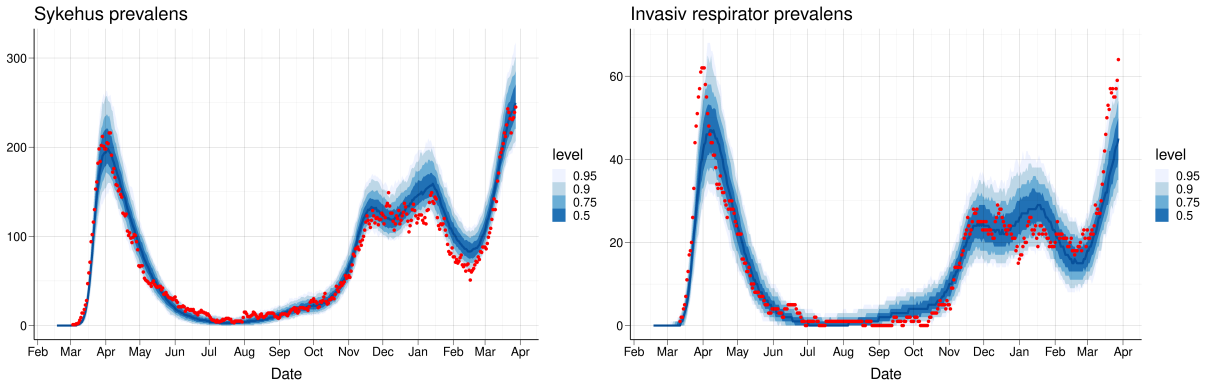


(a) Hospital admissions

(b) Test data

Figure 1: A comparison of true data (red) and predicted values (blue) for hospital admissions and test data. The last four data points (black) are assumed to be affected by reporting delay. B) Comparison of our simulated number of positive cases, with blue median and interquartile bands to the actual true number of positive cases, provided in red. The uncertainty captures the uncertainty in the calibrated parameters, in addition to the stochastic elements of our model and the variability of other model parameters. Note that we do not capture all the uncertainty in the test data–our blue bands are quite narrow. This is likely because we calibrate our model parameters on a 7-days moving average window of test data, instead of daily. This is done to avoid overfitting to random daily variation. Moving averages over 7 days are less variable than the daily data.

In figure 2, we show how our national model fits the national hospital prevalence data (2a) and the daily number of patients receiving ventilator treatment (2b). Those data sources are not used to estimate the parameters, and can therefore be seen as a validation of the model assumptions.



(a) Hospital prevalence

(b) Ventilator prevalence

Figure 2: A comparison of true data (red) and predicted values (blue) for hospital and respirator prevalence.

1.1 National SMC-model: Estimated daily reproduction numbers

In the SMC-model, we allow for estimation of a different reproduction number for each day t. To reduce spurious fluctuation, we report a 7-days moving average, $R(t)$, representing the average reproduction number for the whole week before day t. However, until March 8 we keep the reproduction number constant. By assuming a time varying reproduction number $R(t)$, we can detect changes without introducing explicit changepoints. Thus, we can easier detect unexpected changes.

The SMC model uses the daily number of new admissions to hospital and the daily number of positive and negative lab-confirmed tests, to estimate all its parameters. Because of the time between infection and the possibility to be detected as positive by a test, and because if a delay in reporting tests, the data contain information on the transmissibility until a week before the end of the data (today).

The parameters π_0 and π_1 related to the probability to detect a positive case by testing are estimated off-line.

The figure below shows the SMC estimate of the 7-day-average daily reproduction number $R(t)$ from the start of the epidemic in Norway and until today. In the figure we plot the 95% confidence interval and quantiles of the estimated posterior distribution of $R(t)$.

1.1 National SMC-model: Estimated daily reproduction numbers

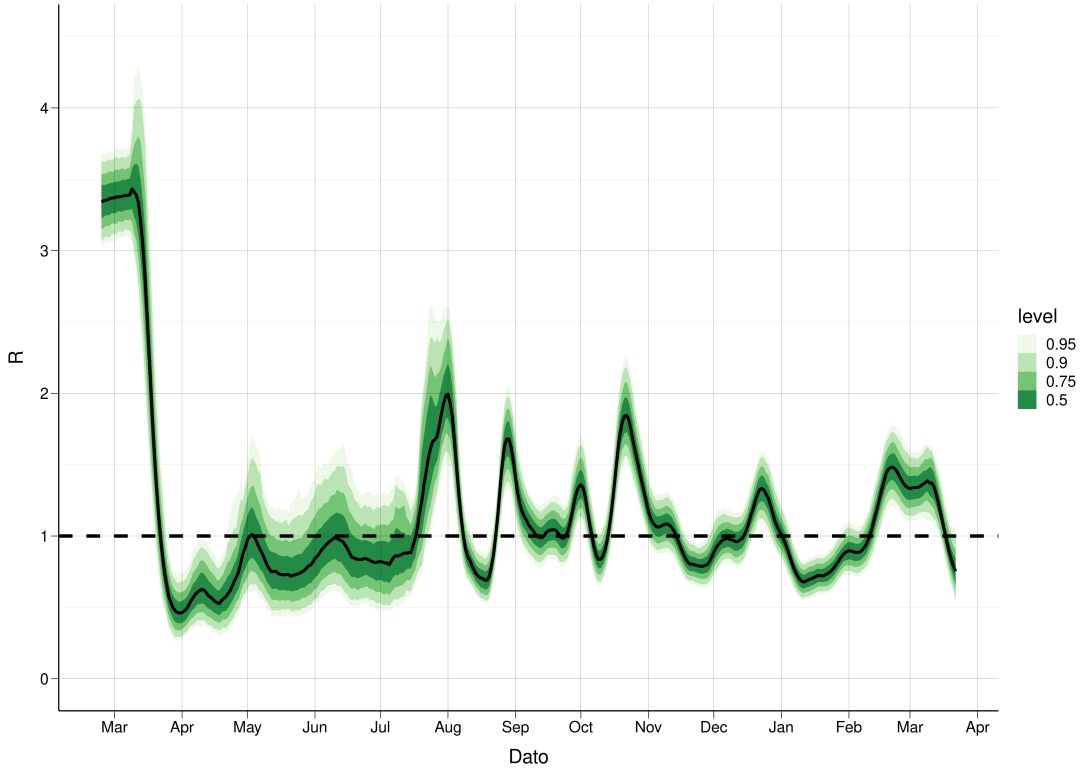


Figure 3: R(t) estimates using a Sequential Monte Carlo approach calibrated to hospitalisation incidence and test data. The large uncertainty during the last 7 days reflects the lack of available data due to the transmission delay, test delay, time between symptoms onset and hospitalisation. The green band shows the 95% posterior credibility interval. As we use test data only from 1 August, the credibility interval becomes more narrow thereafter.

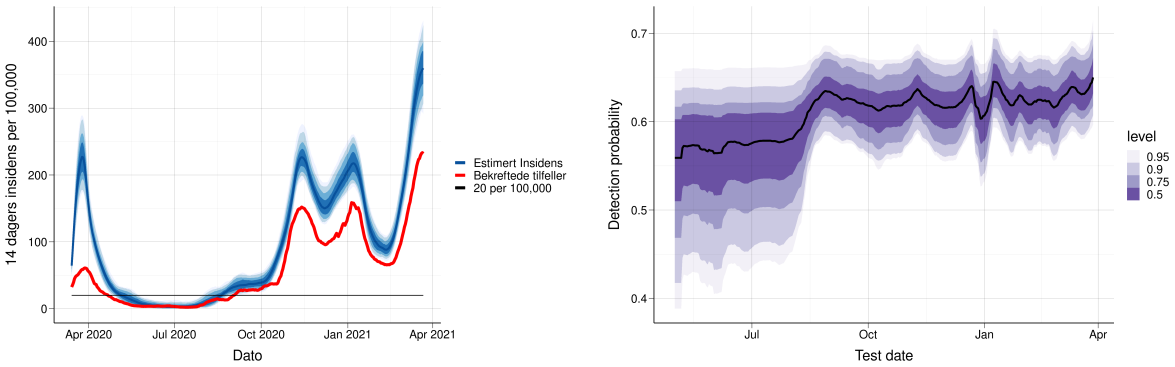
2 National estimate of cumulative (total) number of infections

The national changepoint model estimates the total number of infections and the symptomatic cases that have occurred (Table 2).
Figure 4a shows the modelled expected daily incidence (blue) and the observed daily number of laboratory-confirmed cases (red). When simulating the laboratory-confirmed cases, we also model the detection probability for the infections (both symptomatic, presymptomatic and asymptomatic), Figure 4b. There are two differences between this estimate of the detection probability and the previous one provided in figure 4a. In figure 4b, we calibrate our model to the true number of positive cases, instead of using the test data directly. Furthermore, in figure 4a we use a parametric model to estimate the detection probability that depends on the true total number of tests performed.

Table 2: Estimated cumulative number of infections, 2021-03-28

Region	Total	No. confirmed	Fraction reported	Min. fraction
Norway	169034 (148563; 193993)	93145	55%	48%

Fraction reported=Number confirmed/number predicted; Minimal fraction reported=number confirmed/upper CI



(a) Number of laboratory-confirmed cases vs model-based estimated number of new infected individuals

(b) Estimated detection probability for an infected case per calendar day

Figure 4

3 National 3-week predictions: Prevalence, Incidence, Hospital beds and Ventilator beds

The national changepoint model estimates the prevalence and daily incidence of infected individuals (asymptomatic, presymptomatic and symptomatic) for the next three weeks, aggregated to the whole of Norway (table 5). In addition, the table shows projected national prevalence of hospitalised patients (hospital beds) and prevalence of patients receiving ventilator treatment (ventilator beds). The projected epidemic and healthcare burden are illustrated in figure 5.

Table 3: Estimated national prevalence, incidence, hospital beds and ventilator beds. Median/Mean (CI)

	1 week prediction (Apr 04)	2 week prediction (Apr 11)	3 week prediction (Apr 18)
Prevalence	9140/8988 (6950-12333)	9397/9146 (6446-13120)	9646/9254 (6031-14102)
Daily incidence	1491/1446 (1039-2033)	1534/1478 (1007-2232)	1578/1516 (923-2391)
Hospital beds	272/270 (217-336)	288/288 (208-373)	301/302 (214-411)
Ventilator beds	49/49 (34-66)	53/53 (38-71)	55/54 (34-79)

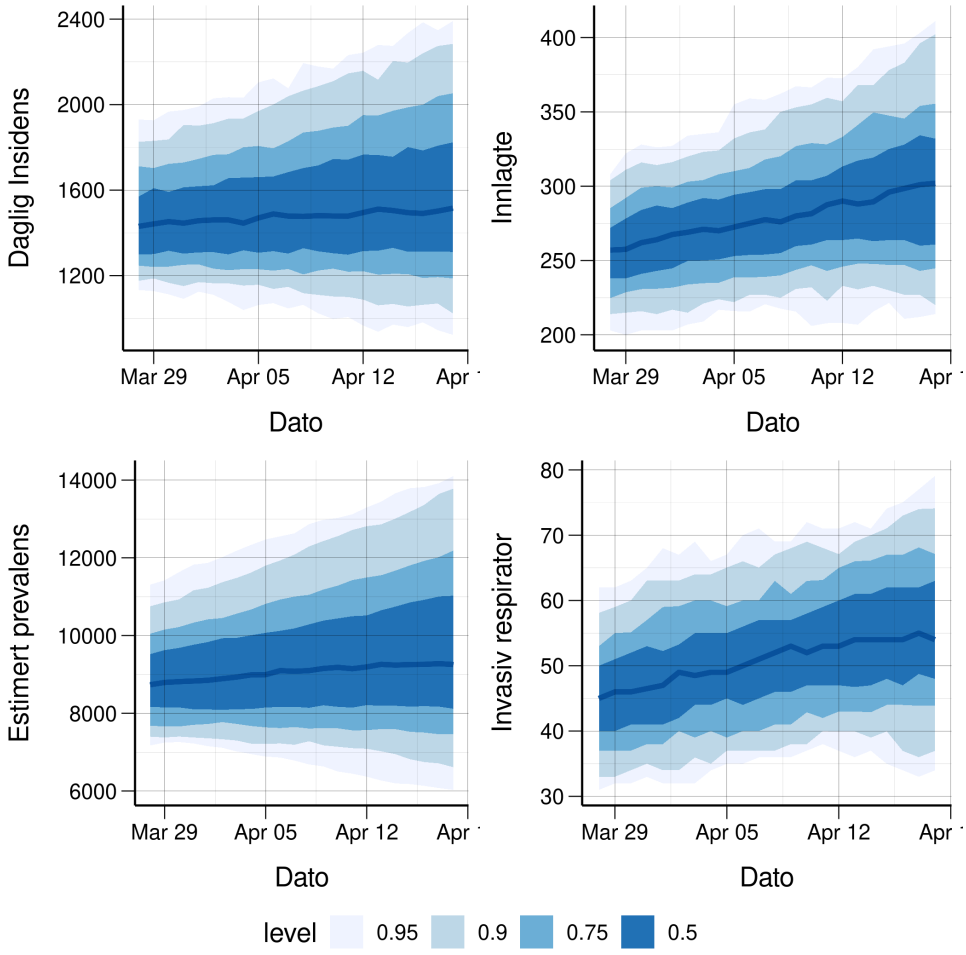


Figure 5: National 3 week predictions for incidence (top left), prevalence (bottom left), hospital beds (top right) and ventilator beds (bottom right)

4 National long-term scenarios with vaccination plans and future interventions: Infections, hospitalisations and ventilator treatments

We present 12-month scenarios from our individual-based model (IBM) with vaccination. Given the suspension of the AstraZeneca vaccine since 11 March 2021 and uncertainty regarding future use of this vaccine and the vaccine from Janssen, we present results assuming three different national covid-19 vaccination plans in the future:

1. PMAJ including the vaccines from Pfizer, Moderna, AstraZeneca and Janssen
2. PMJ excluding the AstraZeneca vaccine
3. PM including only the mRNA vaccines from Pfizer and Moderna

We use data from the Norwegian Immunisation Registry (SYSVAK) on the number of vaccinations carried out up to 29 March 2021. Vaccine deliveries in the future are based on the Norwegian Institute of Public Health's realistic ("nøktern") scenario, updated 19 March 2021. The roll-out accounts for regional prioritization with 20% additional vaccines to Oslo, with six prioritized districts, and to Moss, Sarpsborg and Frederikstad. We assume regional differences in the reproduction number between municipalities by estimating a scaling factor for the reproduction number in each municipality. The scaling factor is calculated from the local proportion of the population who has tested positive, compared to the national one. The initial conditions in the municipalities are set following the results of the regional changepoint model. The simulations of the future 12 months are based on the national reproduction number (Table 1) from our changepoint model, adjusted per municipality as mentioned. The long term scenario results are based on 100 simulations and accounts for stochasticity within the IBM model; however, the uncertainty in the changepoint models is not accounted for.
The future course of the epidemic will depend on the national and local control measures that the authorities impose to curb the transmission in the current and future waves of the epidemic. Therefore, the scenarios shown are not predictions but are the consequence of a specific set of assumptions about the epidemic and how the government and local authorities are assumed to act. We will show results from two scenarios:
Constant Scenario: In this scenario, we assume that the national vaccine roll-out continues as planned and that the current epidemiological situation remains unchanged. In this scenario, the epidemic will evolve according to the current reproduction number, and the government will make no changes to the current interventions.
Controlled Scenario: In this alternative scenario, we assume that the national vaccine roll-out will continue as planned. However, the government chooses to actively control the reopening of the society in relation to the prevalence of hospital admissions at a given time. We set an upper threshold of 200 admitted patients nationally. If this threshold is reached, contact-reducing measures are triggered. In the model, we therefore lower the reproduction number to 0.8. We also include a lower point of 50 hospital admissions nationally. If this threshold is reached, a lowering of contact-reducing measures is triggered. In this case, we increase the reproduction number in the model to 1.2. The number of hospital admissions is evaluated every three weeks to simulate a gradual reopening, and if needed, the reproduction number is changed. We implement the corrections at a regional level by calculating regional threshold values per 100 000 inhabitants based on the national threshold levels.
The scenarios are made given some simplifying assumptions:

- The vaccine uptake is assumed to be 90% in all age groups 16 years and above and we assume full adherence to the vaccination schedule.
- We use modest assumptions on the vaccine efficacy (VE). For the vector vaccines: VE asymp (1. and 2. dose) 22%; VE symp (1. and 2. dose) 60%, 67%. For the mRNA vaccines: VE asymp (1. and 2. dose) 67%; VE symp (1. and 2. dose) 60%, 90%. We assume no additional protection against severe infection compared to that of a symptomatic infection. People who are vaccinated and get infected are assumed to transmit 40% less than those who are not vaccinated.

- We assume a six week interval between the first and second mRNA vaccine doses for and a 12 week interval for the AstraZeneca vaccine.
- No seasonal effects are assumed.
- No waning immunity after infection or vaccination is assumed.

More information about the IBM can be found in the reports Folkehelseinstituttets foreløpige anbefalinger om vaksinasjon mot covid-19 og om prioritering av covid-19-vaksiner, versjon 2 15. desember and Modelleringsrapport, delleveranse Oppdrag 8: Effekt av regional prioritering av covid-19 vaksiner til Oslo eller OsloViken samt vaksinenes effekt på transmisjon for epidemiens videre utvikling, available online at http://www.fhi.no. A detailed description of the controlled scenario's assumptions is provided in recent modelling reports, published shortly.

4.1 Constant Scenario

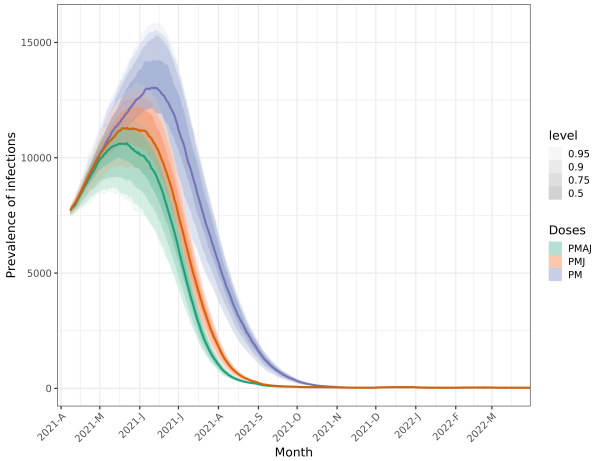
We present 12-month scenarios from our individual-based model (IBM) with vaccination, showing expected prevalence (Figure 6a), hospital beds (Figure 6b) and ventilator beds (Figure 6c).

Table 4: Estimated peak prevalence of infections, hospitalisations and ventilator beds and total infections, admissions and ventilator treatments until 31 March 2022

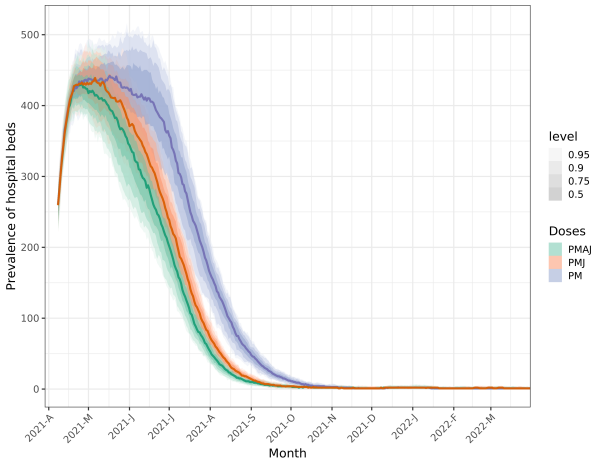
Peak	PMAJ	PMJ	PM
Prevalence, infections	10639 (8572-12319)	11368 (9223-13301)	13151 (9782-15921)
Hospital beds	455 (415-498)	463 (420-507)	475 (425-538)
Ventilator beds	68 (58-84)	71 (59-85)	73 (61-86)
Peak day			
Prevalence, infections	2021-05-18	2021-05-24	2021-06-10
Hospital beds	2021-04-28	2021-05-01	2021-05-13
Ventilator beds	2021-05-10	2021-05-11	2021-05-19
Total			
Infections	175425 (158399-192450)	195806 (177074-214539)	258145 (228957-287332)
Hospitalisations	5456 (5025-5886)	6003 (5533-6473)	7524 (6805-8243)
Ventilator treatments	428 (392-464)	467 (426-508)	564 (508-621)

Given the current epidemiological situation and assuming no change in the interventions or seasonal effects, the epidemic is expected to peak in late May to early June. None of the scenarios exceed a surge capacity need of **500 ICU** ventilator beds (Table 4).

4.1 Constant Scenario



(a)



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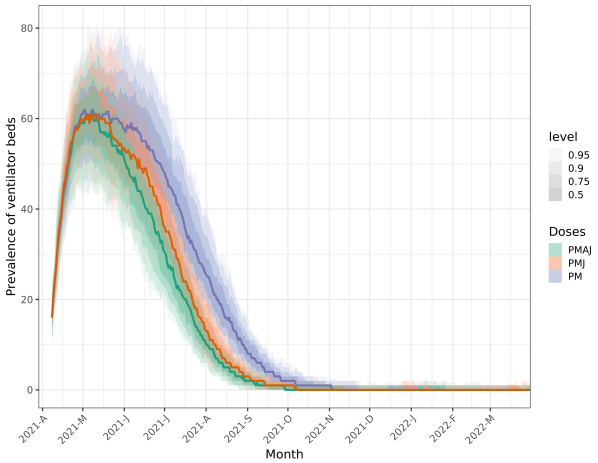


(c)

Figure 6: Long-term predictions for prevalence (a),hospital beds (b) and ventilator beds (c)

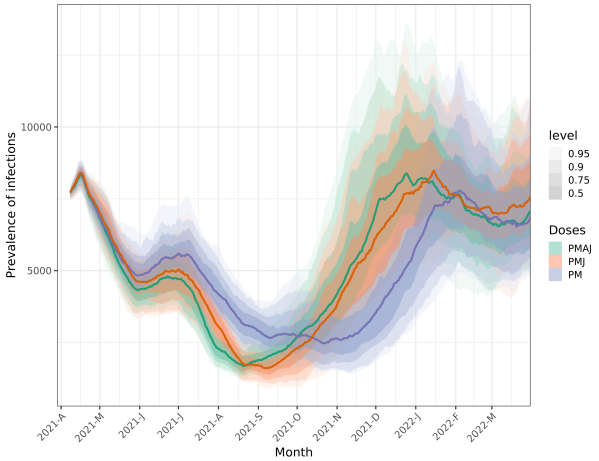
4.2 Controlled Scenario

We present 12-month scenarios from our individual-based model (IBM) with vaccination, showing expected prevalence (Figure 7a), hospital beds (Figure 7b) and ventilator beds (Figure 7c). In a controlled scenario, the vaccination effect will be manifest through an increasing higher average contact rate in the population. Figure 8 illustrates the relative average national contact rate over time, compared to a fully open society with "normal" social interaction.
In a fully open society, All contact-reducing measures are eased, except for improved hygiene measures and the Testing-Isolation-Contact tracing-Quarantining (in Norwegian TISK) intervention, which will remain. Together, these interventions are assumed to reduce the transmissibility by 50%, following Kucharski et al. Lancet Infectious Diseases 20(20): 1151-1160 (2020). We use the county-specific basic reproduction numbers, R0, estimated from the regional changepoint model but adjusted to match the estimated national R0 in March of 2021. To account for the dominance of the new and more transmissible B.1.1.7 virus lineage, we have further adjusted the contact rate up by 50%. The national average contact rate for the different vaccines in the vaccination program is shown in Figure 8.

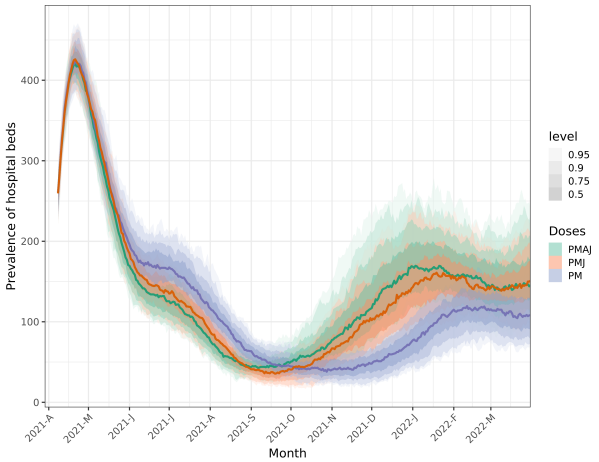
Table 5: Estimated total number of infections, hospitalisations and ventilator beds until 31 March 2022

Total	PMAJ	PMJ	PM
Infections	374314 (330838-417789)	373283 (334684-411881)	356206 (320438-391974)
Hospitalisations	8237 (7469-9004)	8117 (7450-8785)	7467 (6955-7979)
Ventilator treatments	631 (569-692)	617 (563-671)	561 (520-601)

Table 5 shows, that in a controlled scenario with hospital admissions are steering parameter there is a small difference in the expected infections and admissions regardless of the vaccines used. Figure 8 shows that the current, strict level of interventions is required until the late summer. After that, the increasing immunity in the population due to vaccination allows for a gradual reopening. First, in the case where all vaccines are used (PMAJ). The reopening will be delayed if only mRNA vaccines are used (PM). However, because the mRNA vaccines are more effective, the model suggests a higher degree of reopening from late autumn with exclusive use of mRNA vaccines. The reopening leads to more infections in the later months of 2021 and early 2022, while still maintaining an acceptable level of hospitalisations (Figure 7).



(a)



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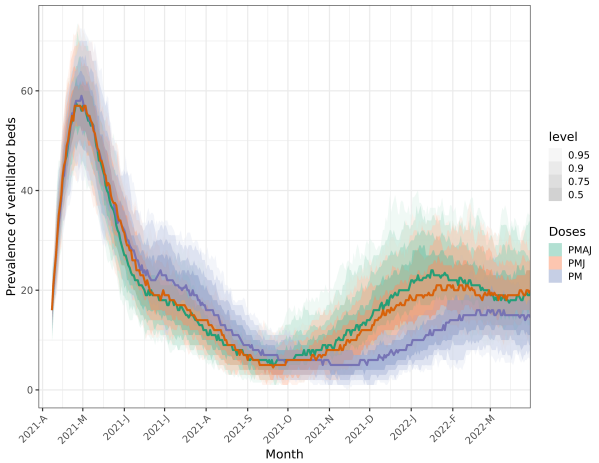


(c)

Figure 7: Long-term predictions for prevalence (a),hospital beds (b) and ventilator beds (c)

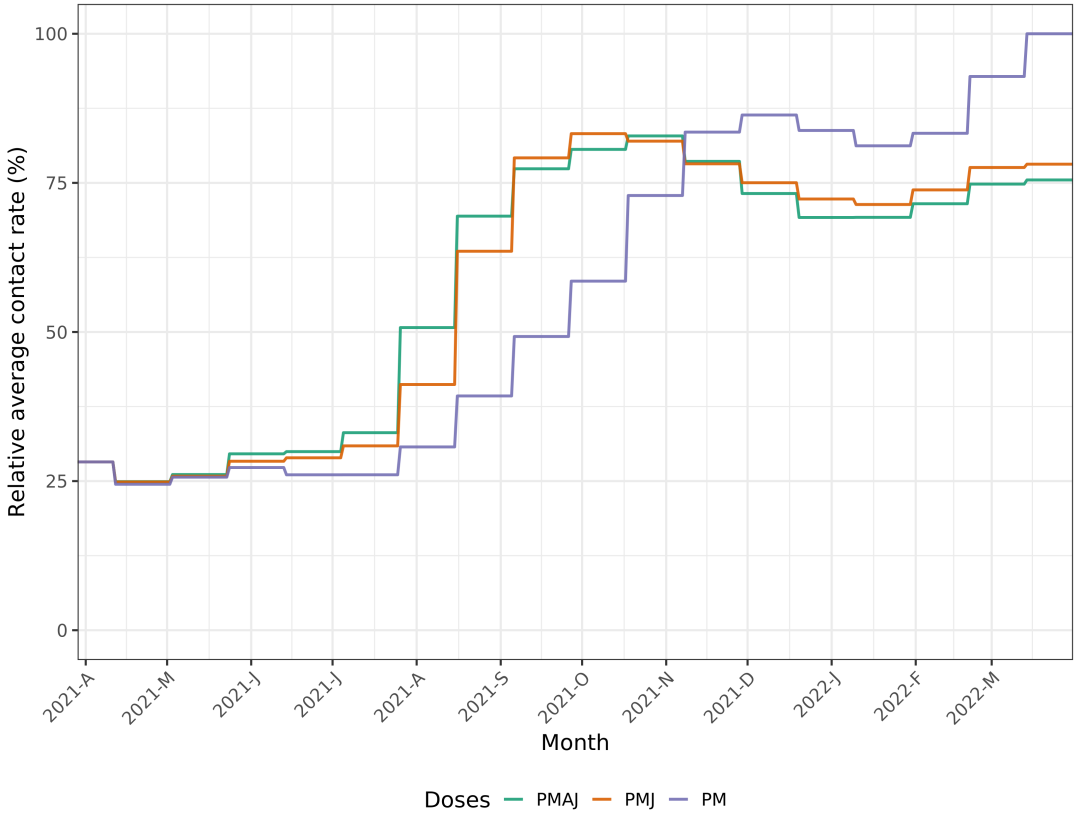


Figure 8: Relative average national contact rate compared to a fully open society in a controlled scenario with use of all four vaccines (PMAJ), exluding the AstraZeneca vaccine (PMJ), only using the mRNA vaccines (PM). The contact rate is population-weighted average in all municipalities, updated every 21 days to simulate gradual reopening by evaluating the number of hospital admission.

5 National scenario-based long-term predictions: Hospital beds and Ventilator beds

IMPORTANT: This section on scenario simulations is not included until we incorporate vaccination plans.

6 Estimated regional reproduction numbers

Calibration of our regional changepoint model to hospitalisation incidence data and test data leads to the following estimates for current regional reproduction numbers by county (Table 6). A full list of all regional reproduction numbers can be found at the end of the report.
Below we show the estimated daily number of COVID-19 patients admitted to hospital and the estimated daily number of laboratory-confirmed SARS-CoV-2 cases for each county. Model estimates are shown with blue medians and interquantile bands, which are compared to the actual true data, provided in red. The blue bands describe the uncertainty in the calibrated parameters, in addition to the stochastic elements of our model. Last four data points are shown in black as they may be affected by reporting delay.

Table 6: Estimated current regional reproduction numbers

R	Parameter	County	From	Pr(R>1)
0.73 (0.48-0.97)	R9	Oslo	2021-03-14	0.01
1.42 (0.71-2.11)	R9	Rogaland	2021-03-09	0.87
1.61 (0.37-3.17)	R8	Møre og Romsdal	2021-03-09	0.79
0.75 (0.15-1.34)	R11	Nordland	2021-03-09	0.21
1.17 (0.99-1.35)	R10	Viken	2021-03-09	0.96
0.72 (0.11-1.34)	R10	Innlandet	2021-03-09	0.18
0.53 (0.13-1.02)	R10	Vestfold og Telemark	2021-03-09	0.03
0.93 (0.14-1.55)	R9	Agder	2021-03-09	0.44
1.86 (0.93-2.75)	R10	Vestland	2021-03-09	0.96
1.06 (0.18-1.94)	R8	Trøndelag	2021-03-09	0.58
0.41 (0.04-0.94)	R9	Troms og Finnmark	2021-03-09	0.01

Mean and 95% credible intervals

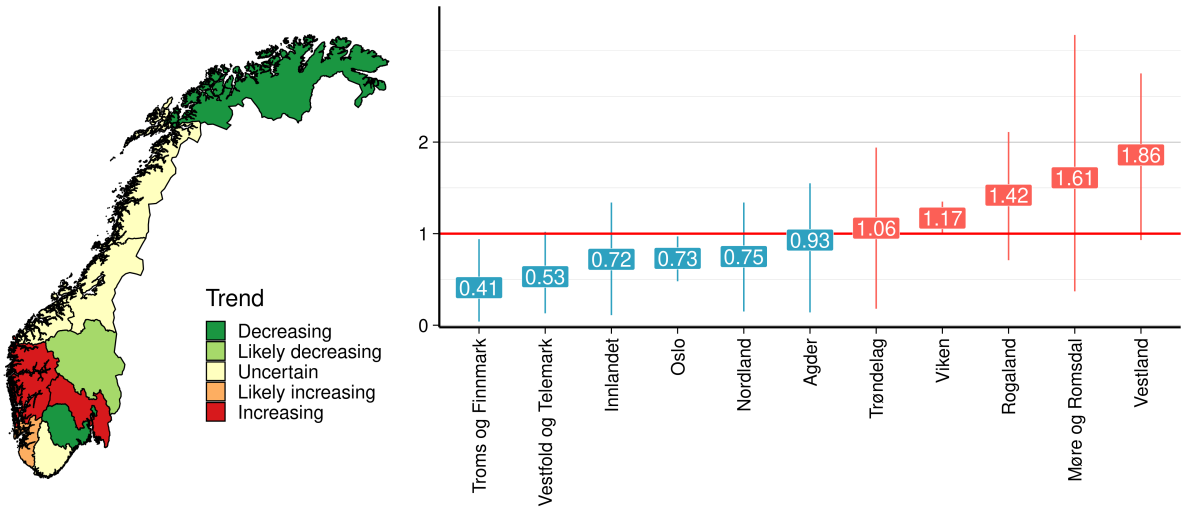
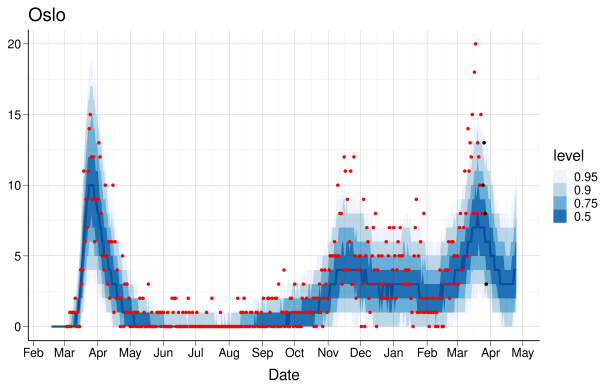
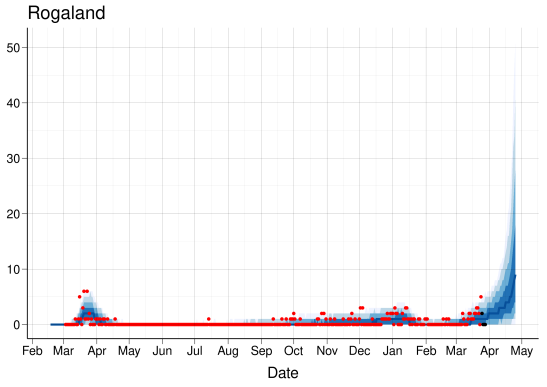
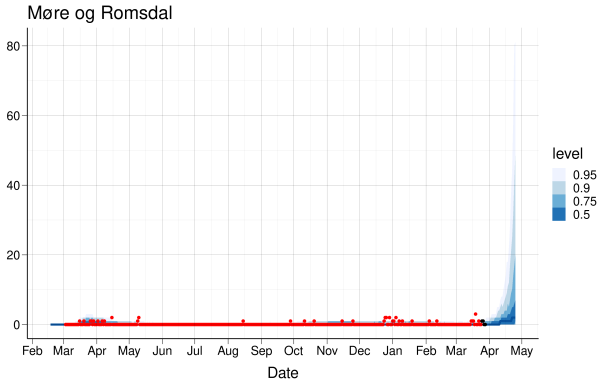


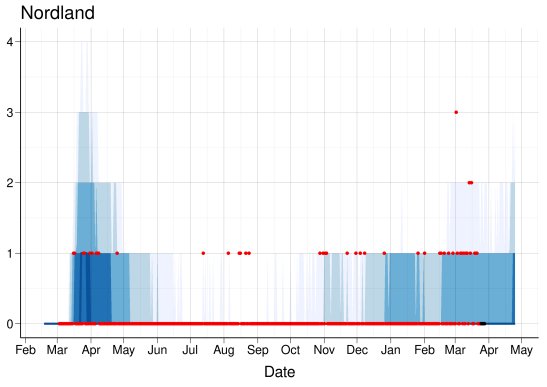
Figure 9: The map shows the direction of the trend in incidence in the counties based on the latest reproduction numbers shown in the other chart. The trend is increasing if the probability that the latest reproduction number is above one is above 95%, the trend is likely increasing if this probability is between 80% and 95%, the trend is uncertain if the probability is between 20% and 80%, the trend is likely decreasing if the probability is between 5% and 20% and is decreasing if the probability that the latest R is above one is less than 5%.

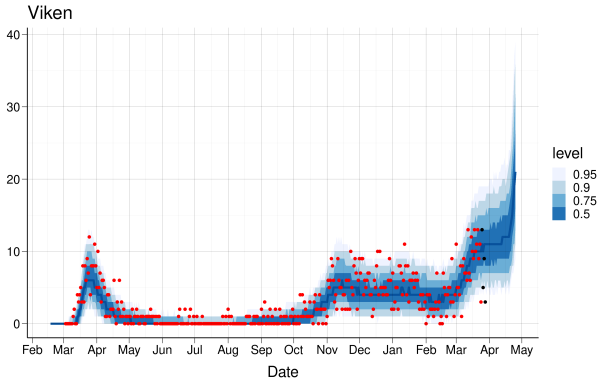
Estimated vs observed hospital incidence data by county:

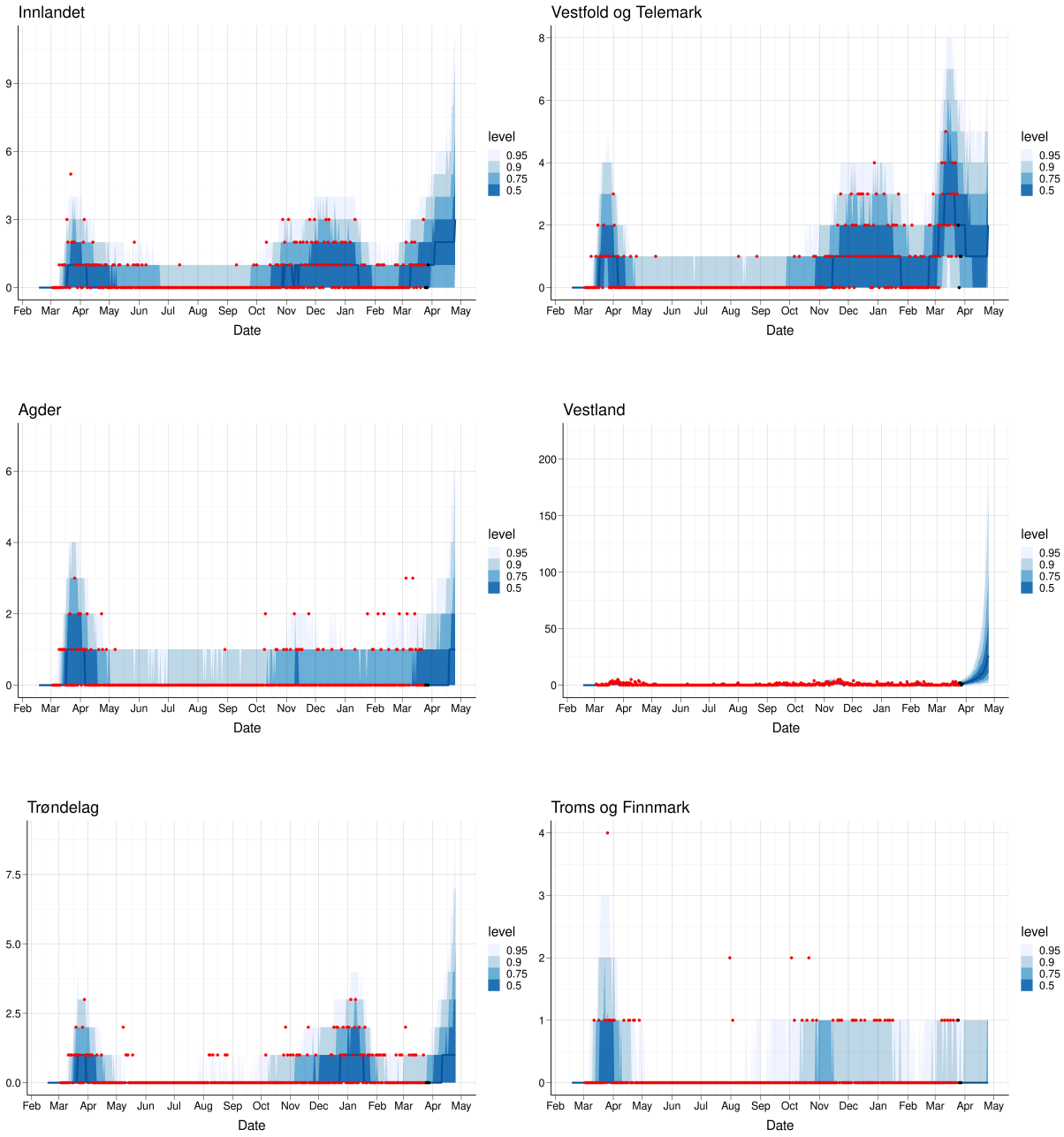




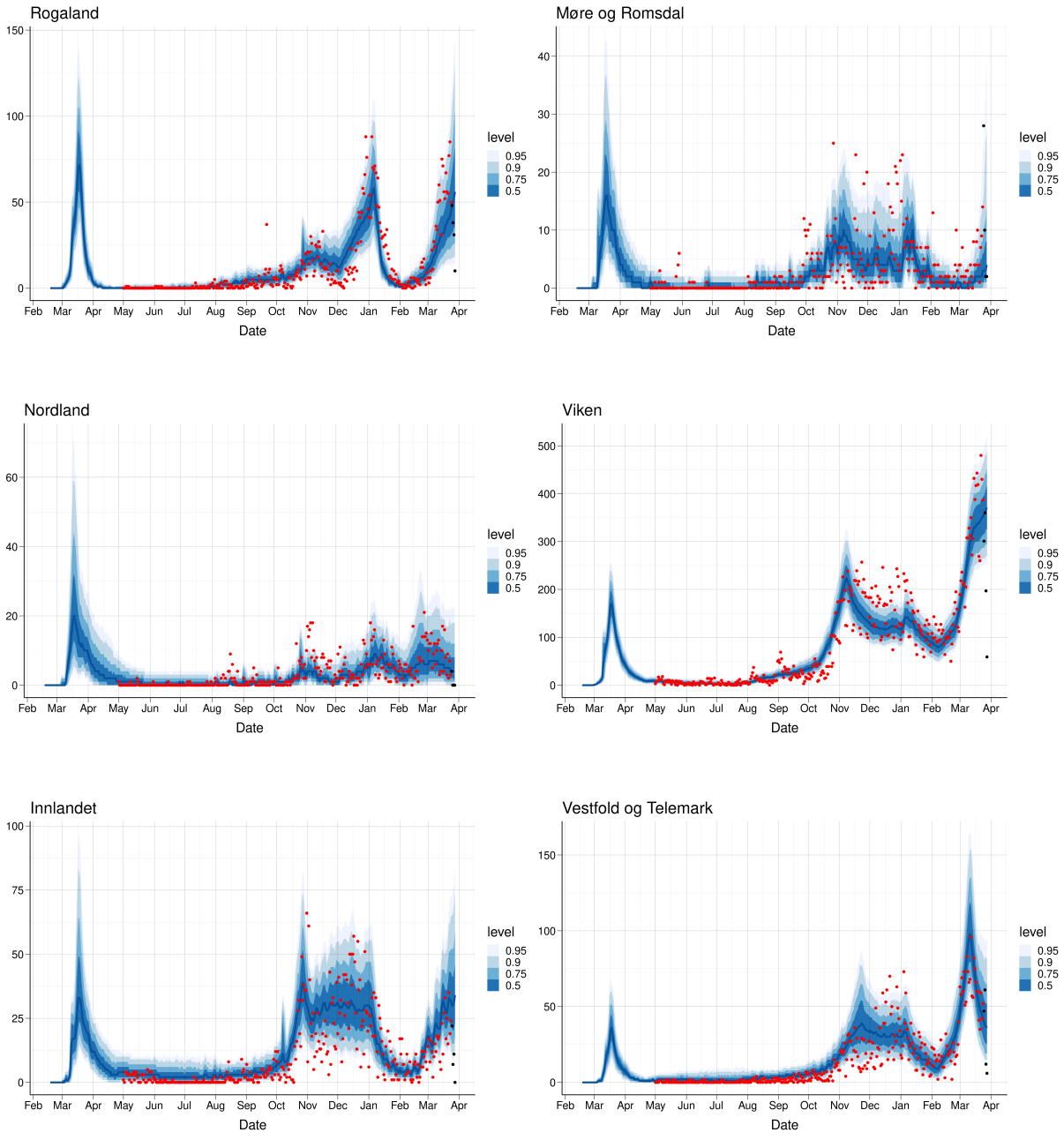


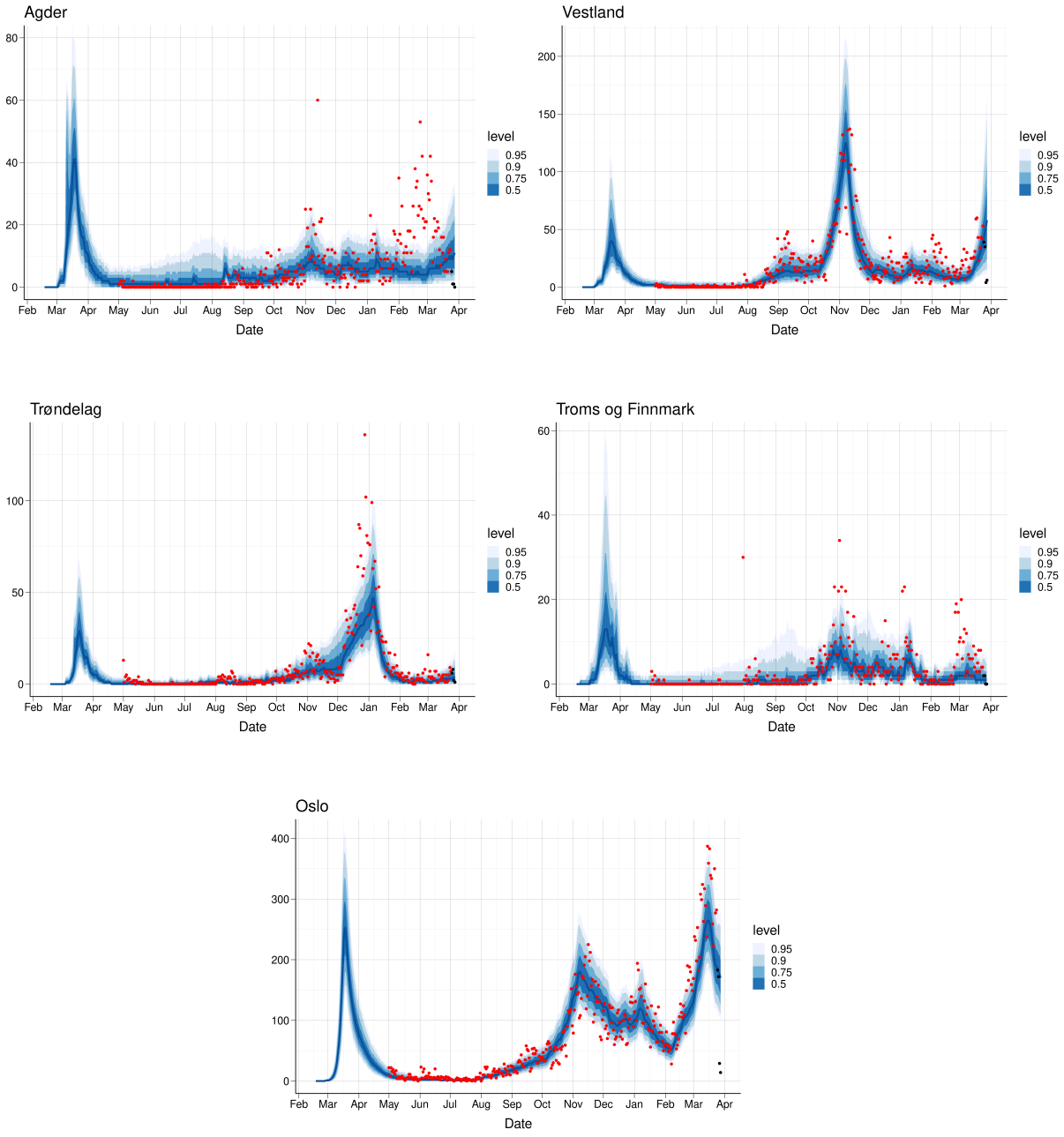





Innlandet
Vestfold og Telemark
Agder
Vestland
Trøndelag
Troms og Finnmark
level
0.95
0.9
0.75
0.5
Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Date

Estimated and observed lab-confirmed test data by county:




Agder
Vestland
Trøndelag
Troms og Finnmark
Oslo
level
0.95
0.9
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0.5
Date
Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr

7 Regional 3-week predictions: Cumulative (total) incidence and Prevalence

Below is shown the estimated short-term forecasting of total incidence of infected individuals (table 7), daily incidence (table 8) and prevalence (table 9) for each county.

Table 7: Estimated cumulative number of infections, 2021-03-28

Region	Total	No. confirmed	Fraction reported	Min. fraction
Oslo	16583 (11665; 22393)	13238	80%	59%
Rogaland	2681 (1399; 4542)	2266	85%	50%
Møre og Romsdal	425 (202; 1006)	410	96%	41%
Nordland	899 (323; 1878)	608	68%	32%
Viken	22825 (16645; 30511)	15628	68%	51%
Innlandet	2050 (1327; 2980)	1047	51%	35%
Vestfold og Telemark	4694 (3067; 6950)	2838	60%	41%
Agder	907 (468; 1681)	1310	144%	78%
Vestland	2211 (1199; 4070)	1768	80%	43%
Trøndelag	1069 (531; 1927)	1060	99%	55%
Troms og Finnmark	295 (161; 607)	399	135%	66%

Fraction reported=Number confirmed/number predicted; Minimal fraction reported=number confirmed/upper CI

Table 8: Predicted incidence per day: Median/Mean (CI)

Region	1 week prediction (04 Apr)	2 weeks prediction (11 Apr)	3 weeks prediction (18 Apr)
Agder	24/28 (5-72)	27/34 (4-103)	32/45 (4-161)
Innlandet	71/79 (28-172)	64/75 (19-202)	62/77 (16-247)
Møre og Romsdal	22/38 (4-183)	35/91 (4-547)	55/234 (3-1745)
Nordland	9/11 (1-33)	8/11 (1-43)	8/12 (1-48)
Oslo	144/147 (78-241)	131/138 (65-245)	136/144 (63-268)
Rogaland	119/142 (27-369)	166/221 (24-707)	241/360 (28-1291)
Troms og Finnmark	4/5 (1-13)	3/4 (0-13)	3/4 (0-14)
Trøndelag	25/28 (7-68)	30/38 (6-123)	39/55 (6-225)
Vestfold og Telemark	51/58 (21-130)	41/50 (14-135)	39/49 (13-138)
Vestland	200/247 (46-753)	356/520 (49-1936)	638/1098 (50-5030)
Viken	546/557 (342-821)	573/590 (347-942)	593/616 (315-1065)

Table 9: Predicted prevalence. Number of infectious individuals (asymptomatic plus pre-symptomatic plus symptomatic) per day. Median/Mean and 95 perc. CI for three weeks prediction.

Region	04 Apr	11 Apr	18 Apr	low CI, 18 Apr	high CI, 18 Apr
Agder	146/163	167/200	224/278	59	808
Innlandet	503.5/534	432.5/487	452/527	179	1425
Møre og Romsdal	112.5/175	182/402	300/990	42	6660
Nordland	57/68	55.5/70	65/85	14	276
Oslo	943/968	839/871	836.5/881	433	1548
Rogaland	640/736	899.5/1127	1305.5/1820	210	5960
Troms og Finnmark	33/36	37/41	54/66	20	187
Trøndelag	150/162	199/230	300.5/373	93	1134
Vestfold og Telemark	377.5/411	299.5/344	287.5/343	128	843
Vestland	966.5/1170	1729.5/2384	3041.5/4892	356	20822
Viken	3283/3356	3486/3579	3632/3752	2077	6263

8 Regional 3-week predictions: Hospital beds and ventilator beds

Below is shown the estimated short-term forecasting of expected hospital prevalence (table 10) and patients on ventilator treatment for each county (table 11).

Table 10: Number of hospitalisation beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (04 Apr)	2 weeks prediction (11 Apr)	3 weeks prediction (18 Apr)
Agder	2/3 (0-11)	3/4 (0-13)	5/5 (0-17)
Innlandet	12/12 (3-27)	14/16 (4-35)	15/17 (4-40)
Møre og Romsdal	1/2 (0-11)	3/5 (0-27)	5/12 (0-74)
Nordland	1/2 (0-8)	1/2 (0-8)	1/2 (0-9)
Oslo	50/52 (28-81)	42/43 (21-69)	36/36 (17-61)
Rogaland	13/14 (3-32)	19/21 (3-51)	26/32 (4-94)
Troms og Finnmark	0/1 (0-3)	0/1 (0-4)	0/1 (0-4)
Trøndelag	1/2 (0-8)	3/4 (0-13)	6/7 (0-21)
Vestfold og Telemark	18/18 (6-36)	15/16 (5-33)	13/14 (3-33)
Vestland	15/17 (3-46)	30/36 (6-105)	54/75 (9-266)
Viken	91/92 (57-133)	96/97 (59-143)	101/104 (60-159)

Table 11: Number of ICU beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (04 Apr)	2 weeks prediction (11 Apr)	3 weeks prediction (18 Apr)
Agder	0/1 (0-3)	0/1 (0-3)	1/1 (0-3)
Innlandet	2/2 (0-6)	2/3 (0-7)	3/3 (0-8)
Møre og Romsdal	0/0 (0-2)	0/1 (0-4)	1/1 (0-9)
Nordland	0/0 (0-2)	0/0 (0-2)	0/0 (0-2)
Oslo	10/11 (4-19)	9/9 (3-17)	8/8 (2-15)
Rogaland	2/2 (0-6)	3/3 (0-9)	4/5 (0-14)
Troms og Finnmark	0/0 (0-1)	0/0 (0-1)	0/0 (0-1)
Trøndelag	0/0 (0-2)	0/1 (0-3)	1/1 (0-4)
Vestfold og Telemark	4/4 (0-9)	3/3 (0-8)	3/3 (0-8)
Vestland	2/2 (0-6)	4/4 (0-13)	7/10 (1-32)
Viken	16/16 (8-26)	18/18 (9-27)	19/19 (10-30)

Table 12: Trend analysis for the last 14 days

	Average daily increase last 14 days		Doubling Time (days)	
County	Hospitalisations	Cases	Hospitalisations	Cases
Agder	Not enough data	3.9 (-2.1, 10.2) %	Not enough data	18.3 (-33.4, 7.2)
Innlandet	Not enough data	4.8 (-1, 11.1) %	Not enough data	14.8 (-68.7, 6.6)
Møre og Romsdal	Not enough data	8.8 (-1.8, 21.2) %	Not enough data	8.2 (-37.2, 3.6)
Nordland	Not enough data	9.7 (0.1, 20.3) %	Not enough data	7.5 (469.5, 3.8)
Norge	7 (2, 12.4) %	4.5 (3.6, 5.5) %	10.2 (35.8, 5.9)	15.6 (19.4, 13)
Oslo	9.6 (1.2, 19.2) %	5.2 (3.6, 6.7) %	7.5 (56, 3.9)	13.7 (19.4, 10.6)
Rogaland	Not enough data	16.7 (7.9, 26.6) %	Not enough data	4.5 (9.1, 2.9)
Troms og Finnmark	Not enough data	48.6 (25.7, 83.7) %	Not enough data	1.8 (3, 1.1)
Trøndelag	Not enough data	10.3 (1.7, 20.2) %	Not enough data	7.1 (40.2, 3.8)
Vestfold og Telemark	Not enough data	-3.7 (-7.2, -0.1) %	Not enough data	-18.3 (-9.3, -534.9)
Vestland	-8.3 (-25.7, 10.6) %	-3 (-7.7, 2) %	-8 (-2.3, 6.9)	-23.1 (-8.6, 34.9)
Viken	6.8 (-1.3, 16) %	4.1 (1.7, 6.4) %	10.5 (-52, 4.7)	17.4 (40, 11.1)

9 14-day trend analysis of confirmed cases and hospitalisations by county

To estimate recent trends in hospitalisation and number of positive tests, we present results in table 12 based on a negative binomial regression where we account for weekend effects. We exclude the last three days to avoid problems of reporting delay and fit the model using data from 17 days to 3 days before the current date. We fit a separate trend model for confirmed cases and for hospital incidence. We only fit a trend model if there has been more than 5 cases or hospitalisations in the 14-day period.

10 Scenario-based short-term predictions for Oslo:

Oslo has experienced increasing infection levels in the last months. Rising case numbers can lead to less efficient contact tracing due to a lack of resources. This, in turn, can cause the reproductive number to increase.To explore the short-term consequences of a less effective contact tracing in Oslo, we compare projections of the regional changepoint model, where the current reproduction number in Oslo is increased to 1.10; 1.15 and 1.20 from today, respectively. In these scenarios we assume no change to the reproductive numbers in the other counties. Table 13 and Figure compares these projected scenarios with a projection of the current epidemiological situation in Oslo.

Table 13: 4 week predictions in Oslo: Prevalence and Incidence (mean/median(CI))

Scenario	Prevalence	Incidence
Current	969/920 (568-1522)	153/146 (86-244)
R=1.10	1510/1482 (922-2207)	260/256 (158-389)
R=1.15	1625/1576 (1008-2410)	285/277 (164-429)
R=1.20	1739/1726 (1074-2543)	307/307 (186-443)

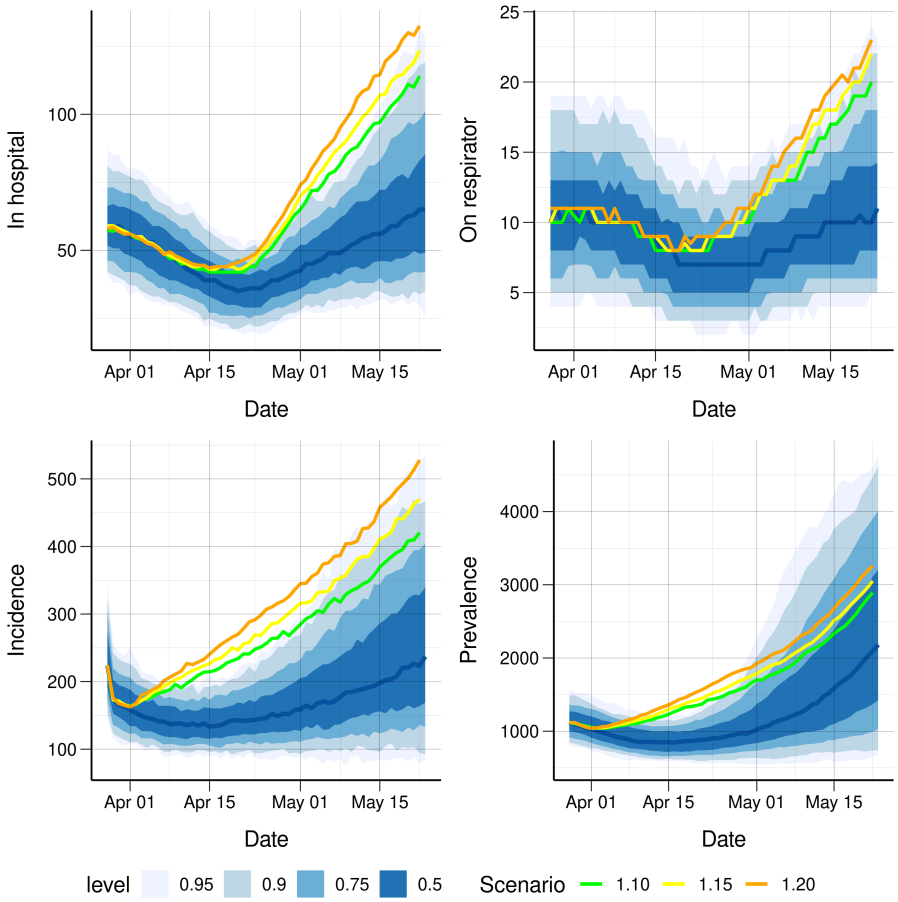


Figure 20: Future predictions for Oslo assuming the reproductive number will remain constant vs alternative scenarios. Confidence intervals correspond to "current scenario". Parameters showed are: Hospitalisations (top left), On respirator (top right),Incidence (bottom left) and Prevalence (bottom right).

11 Regional long-term predictions

IMPORTANT: The long term predictions for each county have not been prepared this week, because we must incorporate regional vaccination plans. Work is ongoing.

12 Mobility data

Number of trips out from each municipality during each day is based on Telenor mobility data. We observed a large reduction in inter-municipality mobility in March 2020 (with minimum reached on Tuesday 17 March 2020), and thereafter we see an increasing trend in the mobility lasting until vacation time in July. The changes in mobility in July coincides with the three-week "fellesferie" in Norway, and during August the mobility resumes approximately the same levels as pre-vacation time. There is however a significant regional variation.

The reference level is set to 100 on March 2nd 2020 for all the figures in this section, and we plot the seven-day, moving average of the daily mobility. Figure 21 shows an overview of the mobility since March 2020 for the largest municipalities in each county, and Figure 22 shows the total mobility out from all municipalities in each county, including Oslo. Figure 23 and 24, zooms in on mobility from January 11 2021, for municipalities and counties, respectively.

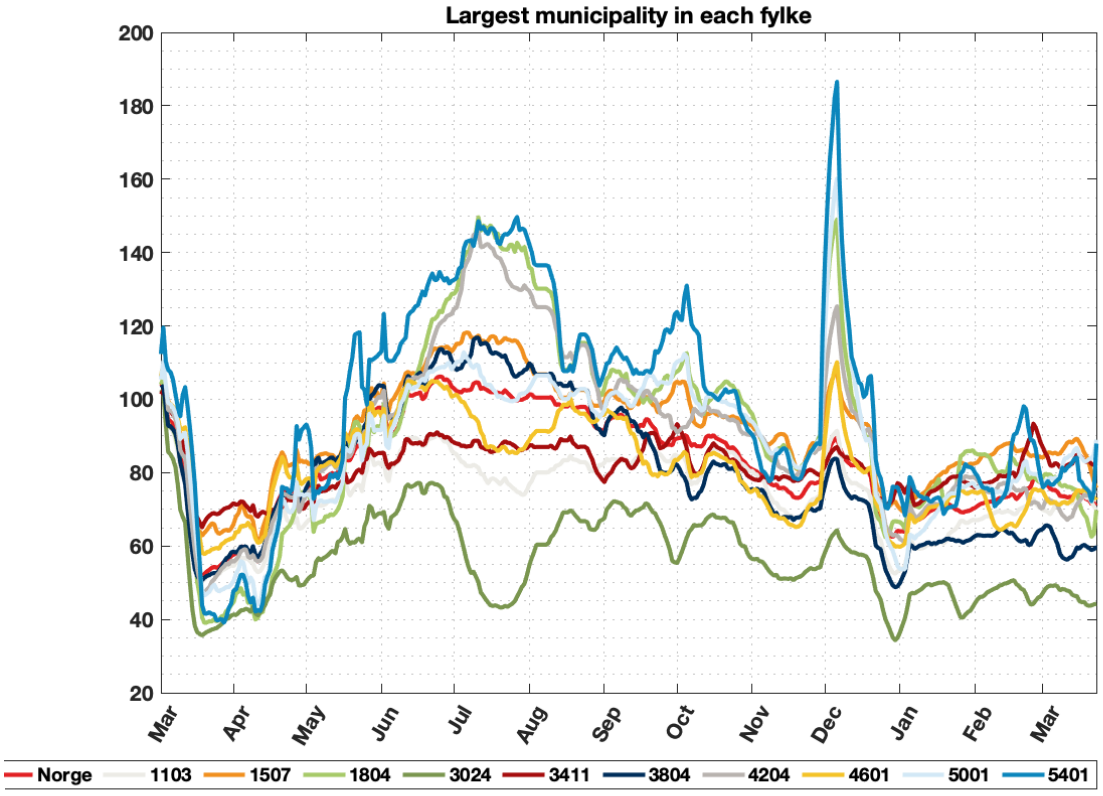


Figure 21: Mobility for selected municipalities since March 2020: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

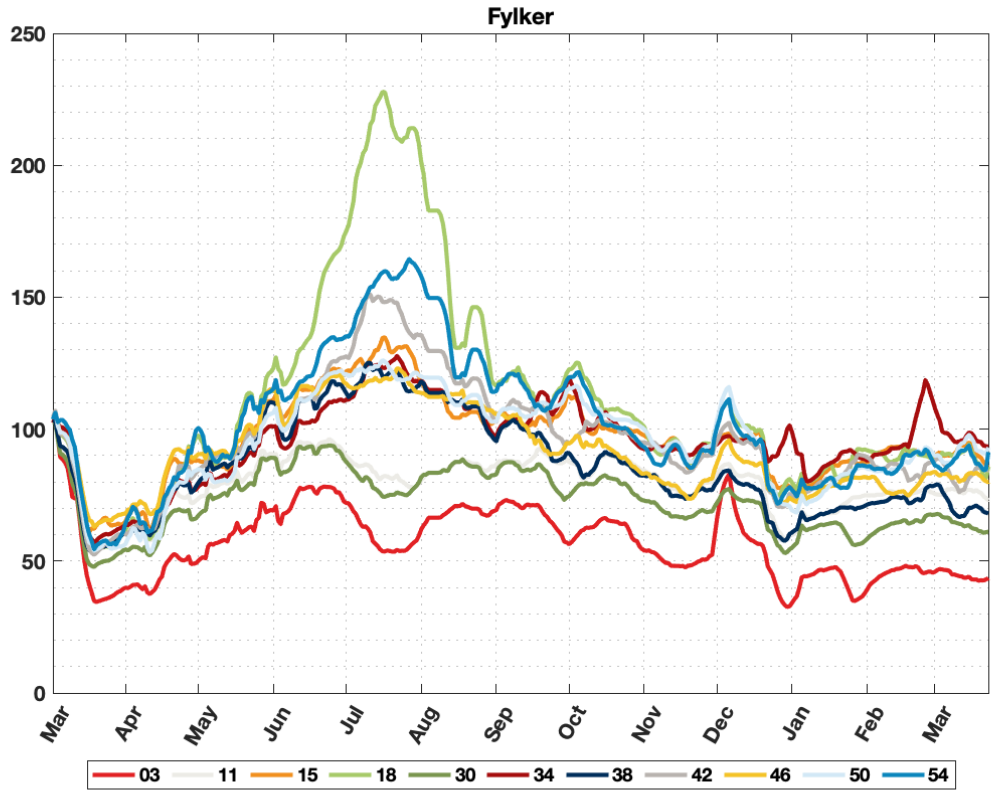


Figure 22: Mobility for fylker since March 2020: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

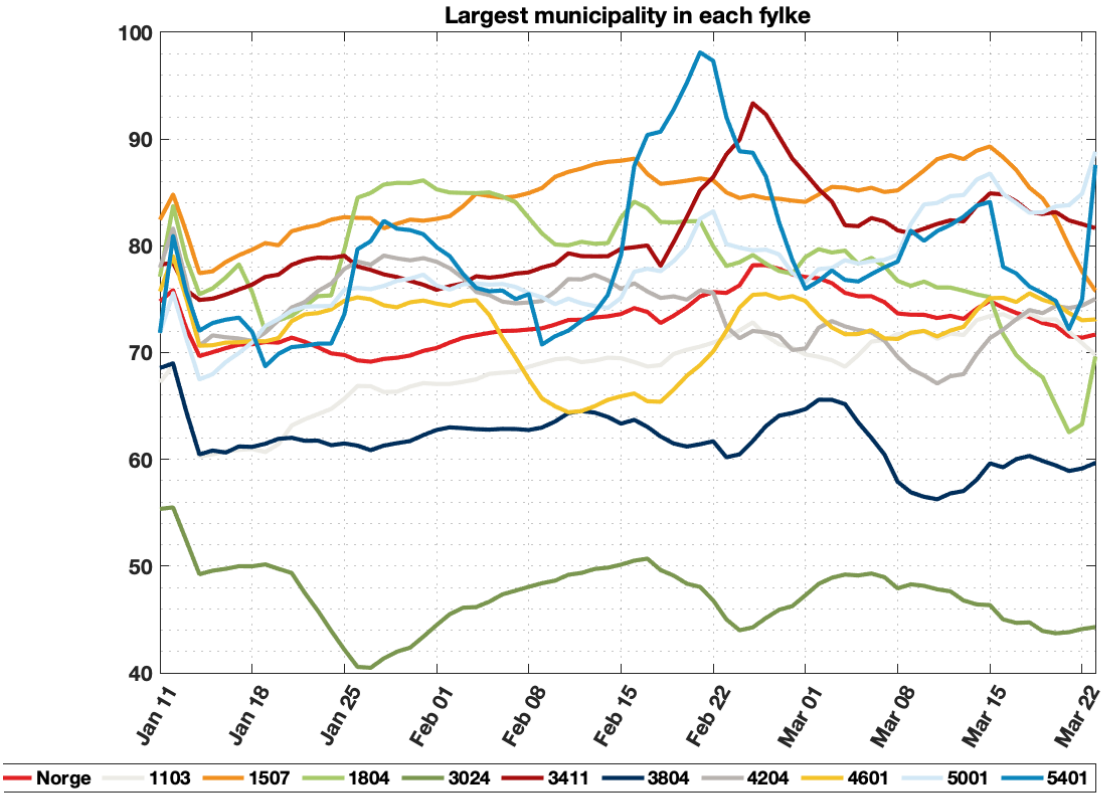


Figure 23: Zoom: Mobility from January 11, 2021 and onwards: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

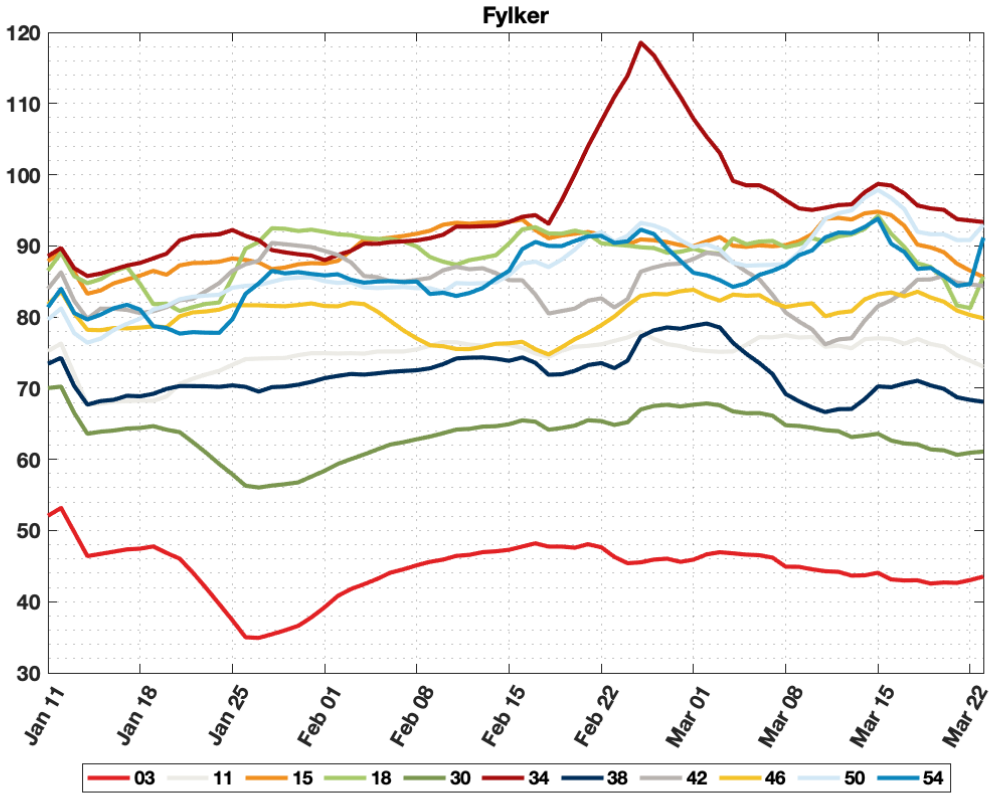


Figure 24: Zoom: Mobility from January 11, 2021 and onwards, per fylker: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finnmark (54).

	10	11	12	13	14
Norge	77.1	73.7	74.8	71.4	66.6
Stavanger	69.8	71.7	73.4	70.9	57.7
Ålesund	84.1	85.2	89.3	77.6	70.3
Bodø	79.0	76.7	75.2	63.3	87.5
Bærum	47.3	47.9	46.3	44.1	37.1
Ringsaker	86.8	81.5	84.9	82.0	72.5
Sandefjord	64.7	57.9	59.6	59.1	50.9
Kristiansand	70.4	69.6	71.4	74.4	69.2
Bergen	74.8	71.3	75.1	73.0	69.9
Trondheim	76.6	79.2	86.8	84.9	88.8
Tromsø	76.0	78.5	84.1	75.0	124.7

Table 14: Municipalities

	10	11	12	13	14
Oslo	45.9	44.9	44.1	43.0	39.3
Rogaland	75.4	77.4	77.0	73.8	60.5
Møre og Romsdal	90.0	90.1	94.8	86.5	82.5
Nordland	89.6	89.8	94.2	81.2	101.1
Viken	67.7	64.8	63.6	60.9	53.0
Innlandet	107.8	96.4	98.7	93.5	92.6
Vestfold og Telemark	78.8	69.2	70.2	68.3	58.8
Agder	88.2	80.6	81.5	84.6	73.7
Vestlandet	83.8	81.4	83.2	80.3	76.2
Trøndelag	89.8	87.4	97.8	90.8	94.1
Troms og Finnmark	86.2	87.3	93.8	84.6	109.5

Table 15: Counties

Weekly mobility for Norway and selected municipalities is displayed in Table 14 and mobility for counties is displayed in Table 15. The percentages in the tables are to be interpreted towards the reference level of 100 for week 10 in March 2020. The color-coding encodes the following: 'Green' monotonic decrease in mobility, 'Yellow' almost monotonic decrease or flat mobility trend, 'Red' increasing mobility.

12.1 Foreign roamers on Telenor's network in Norway

An analysis of foreign roamers in Norway from January 2020 has been carried out, to better understand the potential virus importation. In Figure 25 the total number of roamers per day per county are displayed. We can see an approximate 40% drop in the number of visiting roamers after the lock-down in March 2020. The number of visiting roamers recover during the Summer of 2020, and there is a spike of visitors in August followed by a drop again. During October and November 2020 the levels of visiting, foreign roamers to Norway have reached quite high levels, just 10% short of the all-year high for 2020, and Oslo and Viken have seen big increases in visitors. There is a reduction in visitors during Christmas, and in January 2021 we see an increasing trend again.

Figure 26 showcases the levels of roamers from the following countries: Poland, Lithuania, Sweden, Netherlands, Denmark, Latvia, Germany, Spain, Finland and the rest of the world. These levels represent the total number of foreign, visiting roamers from each of the countries per day in Norway, since November 30 2020.

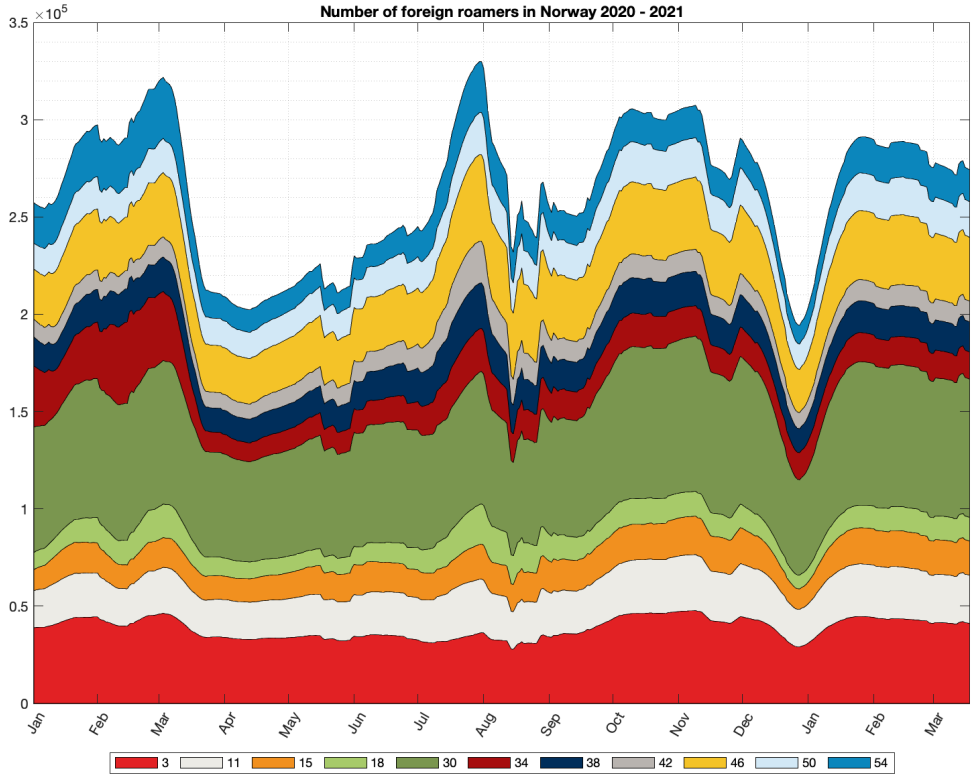


Figure 25: The total number of foreign roamers in Norway broken down on different fylker: Oslo (3), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

12.1 Foreign roamers on Telenor's network in Norway

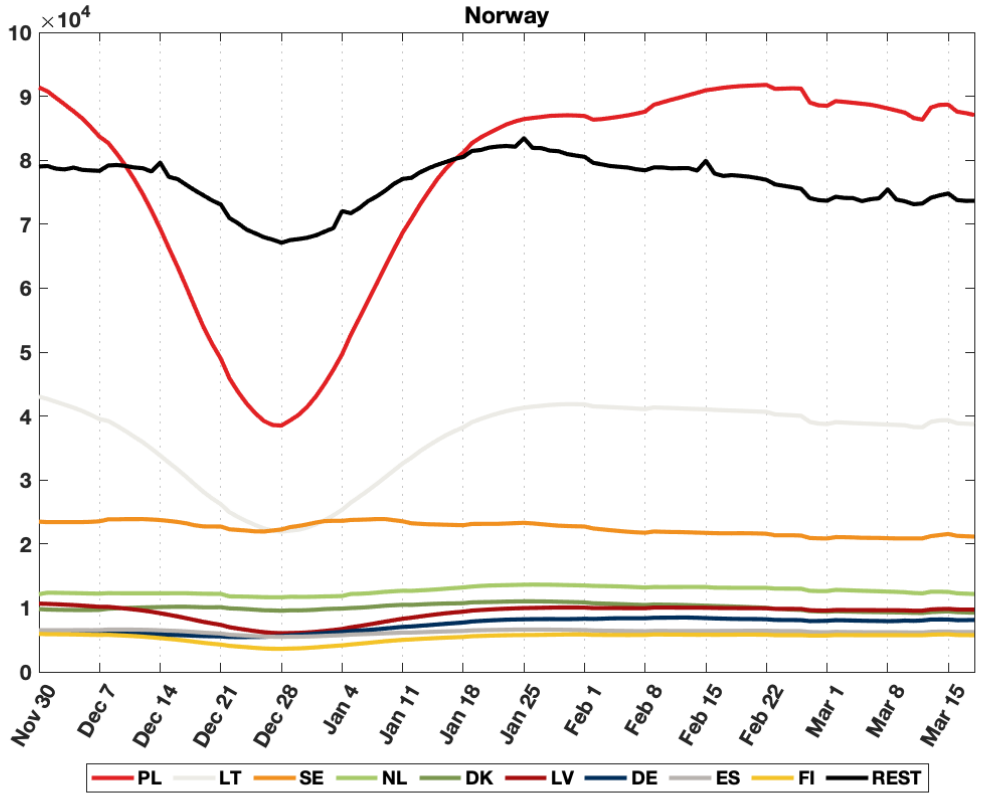
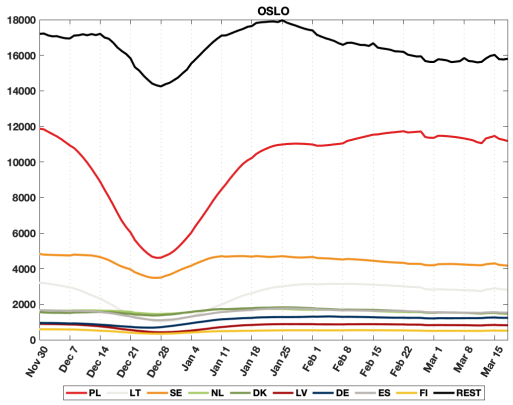
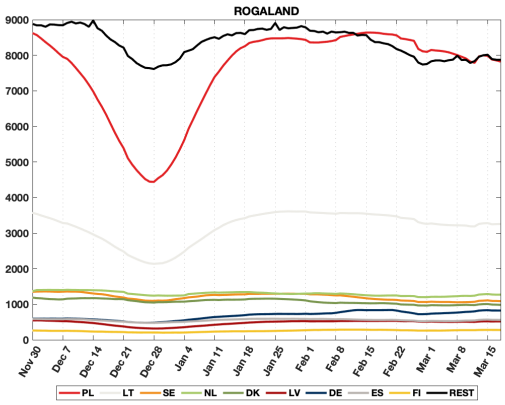
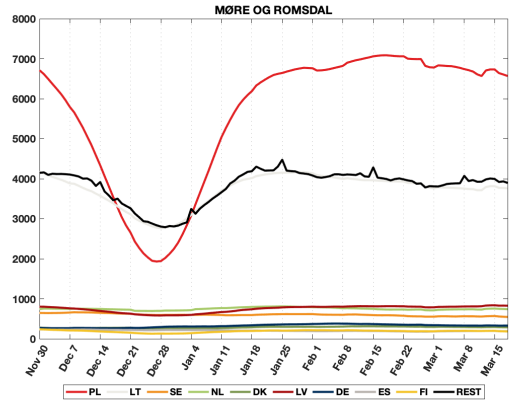


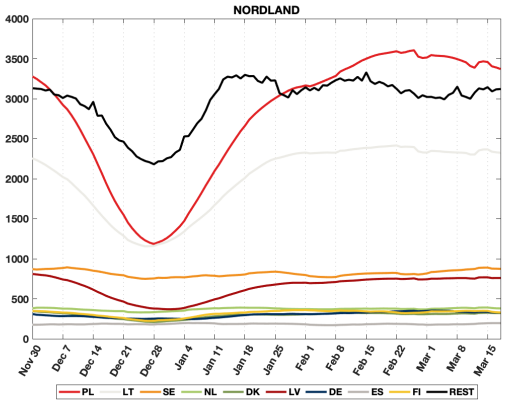
Figure 26: National overview of total number of foreign, visiting roamers from Poland, Lithuania, Sweden, Netherlands, Denmark, Latvia, Germany, Spain, Finland and the rest of the world.

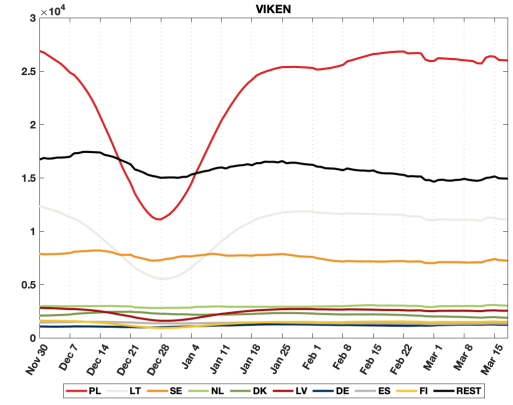
12.2 Foreign roamers per county (fylke) in Norway

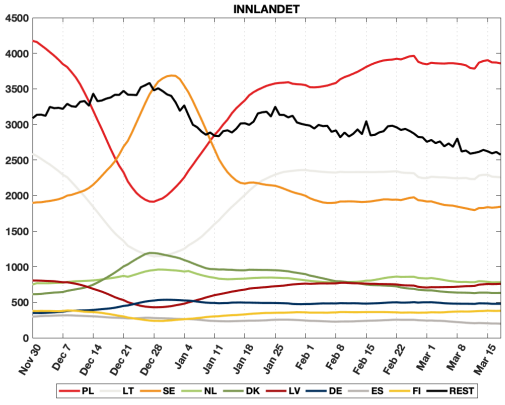




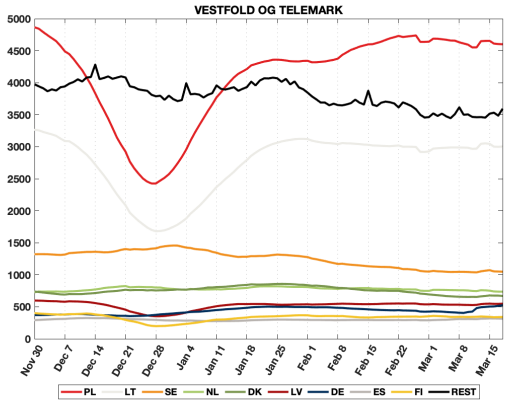


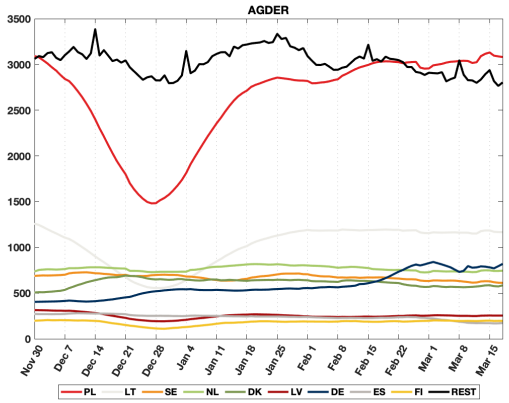


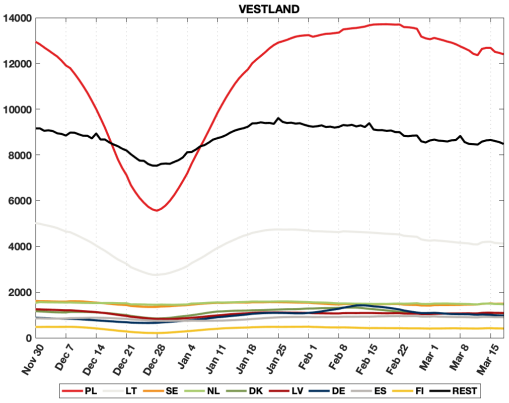


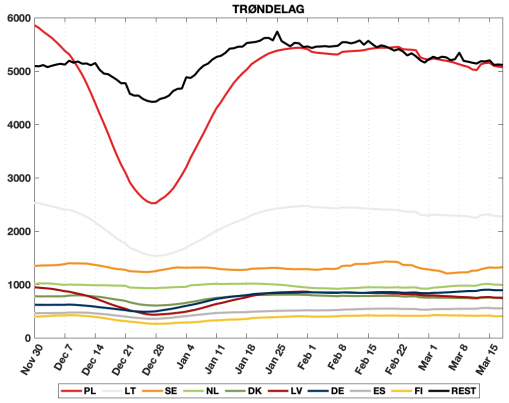


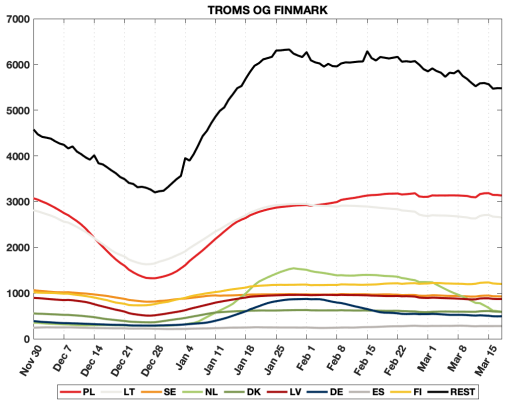
12.2 Foreign roamers per county (fylke) in Norway











13 Methods

13.1 Model

We use a metapopulation model to simulate the spread of COVID-19 in Norway in space and time. The model consists of three layers: the population structure in each municipality, information about how people move between different municipalities, and local transmission within each municipality. In this way, the model can simulate the spread of COVID-19 within each municipality, and how the virus is transported around in Norway.

13.1.1 Transmission model

We use an SEIR (Susceptible-Exposed-Infected-Recovered) model without age structure to simulate the local transmission within each area. Mixing between individuals within each area is assumed to be random. Demographic changes due to births, immigration, emigration and deaths are not considered. The model distinguishes between asymptomatic and symptomatic infection, and we consider presymptomatic infectiousness among those who develop symptomatic infection. In total, the model consists of 6 disease states: Susceptible (S), Exposed, infected, but not infectious (E_1), Presymptomatic infected (E_2), Symptomatic infected (I), Asymptomatic infected (I_a), and Recovered, either immune or dead (R). A schematic overview of the model is shown in figure 29.

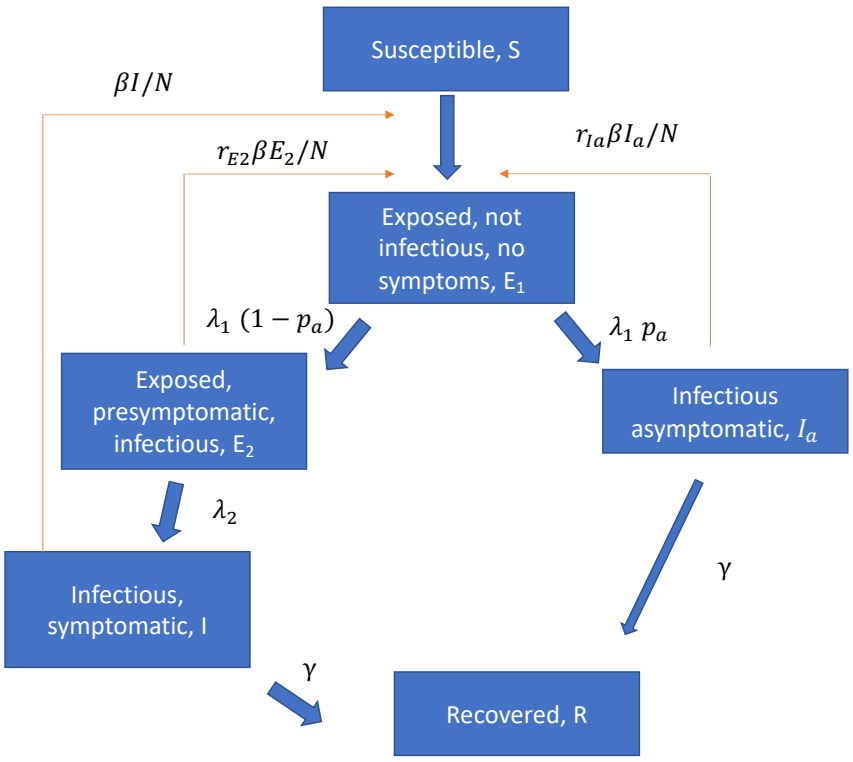


Figure 29: Schematic overview of the model.

13.2 Movements between municipalities:

We use 6-hourly mobility matrices from Telenor to capture the movements between municipalities. The matrices are scaled according to the overall Telenor market share in Norway, estimated to be 48%. Since week 8, we use the actual daily mobility matrices to simulate the past. In this way, alterations in the mobility pattern will be incorporated in our model predictions. To predict future movements, we use the

latest weekday measured by Telenor, regularised to be balanced in total in- and outgoing flow for each municipality.

13.3 Healthcare utilisation

Based on the estimated daily incidence data from the model and the population age structure in each municipality, we calculated the hospitalisation using a weighted average. We correct these probabilities by a factor which represents the over or under representation of each age group among the lab confirmed positive cases. The hospitalisation is assumed to be delayed relative to the symptom onset. We calculate the number of patients admitted to ventilator treatment from the patients in hospital using age-adjusted probabilities and an assumed delay.

13.4 Seeding

At the start of each simulation, we locate 5.367.580 people in the municipalities of Norway according to data from SSB per January 1. 2020. All confirmed Norwegian imported cases with information about residence municipality and test dates are used to seed the model, using the data available until yesterday. For each case, we add an additional random number of infectious individuals, in the same area and on the same day, to account for asymptomatic imported cases who were not tested or otherwise missed. We denote this by the amplification factor.

13.5 Calibration

Estimation of the parameters of the model: the reproduction numbers, the amplification factor for the imported cases, the parameters of the detection probability and the delay between incidence and test, is done using Sequential Monte Carlo Approximate Bayesian Computation (SMC-ABC), as described in Engebretsen et al. (2020): https://royalsocietypublishing.org/doi/10.1098/rsif.2019.0809, where the algorithm can be found in the supplement.

The idea behind ABC is to try out different parameter sets, simulate using these, then compare how much the simulations deviate from the observations in terms of summary statistics. We thus test millions of combinations of the different reproductive numbers, the amplification factor, and the parameters for the positive tests, to determine the ones that lead to the best fits to the true number of hospitalised individuals, from March 10 2020 until the last available data point, and the laboratory-confirmed COVID-19 cases from May 1 until the latest available data point.

In the ABC procedure we thus use two summary statistics, one is the distance between the simulated hospitalisation incidence and the observed incidence, and the other is the distance between the observed number of laboratory-confirmed cases and the simulated ones. As the two summary statistics are not on the same scale, we use two separate tolerances in the ABC-procedure, ensuring that we get a good fit to both data sources.

13.5.1 Calibration to hospitalisation data

In order to calibrate to the hospitalisation data, we need to simulate hospital incidence. The details on how we simulate hospitalisations are described in Section 13.3, using the parameters provided in Section 14, which are estimated from individual-level Norwegian data, and updated regularly. As our distance measure, we calculate the squared distance over each time point and each county.

13.5.2 Calibration to test data

We include the laboratory-confirmed cases in the calibration procedure, as these contain additional information about the transmissibility, and the delay between transmission and testing is shorter than the delay between transmission and hospitalisation. Therefore, we simulate also the number of detected positive cases in our model. We assume that the number of detected positive cases can be modelled as a binomial process of the simulated daily total incidence of symptomatic and asymptomatic cases, with a

success probability π_t, which changes every day. We also assume a delay d between the day of test and the day of transmission.

The data on the number of positive cases are more difficult to use, as the test criteria and capacity have changed multiple times. We take into account these changes by using the total number of tests performed on each day, as a good proxy of capacity and testing criteria. Moreover, we choose not to calibrate to the test data before May 1, because the test criteria and capacity were so different in the early period. The detection probability is modelled as

$$\pi_t = \exp(\pi_0 + \pi_1 \cdot k_t)/(1 + \exp(\pi_0 + \pi_1 \cdot k_t)),$$

where k_t is the number of tests actually performed on day t, and π_0 and π_1 are two parameters that we estimate, assuming positivity of π_1. We also estimate the delay d. We choose to use a 7-days backwards moving average for the covariate k_t. To calculate the distance between the observed number of positive tests and the simulated ones we also use a 7-days backwards moving average. We do this to take into account potential day-of-the-week-effects. For example, it could well be that the testing criteria are different on weekends and weekdays. However, using instead the number of tests and calibrating on a daily basis would lead to a larger day-to-day variance. This is likely why we find that the uncertainty in the simulated positive cases seems somewhat too low, and that we do not capture all the variance in the daily test data. Moreover, the binomial assumption could be too simple, and a beta-binomial distribution would allow more variance. A limitation of our current model for the detection probability, is that we only capture the changes in the test criteria that are captured in the total number of tests performed.

13.6 Specifications for the national changepoint model

In the national changepoint model, we assume a first reproduction number R_0 until March 14, a second reproduction number R_1 until April 19, a third reproduction number R_2 until May 10, a fourth reproduction number R_3 until June 30, R_4 until July 31, R_5 until August 31, R_6 from September 1 until September 30, R_7 from October 1 until October 26, R_8 until November 4, R_9 from November 5th until November 30th, R_{10} from December 1st until January 4, a twelfth reproduction number R_{11} from January 4 until January 21, a thirteenth reproduction number from January 22 to February 7 and a fourteenth reproduction number from February 8. This last reproduction number is used for the future. The changepoints follow the changes in restrictions introduced. In the calibration procedure, we obtain 200 parameter sets that we use to represent the distributions of parameters.

After we have obtained the estimated parameters, we run the model with these 200 parameter sets again, from the beginning until today, plus three weeks into the future (or for an additional year). In this way, we obtain different trajectories of the future, allowing us to investigate different scenarios, with corresponding uncertainty.

13.7 Specifications for the regional changepoint model

In the regional changepoint model, each county has its own reproduction numbers, assumed constant in different periods, just like the national changepoint model. As there are more parameters in the regional changepoint model, we obtain 1000 parameter sets in the ABC-SMC.

Calibrating regional reproduction numbers is a more difficult estimation problem than calibrating national reproduction numbers, as we have a lot more parameters, and in addition less data in each county. Therefore, we cannot include the same amount of changepoints in the regional model as we can for the national model.

After we have obtained the estimated parameters, we run the model with these 1000 parameter sets again, from the beginning until today, plus three weeks into the future (or for an additional year). In this way, we obtain different trajectories of the future, allowing us to investigate different scenarios, with corresponding uncertainty.

14 Parameters used today

Figures 30, 31 and 32 indicate which assumptions we make in our model, related to hospitalisation. We obtained data from the Norwegian Pandemiregister. These estimates will be regularly updated, on the basis of new data.

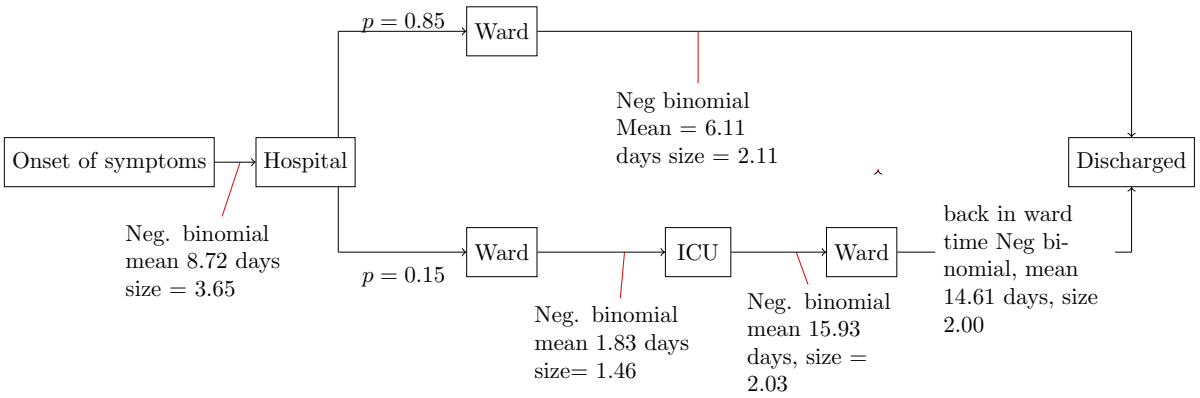


Figure 30: Hospital assumptions and parameters used before 1 June 2020

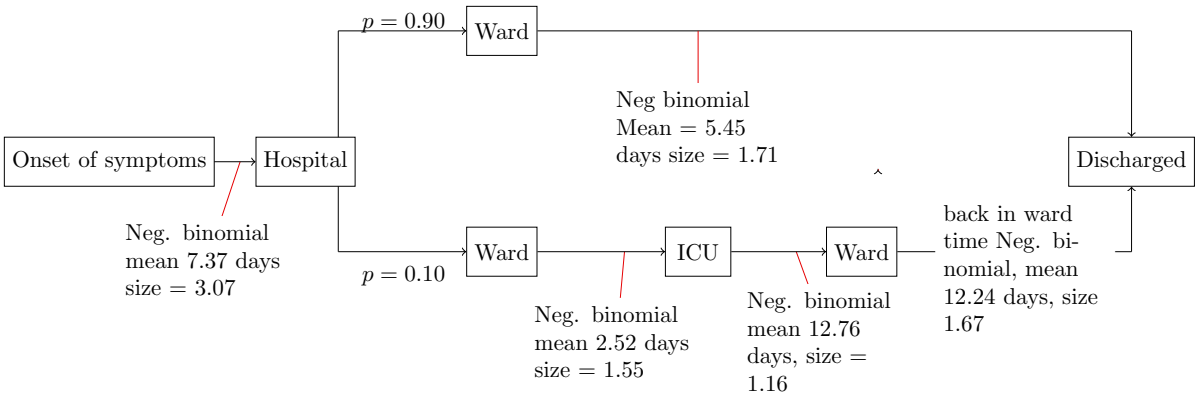


Figure 31: Hospital assumptions and parameters used between 1 June 2020 and 1 January 2021

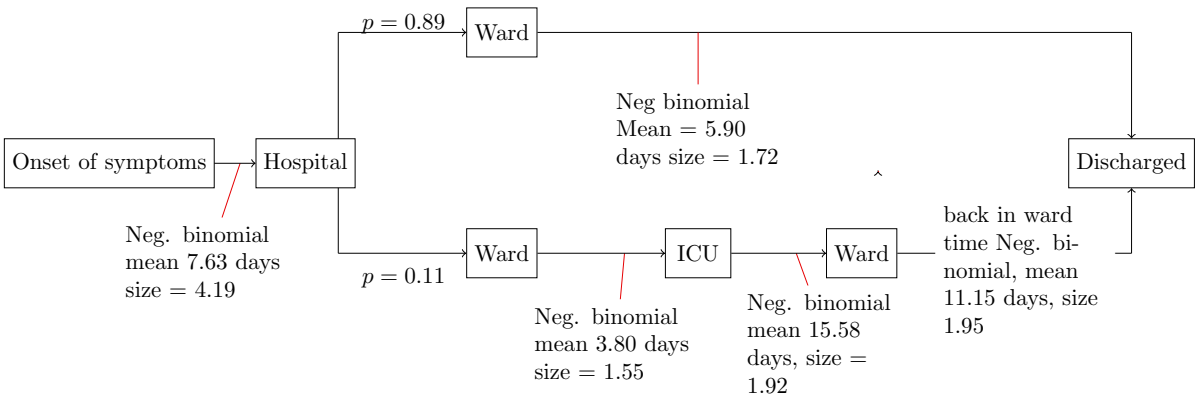


Figure 32: Hospital assumptions and parameters used from 1 January 2021

Table 16: Estimated parameters

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Period
R0s	2.24	2.86	3.152	3.144	3.396	4.143	Until March 14
R1s	0.379	0.468	0.503	0.502	0.538	0.632	From 15 March to 19 April
R2s	0.109	0.527	0.672	0.663	0.8	1.213	From 20 April to 10 May
R3s	0.125	0.466	0.627	0.618	0.799	1.226	From 11 May to 30 June
R4s	0.05	0.759	1.026	1.004	1.224	1.788	From 01 July to 31 July
R5s	0.656	0.94	1.03	1.037	1.129	1.414	From 01 August to 31 August
R6s	0.72	0.874	0.95	0.938	1.004	1.101	From 01 September to 30 September
R7s	1.09	1.198	1.258	1.262	1.321	1.563	From 01 October to 25 October
R8s	0.969	1.188	1.26	1.269	1.348	1.61	From 26 October to 04 November
R9s	0.713	0.781	0.796	0.798	0.822	0.874	From 05 November to 30 November
R10s	1.003	1.06	1.074	1.074	1.086	1.128	From 01 December to 03 January
R11s	0.439	0.543	0.592	0.588	0.627	0.724	From 04 January to 21 January
R12s	0.668	0.775	0.832	0.828	0.874	1	From 22 January to 07 February
R13s	1.308	1.383	1.406	1.412	1.439	1.545	From 08 February to 08 March
R14s	0.832	1.001	1.034	1.036	1.083	1.156	From 09 March
AMPs	1.183	1.752	2.02	2.066	2.412	3.523	-
π_0	-1.054	0	0.207	0.168	0.398	0.733	-
π_1	1.6e-07	1.1e-05	2.3e-05	2.7e-05	3.8e-05	1.1e-04	-
delays	1	3	3	3.275	4	4	-

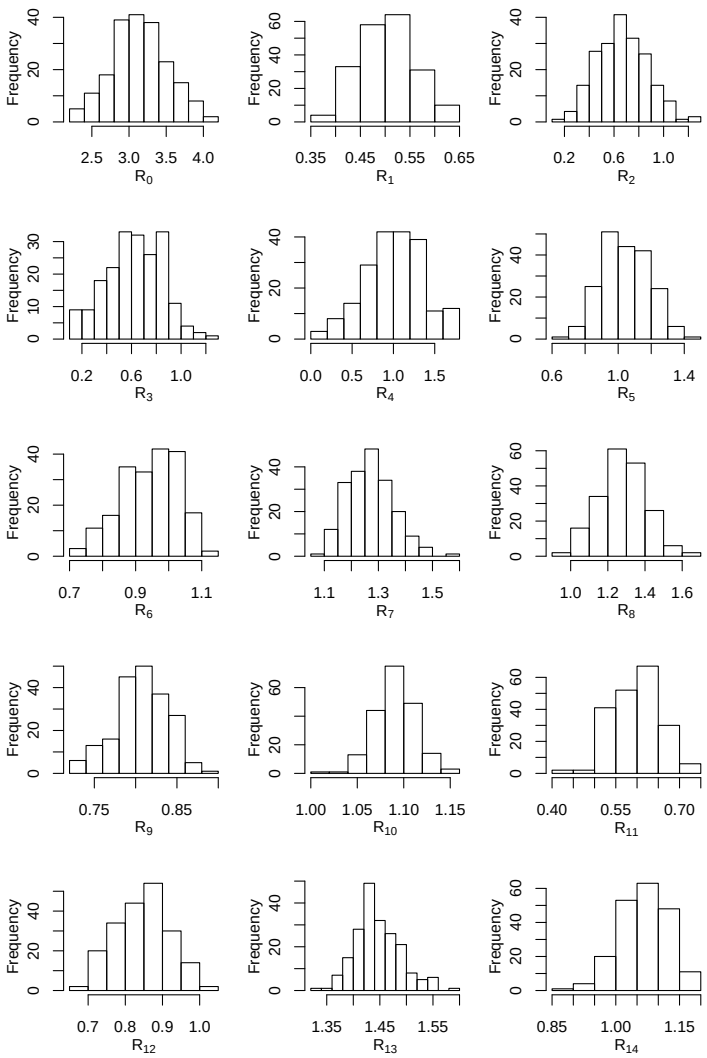


Figure 33: Estimated densities of the reproduction numbers. National model

Table 17

R	Parameter	County	From	To	Pr(R>1)
5.59 (4.87-6.1)	R0	Oslo	2020-02-17	2020-03-14	1
3.52 (2.78-4.2)	R0	Rogaland	2020-02-17	2020-03-14	1
3.18 (1.6-4.75)	R0	Møre og Romsdal	2020-02-17	2020-03-14	0.99
3.44 (0.92-6.07)	R0	Nordland	2020-02-17	2020-03-14	0.97
3.63 (2.96-4.27)	R0	Viken	2020-02-17	2020-03-14	1
2.89 (1.43-4.62)	R0	Innlandet	2020-02-17	2020-03-14	0.99
3.33 (1.89-4.6)	R0	Vestfold og Telemark	2020-02-17	2020-03-14	1
2.75 (1.76-3.68)	R0	Agder	2020-02-17	2020-03-14	1
2.85 (1.74-4.08)	R0	Vestland	2020-02-17	2020-03-14	1
3.89 (2.31-5.32)	R0	Trøndelag	2020-02-17	2020-03-14	1
2.67 (1.48-3.91)	R0	Troms og Finnmark	2020-02-17	2020-03-14	1
0.6 (0.48-0.73)	R1	Oslo	2020-03-15	2020-04-19	0
0.51 (0.15-0.95)	R2	Oslo	2020-04-20	2020-07-24	0.02
1.31 (1.22-1.41)	R3	Oslo	2020-07-25	2020-09-30	1
1.49 (1.4-1.56)	R4	Oslo	2020-10-01	2020-11-04	1
1.01 (0.95-1.08)	R5	Oslo	2020-11-05	2020-12-14	0.64
1.3 (1.12-1.53)	R6	Oslo	2020-12-15	2021-01-03	1
0.82 (0.73-0.93)	R7	Oslo	2021-01-04	2021-02-04	0
1.57 (1.47-1.65)	R8	Oslo	2021-02-05	2021-03-13	1
0.73 (0.48-0.97)	R9	Oslo	2021-03-14		0.01
0.06 (0.01-0.13)	R1	Rogaland	2020-03-15	2020-04-19	0
0.8 (0.47-1.1)	R2	Rogaland	2020-04-20	2020-08-31	0.12
0.82 (0.62-1.02)	R3	Rogaland	2020-09-01	2020-11-04	0.04
0.75 (0.32-1.08)	R4	Rogaland	2020-11-05	2020-11-30	0.09
1.33 (1.08-1.62)	R5	Rogaland	2020-12-01	2021-01-03	1
0.12 (0.01-0.33)	R6	Rogaland	2021-01-04	2021-01-31	0
1.26 (0.66-1.76)	R7	Rogaland	2021-02-01	2021-02-19	0.84
1.86 (1.22-2.63)	R8	Rogaland	2021-02-20	2021-03-08	1
1.42 (0.71-2.11)	R9	Rogaland	2021-03-09		0.87
0.39 (0.12-0.68)	R1	Møre og Romsdal	2020-03-15	2020-04-19	0
0.64 (0.31-0.97)	R2	Møre og Romsdal	2020-04-20	2020-09-14	0.02
0.73 (0.32-1.09)	R3	Møre og Romsdal	2020-09-15	2020-11-04	0.08
0.53 (0.09-1.03)	R4	Møre og Romsdal	2020-11-05	2020-12-14	0.03
0.66 (0.05-1.5)	R5	Møre og Romsdal	2020-12-15	2021-01-03	0.19
0.34 (0.04-0.76)	R6	Møre og Romsdal	2021-01-04	2021-02-04	0
0.59 (0.06-1.1)	R7	Møre og Romsdal	2021-02-05	2021-03-08	0.07
1.61 (0.37-3.17)	R8	Møre og Romsdal	2021-03-09		0.79
0.49 (0.05-0.87)	R1	Nordland	2020-03-15	2020-04-19	0
0.8 (0.5-1.09)	R2	Nordland	2020-04-20	2020-07-24	0.1
0.58 (0.02-1.67)	R3	Nordland	2020-07-25	2020-08-14	0.17
0.63 (0.27-1.03)	R4	Nordland	2020-08-15	2020-10-04	0.03
0.65 (0.22-1.08)	R5	Nordland	2020-10-05	2020-11-04	0.07
0.36 (0.01-1.07)	R6	Nordland	2020-11-05	2020-12-14	0.05
0.97 (0.13-1.72)	R7	Nordland	2020-12-15	2021-01-03	0.48
0.55 (0.15-0.92)	R8	Nordland	2021-01-04	2021-02-04	0.01
1.5 (0.47-2.49)	R9	Nordland	2021-02-05	2021-02-19	0.83
1.03 (0.33-1.83)	R10	Nordland	2021-02-20	2021-03-08	0.52
0.75 (0.15-1.34)	R11	Nordland	2021-03-09		0.21
0.28 (0.13-0.42)	R1	Viken	2020-03-15	2020-04-19	0
0.84 (0.42-1.13)	R2	Viken	2020-04-20	2020-07-24	0.2
1.08 (0.98-1.17)	R3	Viken	2020-07-25	2020-10-09	0.92
1.46 (1.38-1.53)	R4	Viken	2020-10-10	2020-11-04	1
0.8 (0.72-0.88)	R5	Viken	2020-11-05	2020-11-30	0
0.94 (0.87-1.02)	R6	Viken	2020-12-01	2021-01-03	0.05
0.87 (0.73-0.97)	R7	Viken	2021-01-04	2021-02-04	0
1.13 (0.87-1.37)	R8	Viken	2021-02-05	2021-02-21	0.86
1.49 (1.28-1.77)	R9	Viken	2021-02-22	2021-03-08	1
1.17 (0.99-1.35)	R10	Viken	2021-03-09		0.96

Mean and 95% credible intervals

Table 18

R	Parameter	County	From	To	Pr(R>1)
0.5 (0.1-0.81)	R1	Innlandet	2020-03-15	2020-04-19	0
0.96 (0.71-1.18)	R2	Innlandet	2020-04-20	2020-07-24	0.42
0.83 (0.59-1.06)	R3	Innlandet	2020-07-25	2020-10-09	0.06
1.63 (1.06-2.15)	R4	Innlandet	2020-10-10	2020-10-24	0.98
0.53 (0.17-0.94)	R5	Innlandet	2020-10-25	2020-11-04	0.01
0.85 (0.41-1.11)	R6	Innlandet	2020-11-05	2020-12-14	0.18
0.65 (0.11-1.15)	R7	Innlandet	2020-12-15	2021-01-03	0.08
0.22 (0.03-0.44)	R8	Innlandet	2021-01-04	2021-02-21	0
0.72 (0.19-1.39)	R9	Innlandet	2021-02-22	2021-03-08	0.16
0.72 (0.11-1.34)	R10	Innlandet	2021-03-09		0.18
0.19 (0.07-0.33)	R1	Vestfold og Telemark	2020-03-15	2020-04-19	0
0.93 (0.5-1.24)	R2	Vestfold og Telemark	2020-04-20	2020-07-24	0.36
0.76 (0.48-0.99)	R3	Vestfold og Telemark	2020-07-25	2020-10-09	0.02
0.8 (0.49-1.08)	R4	Vestfold og Telemark	2020-10-10	2020-11-04	0.1
1.1 (0.33-1.69)	R5	Vestfold og Telemark	2020-11-05	2020-11-19	0.65
0.88 (0.66-1.09)	R6	Vestfold og Telemark	2020-11-20	2021-01-03	0.13
0.57 (0.27-0.85)	R7	Vestfold og Telemark	2021-01-04	2021-02-04	0
1.42 (0.87-2.07)	R8	Vestfold og Telemark	2021-02-05	2021-02-21	0.91
1.76 (1.23-2.24)	R9	Vestfold og Telemark	2021-02-22	2021-03-08	1
0.53 (0.13-1.02)	R10	Vestfold og Telemark	2021-03-09		0.03
0.36 (0.07-0.57)	R1	Agder	2020-03-15	2020-04-19	0
0.86 (0.41-1.27)	R2	Agder	2020-04-20	2020-07-31	0.29
0.76 (0.43-1.18)	R3	Agder	2020-08-01	2020-09-19	0.09
0.86 (0.38-1.28)	R4	Agder	2020-09-20	2020-10-09	0.28
0.87 (0.43-1.4)	R5	Agder	2020-10-10	2020-11-04	0.29
0.54 (0.16-0.89)	R6	Agder	2020-11-05	2021-01-03	0
0.81 (0.63-0.98)	R7	Agder	2021-01-04	2021-02-19	0.01
0.74 (0.15-1.31)	R8	Agder	2021-02-20	2021-03-08	0.2
0.93 (0.14-1.55)	R9	Agder	2021-03-09		0.44
0.4 (0.16-0.65)	R1	Vestland	2020-03-15	2020-04-19	0
0.79 (0.56-1.04)	R2	Vestland	2020-04-20	2020-07-24	0.05
1.38 (1.12-1.65)	R3	Vestland	2020-07-25	2020-09-04	1
0.95 (0.79-1.13)	R4	Vestland	2020-09-05	2020-10-09	0.29
1.67 (1.52-1.81)	R5	Vestland	2020-10-10	2020-11-04	1
0.4 (0.14-0.65)	R6	Vestland	2020-11-05	2020-11-30	0
0.51 (0.08-0.97)	R7	Vestland	2020-12-01	2021-01-03	0.02
0.79 (0.51-1.07)	R8	Vestland	2021-01-04	2021-02-04	0.08
0.74 (0.41-1.09)	R9	Vestland	2021-02-05	2021-03-08	0.06
1.86 (0.93-2.75)	R10	Vestland	2021-03-09		0.96
0.26 (0.04-0.53)	R1	Trøndelag	2020-03-15	2020-04-19	0
0.62 (0.28-0.98)	R2	Trøndelag	2020-04-20	2020-08-31	0.02
0.6 (0.21-1.07)	R3	Trøndelag	2020-09-01	2020-11-04	0.05
0.92 (0.25-1.51)	R4	Trøndelag	2020-11-05	2020-11-30	0.42
1.27 (0.93-1.56)	R5	Trøndelag	2020-12-01	2021-01-03	0.95
0.25 (0.06-0.44)	R6	Trøndelag	2021-01-04	2021-02-04	0
0.6 (0.12-1.04)	R7	Trøndelag	2021-02-05	2021-03-08	0.04
1.06 (0.18-1.94)	R8	Trøndelag	2021-03-09		0.58
0.16 (0.01-0.4)	R1	Troms og Finnmark	2020-03-15	2020-04-19	0
0.74 (0.1-1.21)	R2	Troms og Finnmark	2020-04-20	2020-09-14	0.27
0.76 (0.29-1.19)	R3	Troms og Finnmark	2020-09-15	2020-11-04	0.15
0.51 (0.05-1.24)	R4	Troms og Finnmark	2020-11-05	2020-11-30	0.06
0.41 (0.02-0.94)	R5	Troms og Finnmark	2020-12-01	2021-01-03	0.02
0.22 (0.02-0.54)	R6	Troms og Finnmark	2021-01-04	2021-02-04	0
0.93 (0.24-1.58)	R7	Troms og Finnmark	2021-02-05	2021-02-19	0.41
0.96 (0.18-1.8)	R8	Troms og Finnmark	2021-02-20	2021-03-08	0.44
0.41 (0.04-0.94)	R9	Troms og Finnmark	2021-03-09		0.01
1.26 (1.05-1.53)	AMP factor	All			-

Mean and 95% credible intervals

Table 19: Assumptions

Assumptions	Mean	Distribution	Reference
Mobile Mobility Data			
Telenor coverage	48%		https://ekomstatistikken.nkom.no/
Data updated	March 25th		
Data used in the predictions	March 26th	Fixed	Corrected to preserve population
Model parameters			
Exposed period ($1/\lambda_1$)	3 days	Exponential	Feretti et al 2020
Pre-symptomatic period ($1/\lambda_2$)	2 days	Exponential	Feretti et al 2020
Symptomatic infectious period ($1/\gamma$)	5 days	Exponential	Feretti et al 2020
Asymptomatic, infectious period ($1/\gamma$)	5 days	Exponential	Feretti et al 2020
Infectiousness asympt. (r_{I_a})	0.1	Fixed	Feretti et al 2020
Infectiousness presymp (r_{E_2})	1.25	Fixed	guided by Feretti et al 2020
Prob. asymptomatic infection (p_a)	0.4		Feretti et al 2020
Healthcare			
Fraction asymptomatic infections	40%	Fixed	Mizumoto et al 2020 20% for the old population, Diamond Princess
% symptomatic and asymptomatic infections requiring hospitalization: 0-9 years 10 - 19 years 20 - 29 years 30 - 39 years 40 - 49 years 50 - 59 years 60 - 69 years 70 - 79 years 80+ years	 0.1% 0.1% 0.5% 1.1% 1.4% 2.9% 5.8% 9.3% 22.3%	Fixed	Saljie et al 2020 corrected for: % of elderly living in elderly homes in Norway (last two age groups) and corrected for presence among positive tested since May 1.
Probability that an admission has been reported on Monday From Sunday From Saturday From Friday From Thursday	 32% 49% 68% 86%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Probability that an admission has been reported From one day before From two days before From three days before From four days before	 53% 77% 82% 91%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Probability that a positive laboratory test has been reported From one day before From two days before From three days before From four days before	 6.7% 59% 90% 97%	Fixed	Estimated from MSIS
Probability that a negative laboratory test has been reported From one day before From two days before From three days before From four days before	 16% 74% 92% 98%	Fixed	Estimated from MSIS

Supplementary analysis: EpiEstim estimation of reproduction number based on laboratory-confirmed cases

To complement the results of the metapopulation model, we present estimates of the temporal evolution of the reproduction number in Norway based on an analysis of laboratory-confirmed cases. The primary purpose of this analysis is to provide a more comprehensive perspective on the epidemic situation, taking into account several data sources.
The hospitalisation data are a less biased information source for the number of infections compared to case data because the testing criteria in Norway has changed. For this reason, the present results should be interpreted with caution. During the early part of the period, testing of individuals was mainly based on travel history to areas with an ongoing outbreak. Since the middle of March, testing is recommended for people with an acute respiratory infection. From early May, the testing criteria have been expanded to include less severe symptoms. The analysis of laboratory-confirmed cases does not take into account the effect of imported cases during the early outbreak in Norway; the early results are less reliable than later results when the impact of importations is negligible.

EpiEstim method and assumptions: We estimate the instantaneous reproduction number using the procedure outlined in Thompson et al. (2019). This method, implemented in the EpiEstim R-package, uses a Bayesian approach to estimate the instantaneous reproduction number smoothed over a sliding window of 5 days, see figure 34. For the results to be comparable to those of the metapopulation model, we use the same natural history parameters. We estimate the date of infection for each confirmed case by first estimating the date of symptom onset and then subtracting 5 days for the incubation period. We estimate the date of symptom onset from the empirical delay between onset and testing in the first reported cases. For each case, we draw 100 possible onset dates from the delay distribution; this gives us 100 epi-curves that we use to estimate the reproduction number. The displayed results are the combined results from all these 100 simulated epi-curves. The serial interval was assumed to be 5 days with uncertainty; the serial interval refers to the time between symptom onset between successive cases in a chain of transmission (see https://www.medrxiv.org/content/10.1101/2020.02.03.20019497v2). To account for censoring of observations with onset dates in the last few days we correct the observed data by the mean of a negative binomial distribution with observation probability given by the empirical cumulative distribution of the onset to reporting date distributions. Due to this correction, the results from the last few days are uncertain, as indicated by increasing credible intervals.

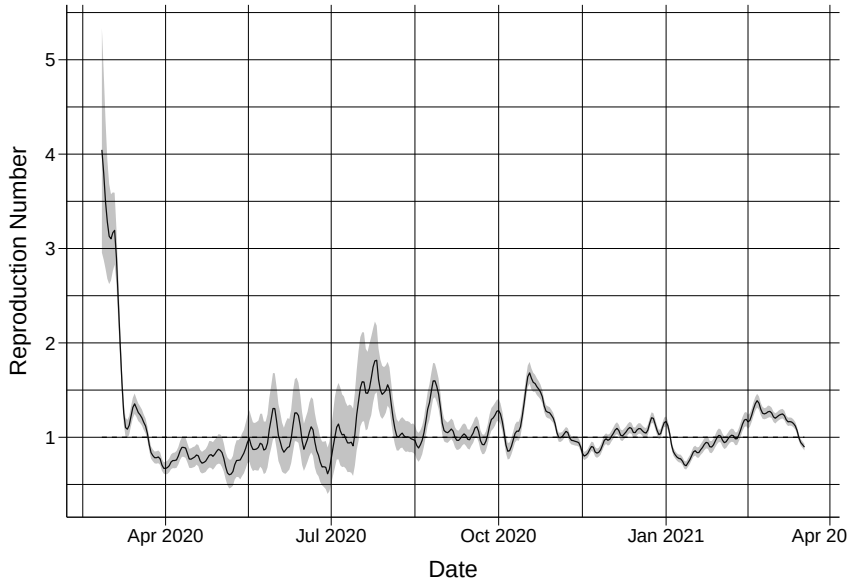


Figure 34: Reproduction number estimated using the R package EpiEstim.

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