NIPH
Norwegian Institute of Public Health

Situational awareness and forecasting for Norway

FHI COVID-19 modelling team

Week 14, 14 April 2021

Highlights:

- **National epidemiological situation:** Our models indicate that the reproduction number has stabilised below 1, being 0.84 (median, 95% CI 0.7-0.97) from 25 March until 11 April. The estimated probability that R is larger than 1 is 1.5%. The estimated reproduction number between 2 March and 24 March is 1.1 [1.01-1.17], which shows a significant decrease due to the interventions in March. The SMC model estimates the 7-days averaged effective reproduction number during week 13 to be 0.76 (mean, 95% CI 0.56-1.01). In the SMC model, the estimated probability that the daily reproduction number one week ago was above 1 is 2.8%. There is a good agreement between the two models. In the present situation, the number of new cases and new hospital admissions are expected to decrease in the next three weeks.

  Since the start of the epidemic, we estimate that in total, 190.000 (95% CI 165.000- 216.000) individuals in Norway have been infected (between 3% and 4% of the total population). The current estimate of the detection probability is around ∼60%.

- **Changes introduced this week: updated times in hospital.** We have re-estimated the length of stay in hospital and found in particular differences between the Oslo hospitals and the rest of the country from the beginning of 2021. We give separate estimates until February and from March. See figures 32-35. For example, Oslo has a shorter time between the onset of symptoms and hospitalisation.

- **National forecasting:** In one week, on 18 April, we estimate ca 900 new cases per day (median; 95% CI 500-1350), and a prevalence (total number of presently infected individuals in Norway) of 6.000 (median; 95% CI 4.000-8.000). The number of COVID-19 patients in hospital (daily prevalence) on 18 April is estimated to be 260 (median 95% CI 200-320), and the number of patients on ventilator treatment is estimated to be 60 (median 95% CI 43-76); the corresponding predictions in three weeks (2 May) are 220 (95% CI 150 - 300) and 50 (95% CI 30 - 70).
  We have this week implemented a seasonal effect of 20% or 50% with a smoothed transition (was 20% in June, July and August last week). Long-term predictions show that a slow gradual reopening is possible during the coming month, and faster from late July. A higher level of reopening is possible assuming a high seasonality effect of 50%. The probability that the surge capacity will exceed 500 ventilator beds is now estimated to be 0% because of vaccination.

- **Regional epidemiological situation and forecasting:** The estimated reproduction number in Oslo since March 17 is 0.97 (CI 0.82-1.12). Between March 2 and March 16 it is estimated to be 1.36 (1.17-1.55), which confirms the reduction of transmissibility in Oslo following the March interventions. In Viken, we estimate the reproduction number since March 24 to be 0.89 (0.72-1.07). The estimated reproduction number in Viken between 22 February and 23 March was 1.35 (1.26-1.44). All other estimated effective reproduction numbers are estimated since March 24. There is very much uncertainty in our estimates for Møre og Romsdal, Trøndelag and Vestland. We obtain an estimate above 1 but with a 95% confidence interval which is too broad to make the estimate useful. All other counties appear to have a reproduction number most likely below 1.

Oslo: The number of new cases per day is estimated to be about 250 (mean, 95% CI 150 -400) on 18 April and on 2 May to be 200 (95% CI 100-400). Hospital prevalence in one week is estimated to be 71 (median; 95% CI 46-101), and in three weeks it will be 60 (median; 95% CI 35-98). The situation is slowly improving.

Change introduced this week: EpiEstim-based estimates of daily reproduction number per county. Remember that EpiEstim uses only test data (not hospital data) and is, in principle, unable to distinguish changes due to transmission rates from testing power. However, as in this period, testing appears rather stable, results are of interest and are compatible with the estimates obtained by our other model, except for Agder, whose reproduction number is estimated to be above 1.

- **Telenor mobility data, local mobility and foreign visitors:** Inter-municipality mobility, measured as outgoing mobility of mobile phones from each municipality, has increased in several counties during the Easter break, but appears back to the level before the break. Particular increases of mobility have been registered in Troms og Finnmark, Viken, Trøndelag and Innlandet. The number of foreign visitors to Norway continues to decrease slowly since the start of the year, but remains at a rather 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. We use a metapopulation model (MPM) for situational awareness and short-term forecasting and an individual-based model (IBM) for long-term predictions. The metapopulation model (MPM) 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 MPM 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. 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 the national changepoint model results 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 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 multiple times 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 associated with the hospitalisation timing 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 following new evidence and local data as they become available. A complete list of all updates can be found 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).

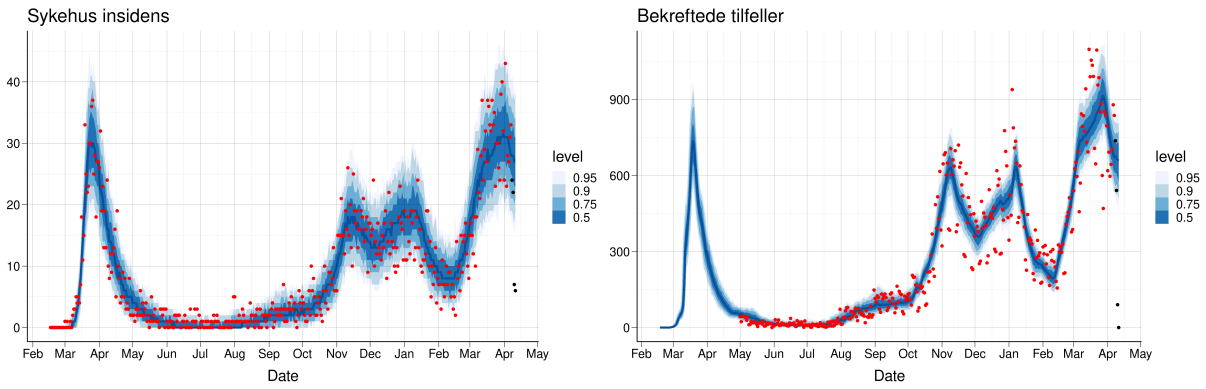
1 Estimated national reproduction numbers

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
3.27/3.26(2.44-4.15)	From Feb 17 to Mar 14
0.5/0.51(0.42-0.61)	From Mar 15 to Apr 19
0.76/0.75(0.38-1.09)	From Apr 20 to May 10
0.66/0.64(0.24-1.02)	From May 11 to Jun 30
1.06/1.02(0.32-1.61)	From Jul 01 to Jul 31
1.01/1.04(0.75-1.42)	From Aug 01 to Aug 31
0.95/0.95(0.76-1.12)	From Sep 01 to Sep 30
1.25/1.25(1.07-1.42)	From Oct 01 to Oct 25
1.29/1.31(1.04-1.6)	From Oct 26 to Nov 04
0.81/0.81(0.74-0.87)	From Nov 05 to Nov 30
1.07/1.07(1.03-1.12)	From Dec 01 to Jan 03
0.62/0.62(0.48-0.73)	From Jan 04 to Jan 21
0.79/0.79(0.64-0.97)	From Jan 22 to Feb 07
1.48/1.48(1.36-1.62)	From Feb 08 to Mar 01
1.09/1.09(1.01-1.17)	From Mar 02 to Mar 24
0.84/0.84(0.7-0.97)	From Mar 25

Median/Mean (95% credible intervals)

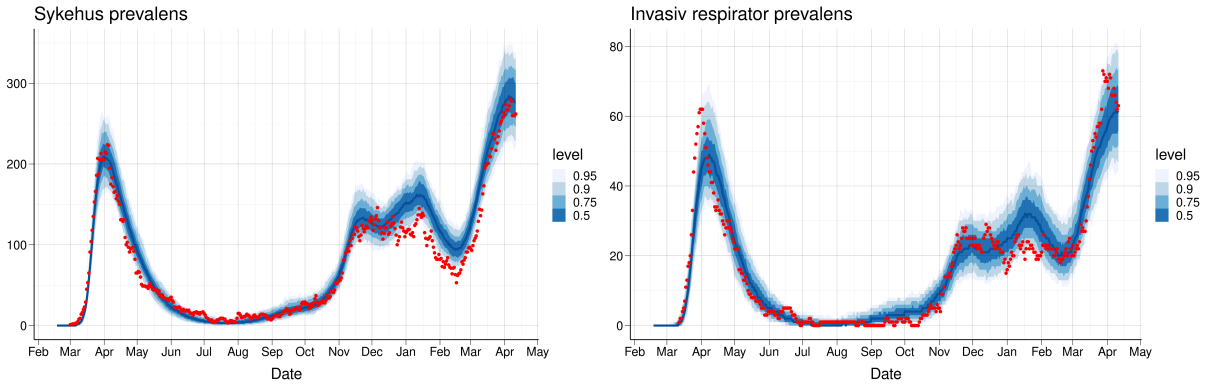


(a) Hospital admissions

(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

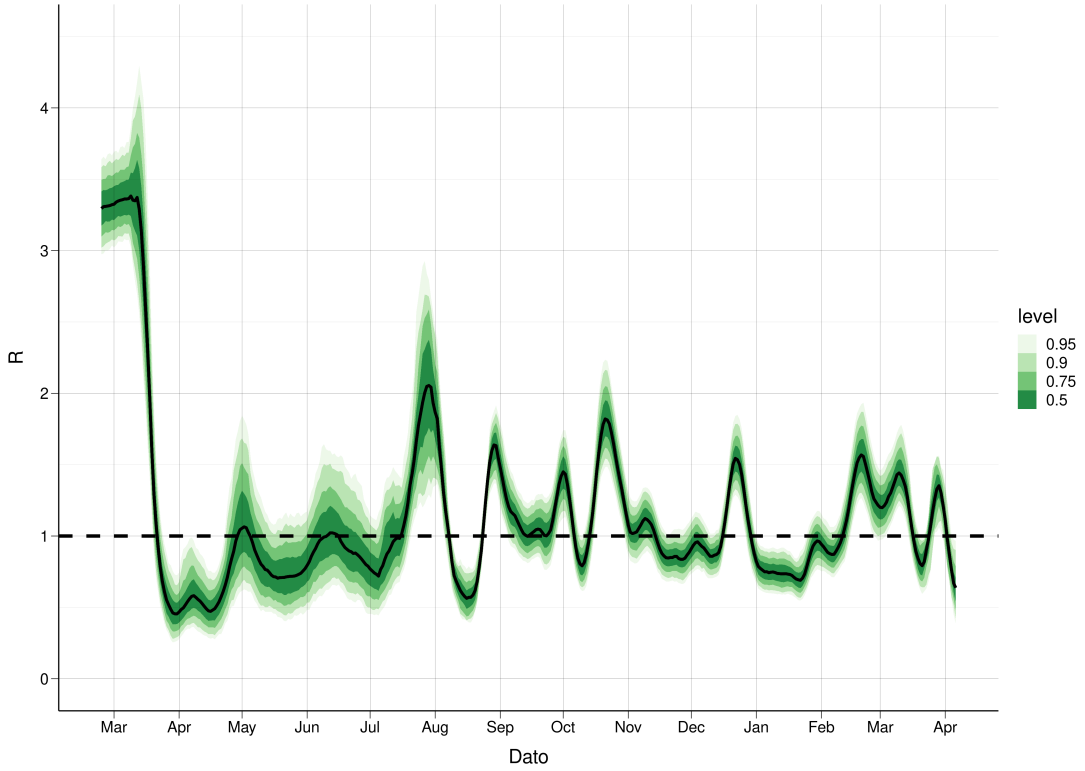


Figure 3: R(t) estimates using a Sequential Monte Carlo approach calibrated to hospitalisation incidence and test data. The large uncertainty during the last 7 days reflects the lack of available data due to the transmission delay, test delay, time between symptoms onset and hospitalisation. The green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

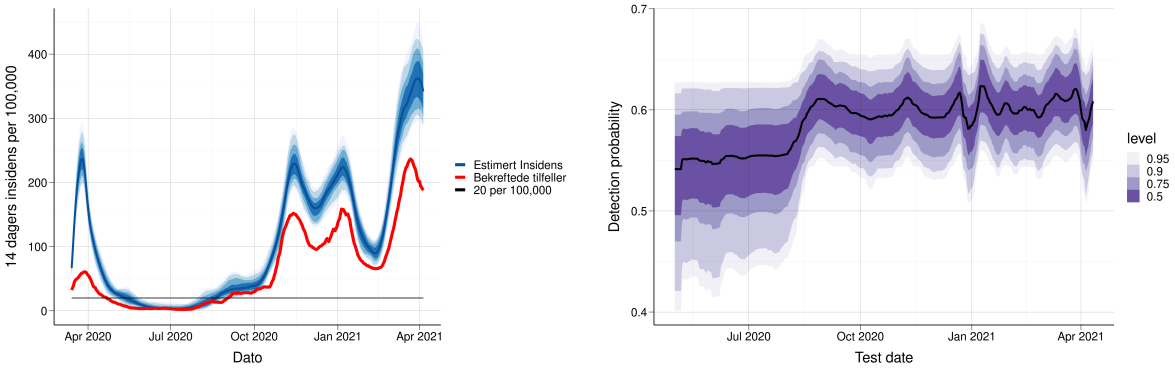
2 National estimate of cumulative (total) number of infections

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, 2021-04-11

Region	Total	No. confirmed	Fraction reported	Min. fraction
Norway	189701 (164508; 216081)	103620	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 18)	2 week prediction (Apr 25)	3 week prediction (May 02)
Prevalence	6021/5968 (3995-8284)	5267/5110 (3094-8132)	4630/4434 (2333-7951)
Daily incidence	900/879 (538-1342)	790/754 (436-1272)	697/672 (315-1288)
Hospital beds	264/262 (204-324)	241/237 (178-315)	220/216 (153-307)
Ventilator beds	60/59 (43-76)	55/55 (38-75)	50/51 (32-70)

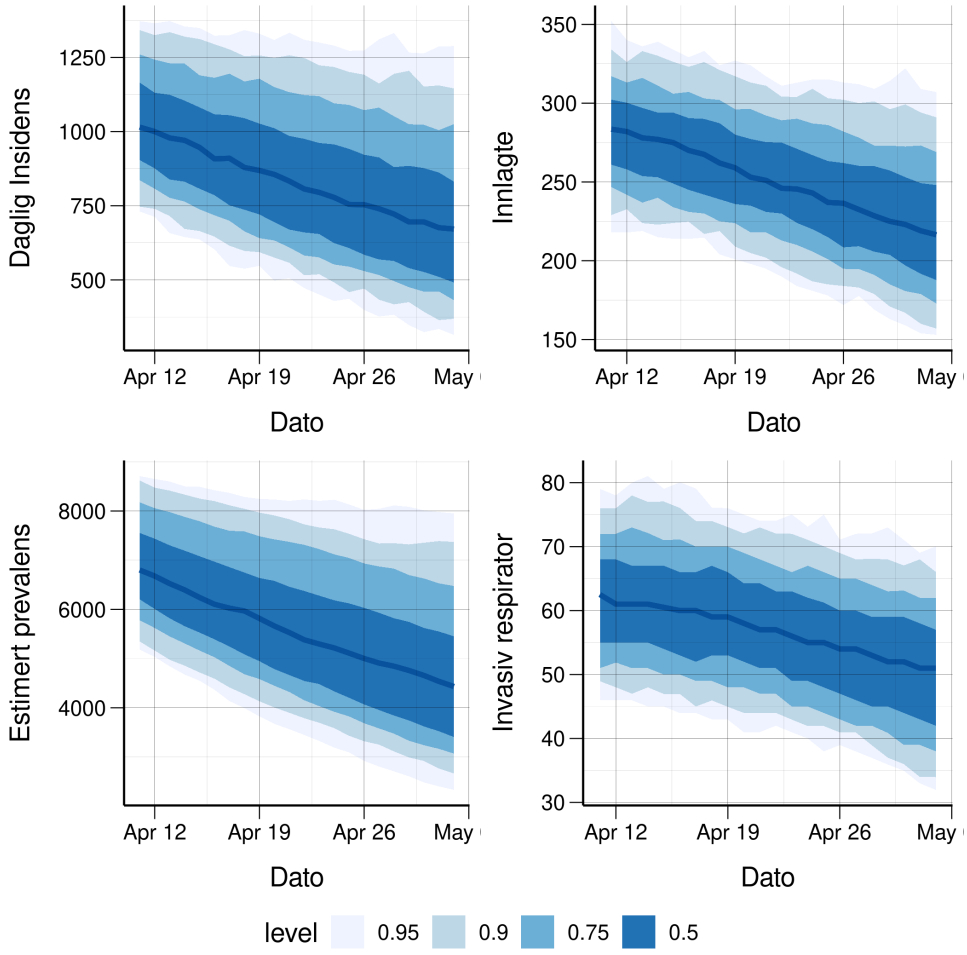


Figure 5: National 3 week predictions for incidence (top left), prevalence (bottom left), hospital beds (top right) and ventilator beds (bottom right)

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 including the vaccines from Pfizer, Moderna and Janssen, which are currently in the program. We present results with and without a seasonal effect. The seasonal effect is implemented by varying the transmission rate in accordance with the mean daily temperature for Norway; the transmission rate varying by by up to 20% or 50% between the coldest and warmest day during the year.
We use data from the Norwegian Immunisation Registry (SYSVAK) on the number of vaccinations carried out up to 12 April 2021. Vaccine deliveries in the future are based on the Norwegian Institute of Public Health's realistic ("nøktern") scenario, updated 2 April 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.

4.1 Scenarios and how to interpret them

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 modelled outcomes of a specific set of assumptions about the epidemic and how the government and local authorities are assumed to act. We present results from two different 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. We also have a middle threshold of 125 hospital admissions nationally. If the prevalence of hospital admissions is between 50 and 125, we update the reproduction number to 1.05; while if the prevalence of hospital admissions is between 125 and 200, we update the reproduction number to 1.0. The number of hospital admissions is evaluated every three weeks to simulate a gradual reopening or closing, 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) 70%; VE sev (1. and 2. dose) 80%. For the mRNA

vaccines: VE asymp (1. and 2. dose) 70%, 90%; VE symp (1. and 2. dose) 70%, 90%; VE sev (1. and 2. dose) 80%, 94%. People who are vaccinated and get infected are assumed to transmit 40% less than those who are not vaccinated.

- We assume the following number of importations per months: April and May 750; June 1125; July 800; August 500; September 200; October 150; November 100; December 200; January through March 2022 100; the values are identical to assumptions made in modelling reports for Oppdrag 346/8 vaccination.
- 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 waning immunity after infection or vaccination is assumed.
- We assume that the vaccines are effective against all circulating variants.

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, to be published shortly.

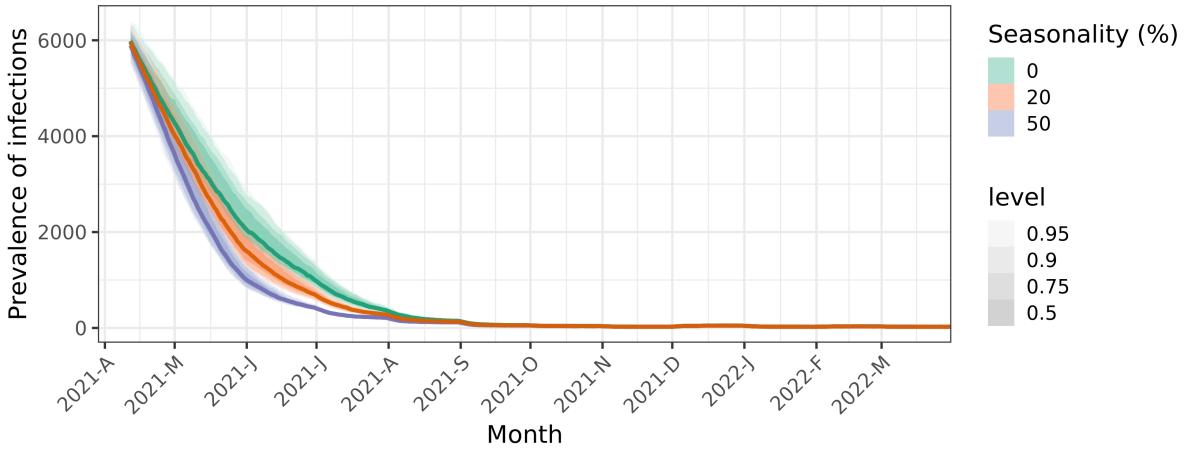
4.2 Constant Scenario

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).

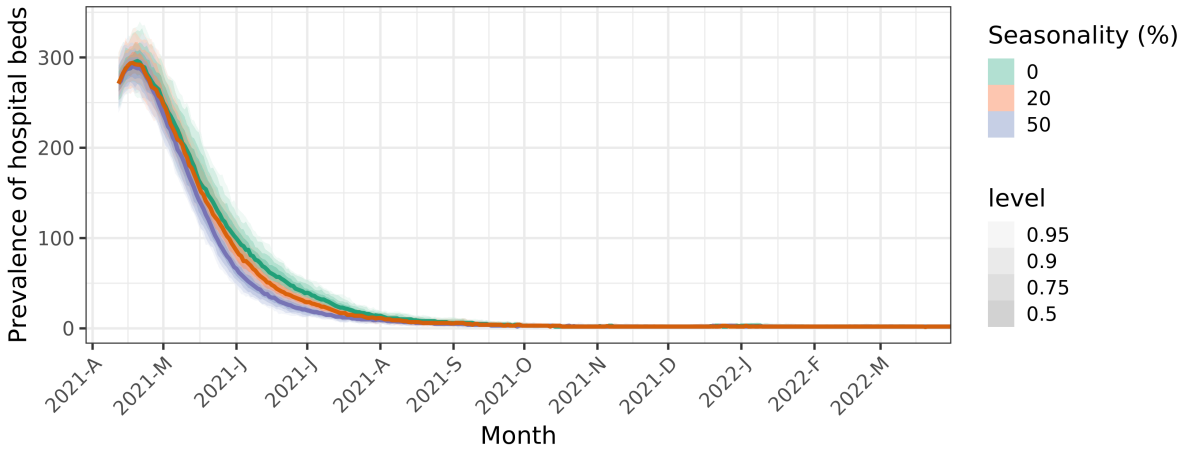
Table 4: Estimated peak prevalence of infections, hospitalisations and ventilator beds and total infections, admissions and ventilator treatments until 31 March 2022

Total	Without seasonality	20% seasonality	50% seasonality
Infections	61647 (55514-67780)	54760 (50116-59403)	46925 (43689-50161)
Hospitalisations	2067 (1900-2234)	1919 (1785-2053)	1740 (1636-1843)
Ventilator treatments	173 (156-190)	162 (146-179)	149 (136-163)

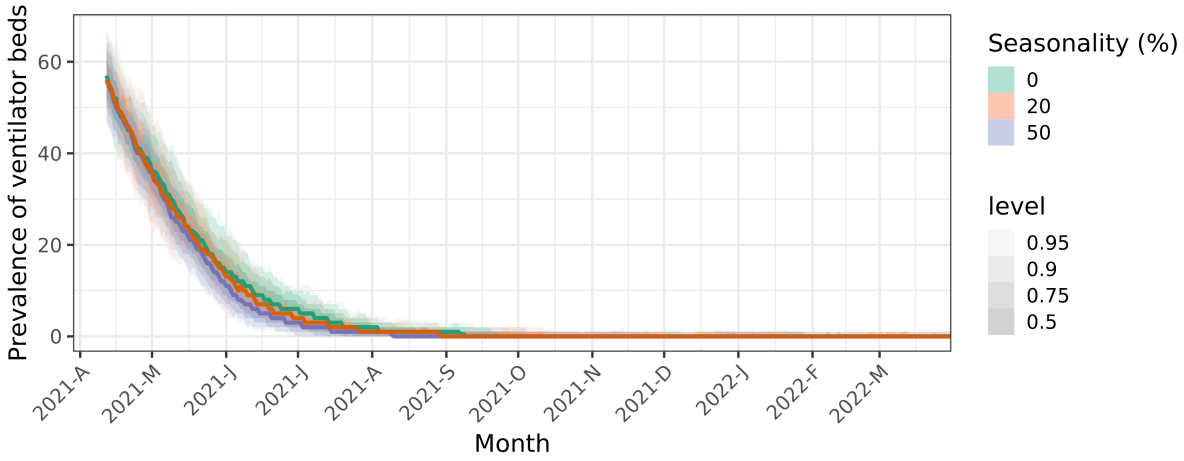
Given the current epidemiological situation and assuming no change in the interventions or seasonal effects, the epidemic is decreasing. None of the scenarios exceed a surge capacity need of **500 ICU** ventilator beds (Table 4).



(a)



(b)



(c)

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

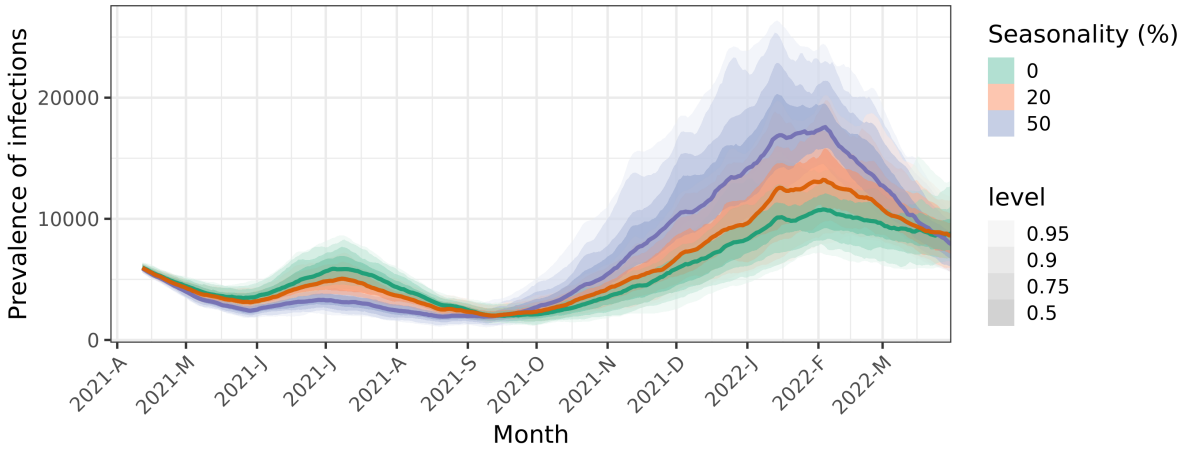
4.3 Controlled Scenario

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 manifest itself 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.

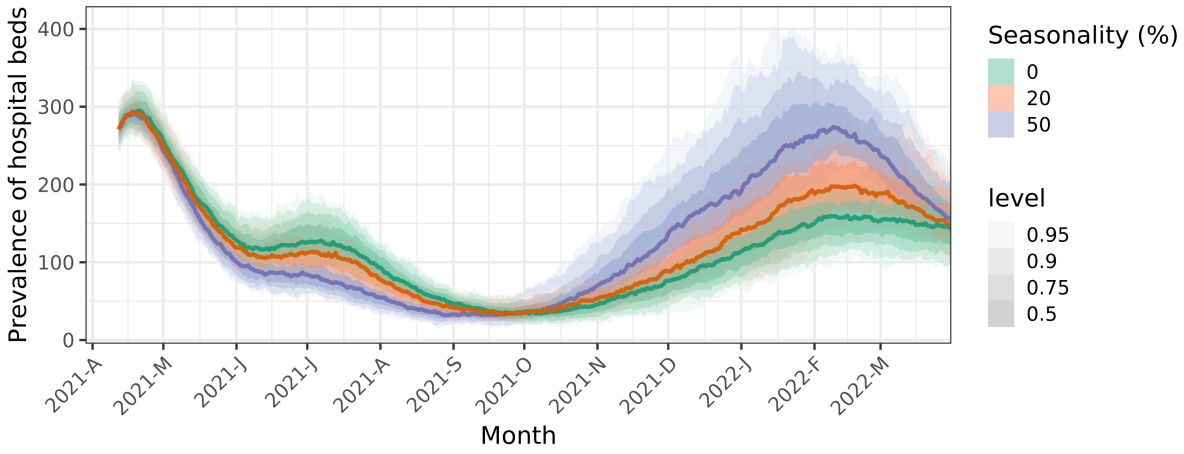
Table 5: Estimated total number of infections, hospitalisations and ventilator beds until 31 March 2022

Total	With seasonality	20% seasonality	50% seasonality
Infections	396017 (354914-437121)	426514 (378255-474773)	492927 (429992-555862)
Hospitalisations	6105 (5587-6622)	6412 (5797-7027)	7125 (6318-7932)
Ventilator treatments	444 (405-483)	468 (423-514)	525 (465-585)

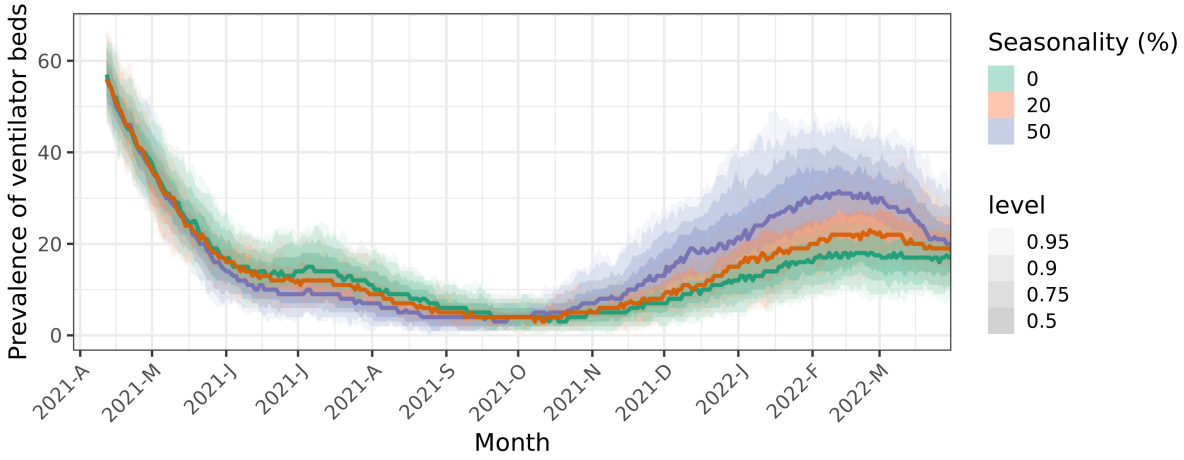
Table 5 shows that, in a controlled scenario with hospital admissions as steering parameter, there is a small difference in the expected infections and admissions regardless of the vaccines used. Figure 8 indicates that a slow gradual reopening is possible the coming months. In the scenario assuming a high seasonal effect (50%), a faster reopening is possible reaching normal levels in September; however, the model suggests that it will be necessary to implement measures to limit the contact during the autumn and winter. With a low seasonal effect (20%) or no seasonal effect, the reopening will be shifted around a month later and with a lower level of reopening. The reduced contact rate in the last part (January to March) is likely due to time-delay in the response. The hospital level is delayed with respect to the infection incidence curve.(Figure 7).



(a)



(b)



(c)

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

4.3 *Controlled Scenario*

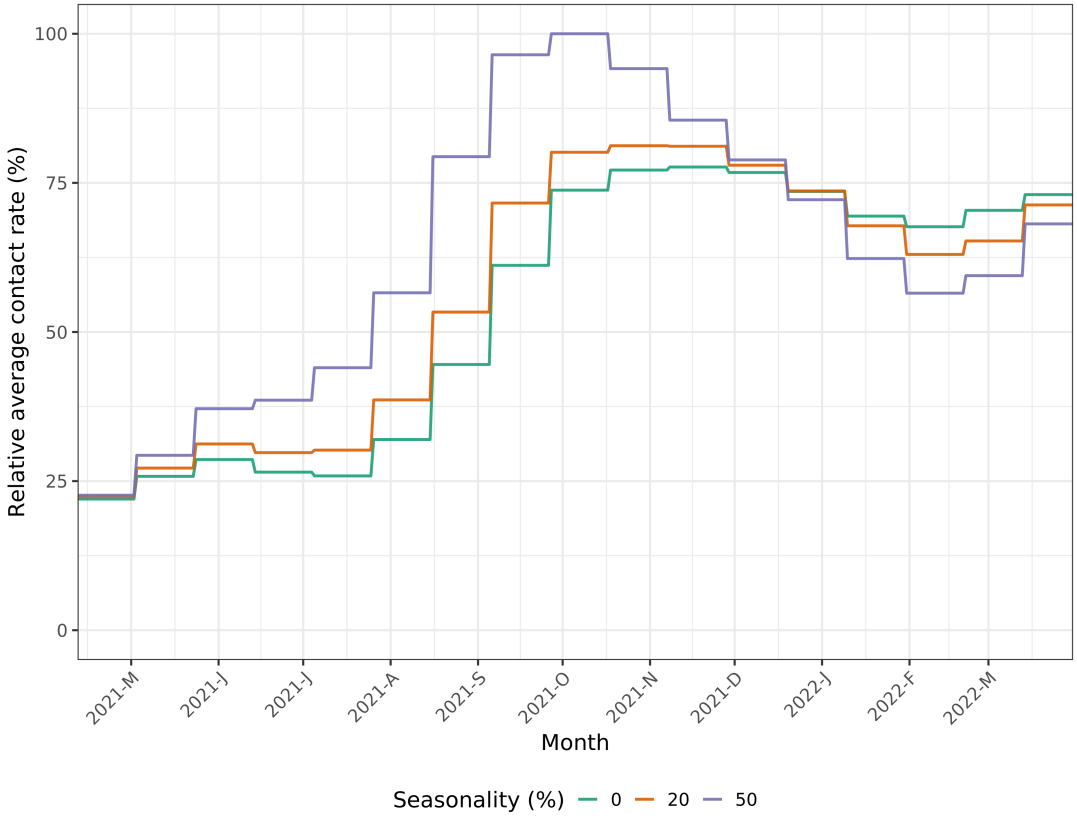


Figure 8: Relative average national contact rate compared to a fully open society in a controlled scenario, with and without assumptions of a seasonal effect during the summer month. Simulations are made with vaccines from Pfizer, Moderna and Janssen, assuming the modest ("Nøktern") vaccine delivery schedule. 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 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)
0.97 (0.82-1.12)	R11	Oslo	2021-03-17	0.36
0.67 (0.15-1.22)	R9	Rogaland	2021-03-24	0.1
1.01 (0.13-2.04)	R8	Møre og Romsdal	2021-03-24	0.47
0.53 (0.03-1.29)	R11	Nordland	2021-03-24	0.11
0.89 (0.72-1.07)	R10	Viken	2021-03-24	0.13
0.39 (0.08-0.66)	R10	Innlandet	2021-03-24	0
0.42 (0.07-0.8)	R10	Vestfold og Telemark	2021-03-24	0
0.51 (0.04-1.27)	R9	Agder	2021-03-24	0.08
1.4 (0.53-2.42)	R10	Vestland	2021-03-24	0.79
1.31 (0.15-2.71)	R8	Trøndelag	2021-03-24	0.65
0.71 (0.08-1.5)	R9	Troms og Finnmark	2021-03-24	0.22

Mean and 95% credible intervals

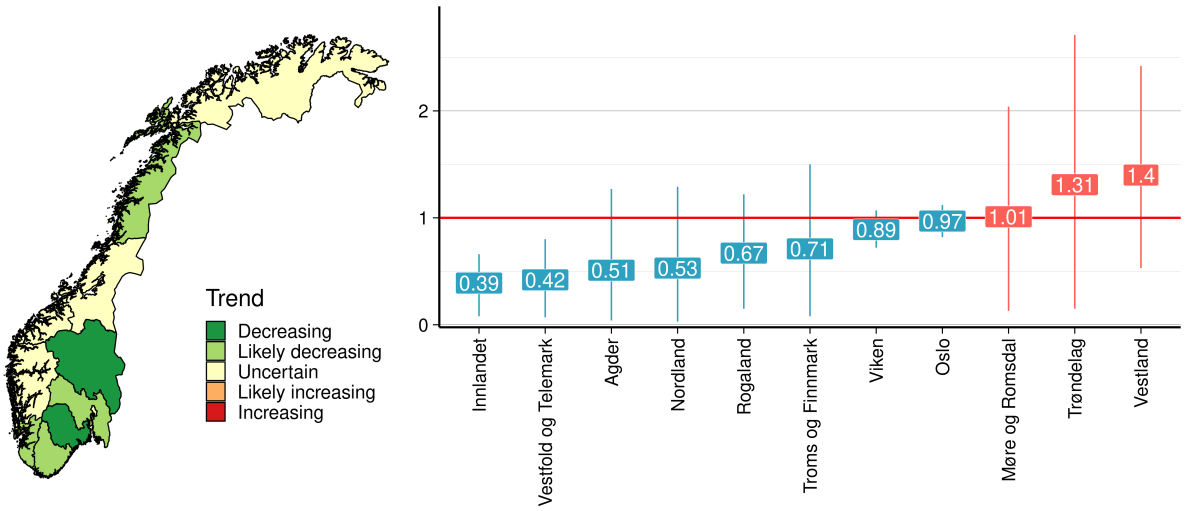
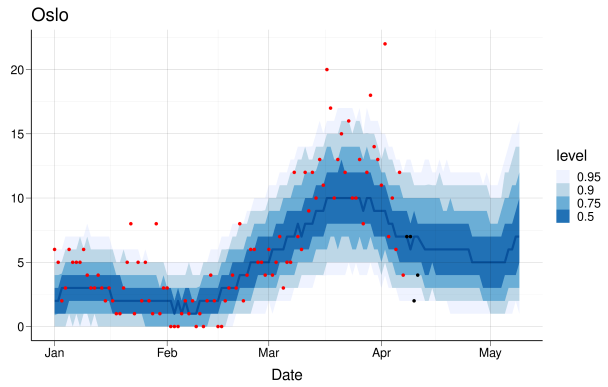
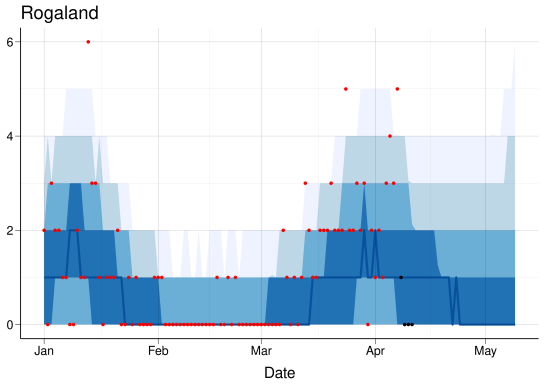
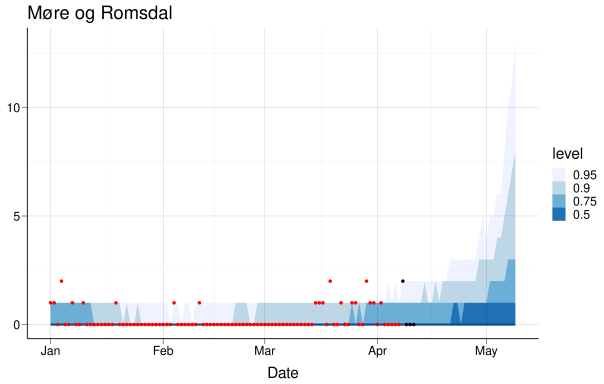


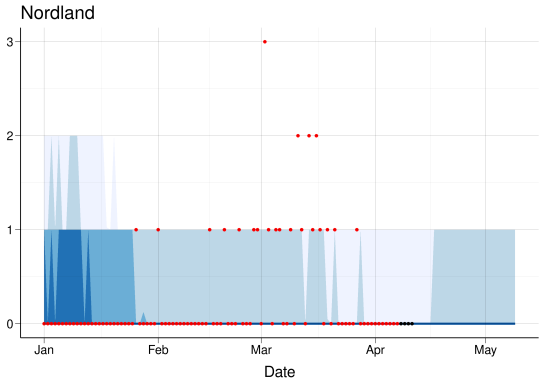
Figure 9: The map shows the direction of the trend in incidence in the counties based on the latest reproduction numbers shown in the other chart. The trend is increasing if the probability that the latest reproduction number is above one is above 95%, the trend is likely increasing if this probability 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%.

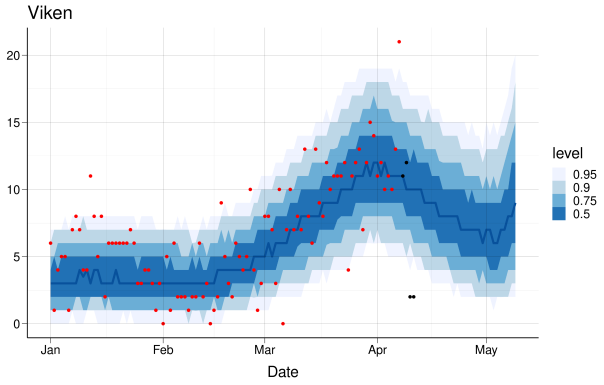
Estimated vs observed hospital incidence and 3 weeks forecast by county:

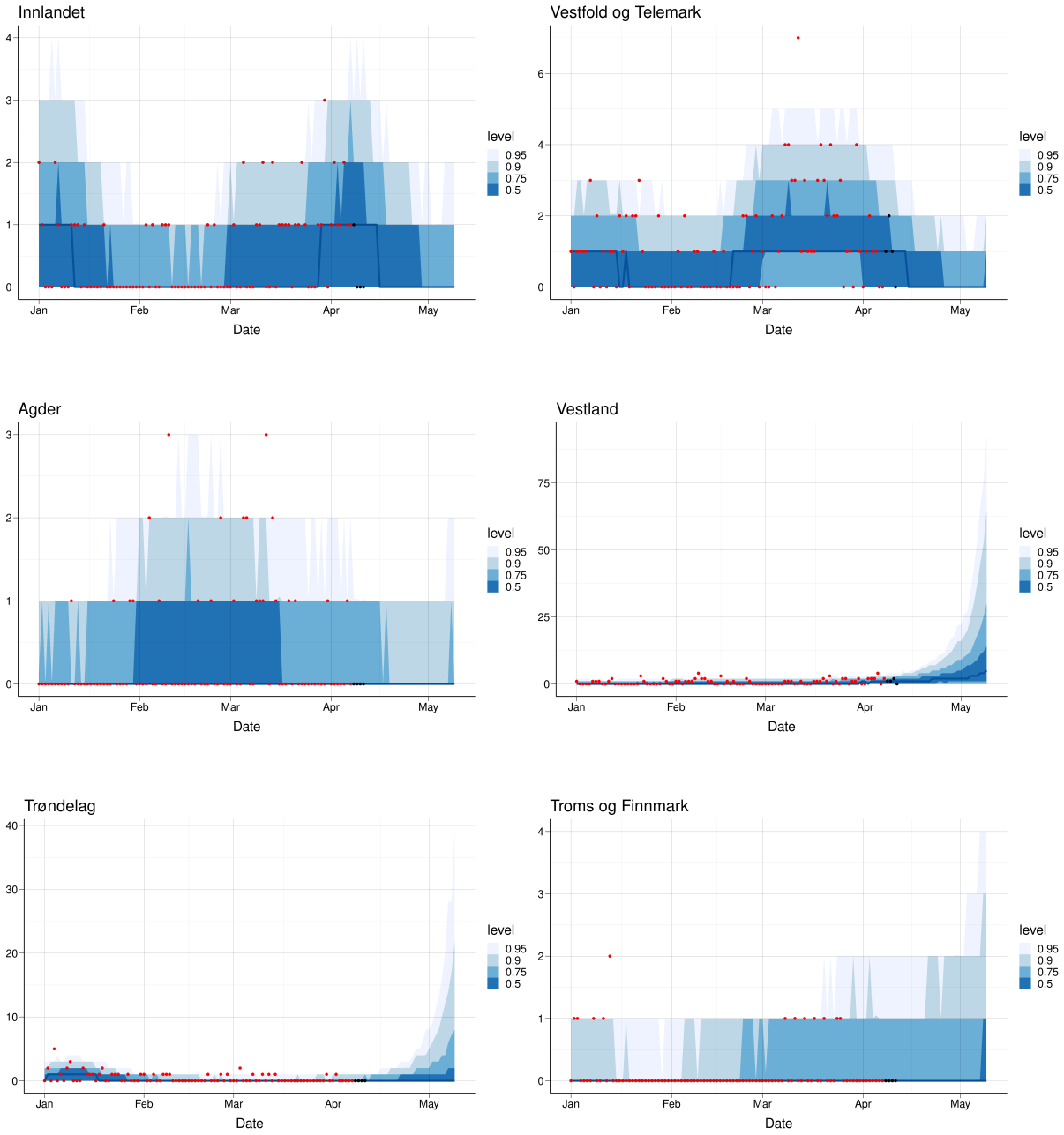




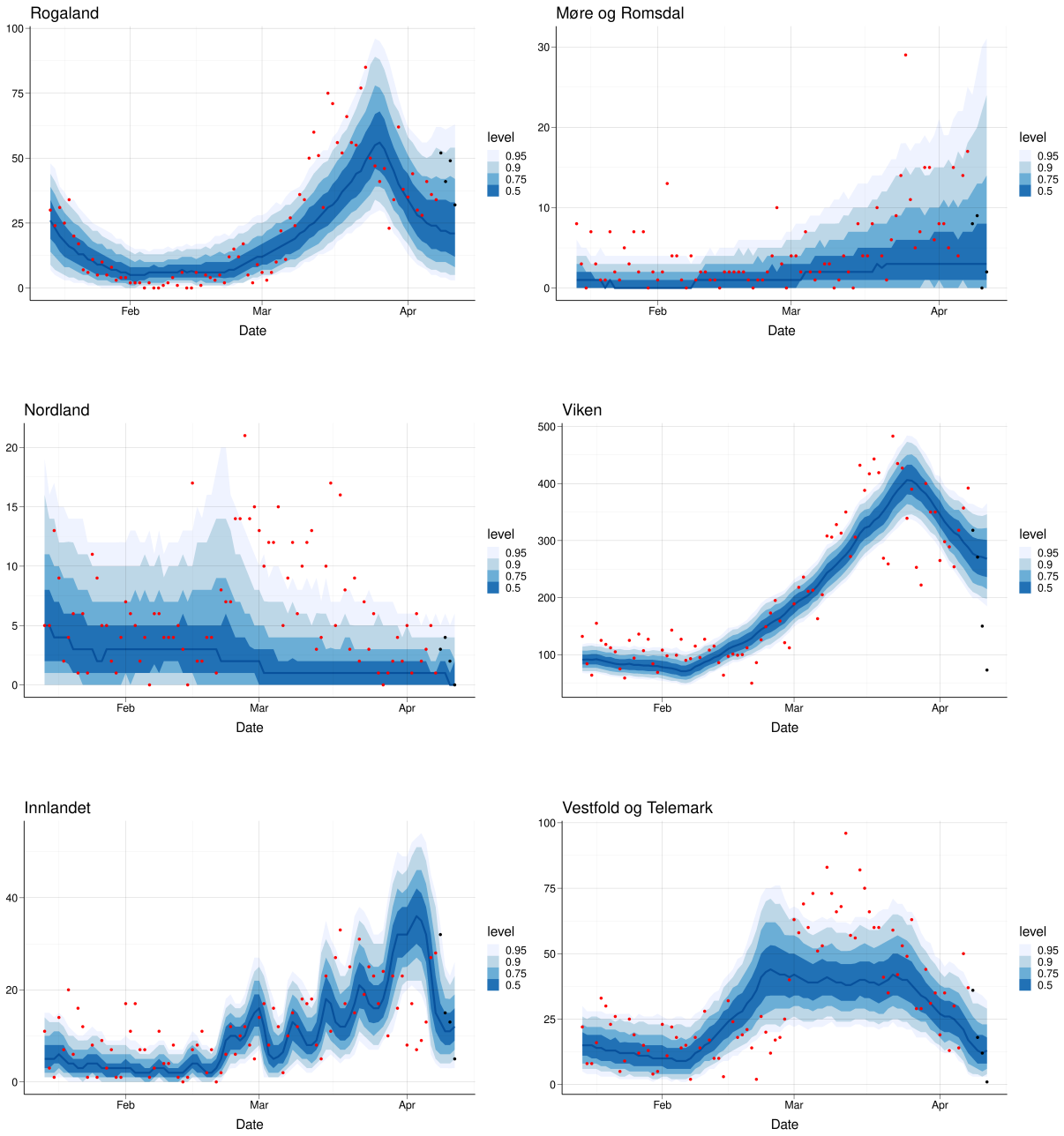


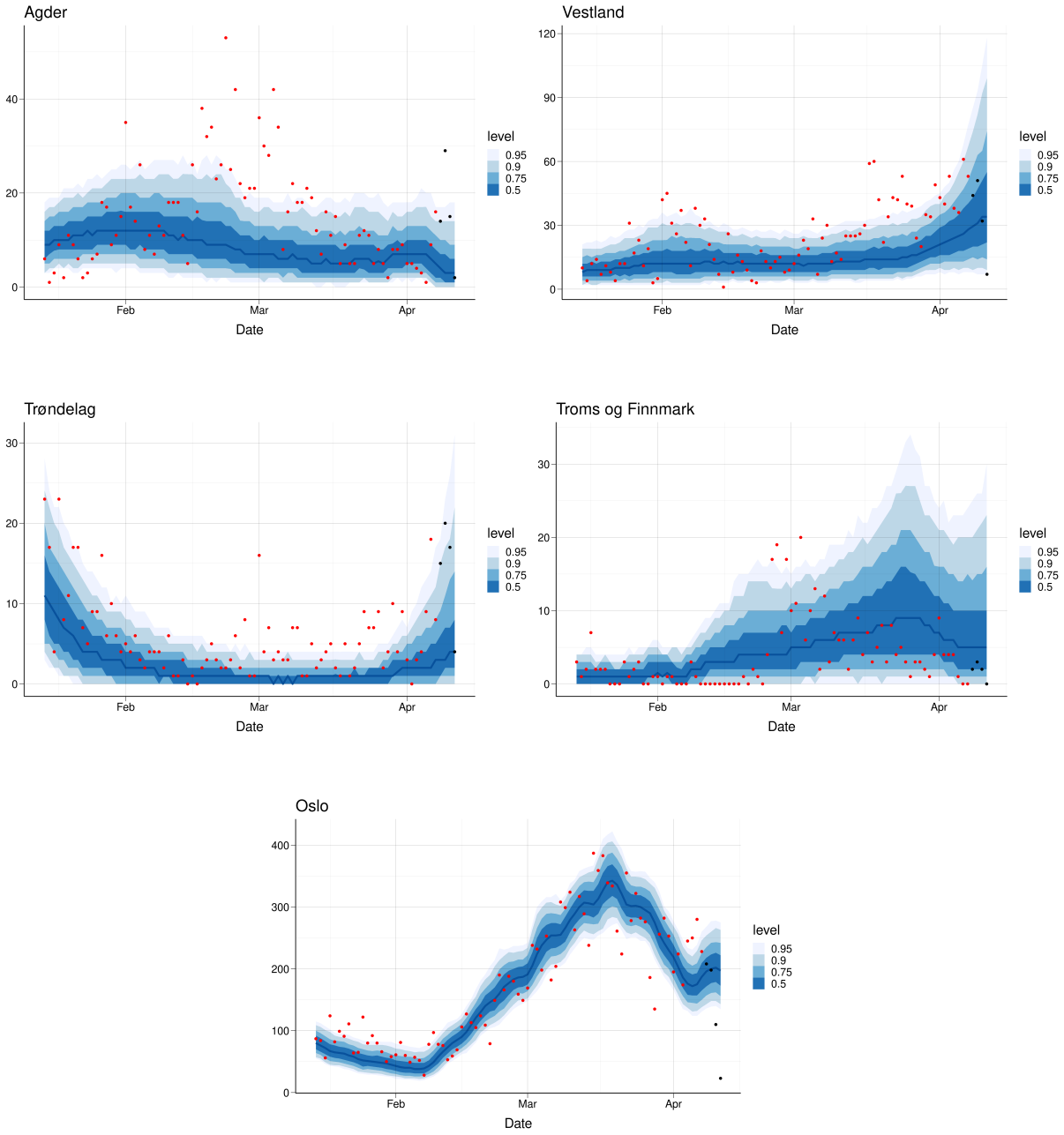





Innlandet
Vestfold og Telemark
Agder
Vestland
Trøndelag
Troms og Finnmark
level
0.95
0.9
0.75
0.5
Jan
Feb
Mar
Apr
May
Date

Estimated and observed lab-confirmed test data by county:




Agder
Vestland
Trøndelag
Troms og Finnmark
Oslo
level
0.95
0.9
0.75
0.5
Feb
Mar
Apr
Date

6 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 from 2021-02-01 until 2021-04-11

Region	Total	No. confirmed	Fraction reported	Min. fraction
Oslo	20498 (17756; 23374)	13403	65%	57%
Rogaland	2342 (1390; 3570)	1847	79%	52%
Møre og Romsdal	306 (56; 1014)	349	114%	34%
Nordland	249 (73; 766)	450	181%	59%
Viken	24082 (21258; 26901)	16027	67%	60%
Innlandet	1338 (993; 1789)	896	67%	50%
Vestfold og Telemark	3226 (2289; 4479)	2537	79%	57%
Agder	871 (399; 1637)	1169	134%	71%
Vestland	1808 (964; 3086)	1916	106%	62%
Trøndelag	190 (61; 525)	337	177%	64%
Troms og Finnmark	657 (124; 1395)	291	44%	21%

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 (18 Apr)	2 weeks prediction (25 Apr)	3 weeks prediction (02 May)
Agder	3/6 (0-31)	2/6 (0-38)	1/7 (0-44)
Innlandet	11/12 (3-28)	7/8 (1-21)	5/6 (0-16)
Møre og Romsdal	6/16 (0-86)	6/24 (0-151)	7/42 (0-266)
Nordland	2/3 (0-13)	1/3 (0-14)	1/3 (0-17)
Oslo	266/268 (162-407)	238/244 (129-405)	213/222 (103-391)
Rogaland	24/32 (2-111)	18/29 (1-122)	15/29 (1-146)
Troms og Finnmark	7/13 (0-52)	6/13 (0-74)	5/15 (0-97)
Trøndelag	8/21 (0-126)	11/45 (0-322)	15/107 (0-883)
Vestfold og Telemark	9/12 (1-36)	6/9 (1-32)	5/8 (1-27)
Vestland	78/113 (8-435)	101/200 (5-1043)	134/370 (5-2263)
Viken	337/342 (201-530)	298/307 (157-528)	261/276 (118-518)

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	18 Apr	25 Apr	02 May	low CI, 02 May	high CI, 02 May
Agder	22/40	15/38	14/42	2	245
Innlandet	92/97	57/62	38/44	12	112
Møre og Romsdal	36/82	36/125	37/208	2	1380
Nordland	17/23	13/20	12/22	2	91
Oslo	1732/1749	1561/1591	1396/1447	722	2435
Rogaland	180/219	131/191	97/176	10	859
Troms og Finnmark	53/80	41/80	33/89	2	523
Trøndelag	43/97	58/209	79/482	3	3797
Vestfold og Telemark	77/92	48/64	33/48	7	189
Vestland	417/570	543/980	734/1793	38	10361
Viken	2246/2261	1978/2019	1748/1816	869	3224

7 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 (18 Apr)	2 weeks prediction (25 Apr)	3 weeks prediction (02 May)
Agder	1/2 (0-7)	1/2 (0-7)	1/1 (0-7)
Innlandet	6/7 (1-16)	5/6 (1-13)	4/4 (0-11)
Møre og Romsdal	1/2 (0-10)	1/3 (0-16)	1/4 (0-24)
Nordland	0/0 (0-3)	0/1 (0-3)	0/1 (0-3)
Oslo	71/72 (46-101)	66/67 (41-98)	60/62 (35-98)
Rogaland	9/11 (2-25)	8/10 (1-26)	6/9 (1-27)
Troms og Finnmark	1/2 (0-10)	1/3 (0-12)	1/3 (0-13)
Trøndelag	1/1 (0-6)	1/3 (0-15)	1/6 (0-38)
Vestfold og Telemark	8/9 (2-20)	6/7 (1-16)	4/5 (0-13)
Vestland	10/11 (1-28)	13/16 (1-53)	16/27 (1-121)
Viken	91/91 (62-123)	83/83 (54-118)	75/76 (43-114)

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

Region	1 week prediction (18 Apr)	2 weeks prediction (25 Apr)	3 weeks prediction (02 May)
Agder	0/0 (0-2)	0/0 (0-2)	0/0 (0-2)
Innlandet	1/2 (0-5)	1/1 (0-4)	1/1 (0-4)
Møre og Romsdal	0/0 (0-2)	0/0 (0-3)	0/1 (0-4)
Nordland	0/0 (0-1)	0/0 (0-1)	0/0 (0-1)
Oslo	17/17 (9-26)	16/16 (8-25)	14/15 (7-25)
Rogaland	2/3 (0-6)	2/2 (0-7)	1/2 (0-6)
Troms og Finnmark	0/0 (0-3)	0/1 (0-3)	0/1 (0-3)
Trøndelag	0/0 (0-1)	0/0 (0-2)	0/1 (0-5)
Vestfold og Telemark	2/2 (0-6)	1/2 (0-5)	1/1 (0-4)
Vestland	2/2 (0-6)	2/3 (0-9)	3/4 (0-17)
Viken	20/20 (11-29)	18/18 (11-28)	17/17 (8-27)

8 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.

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	13.4 (6.2, 21.3) %	Not enough data	5.5 (11.5, 3.6)
Innlandet	-4.1 (-16.8, 10.1) %	3.1 (-1.2, 7.5) %	-16.7 (-3.8, 7.2)	22.9 (-58.9, 9.5)
Møre og Romsdal	Not enough data	-1.3 (-7.1, 4.9) %	Not enough data	-52.7 (-9.4, 14.6)
Nordland	Not enough data	2.6 (-4.6, 10.5) %	Not enough data	27.1 (-14.6, 7)
Norge	-1.4 (-3.8, 1) %	-0.1 (-1.6, 1.5) %	-48.6 (-18, 69.2)	-784.3 (-42.3, 47.4)
Oslo	-6.2 (-10, -2.2) %	-0.8 (-2.9, 1.4) %	-10.9 (-6.6, -30.9)	-85.3 (-23.3, 51.5)
Rogaland	3.8 (-5.6, 14.5) %	1.7 (-1, 4.4) %	18.4 (-12.1, 5.1)	42.1 (-67.1, 16)
Troms og Finnmark	Not enough data	-6.7 (-15.5, 2.5) %	Not enough data	-10 (-4.1, 27.6)
Trøndelag	Not enough data	11.8 (5.5, 18.6) %	Not enough data	6.2 (13, 4.1)
Vestfold og Telemark	2.9 (-8.9, 16.6) %	-1.8 (-6.1, 2.6) %	24.2 (-7.5, 4.5)	-37.8 (-11, 26.5)
Vestland	-3 (-15.6, 11) %	2.9 (0, 5.8) %	-22.7 (-4.1, 6.6)	24.4 (2192.6, 12.3)
Viken	1.4 (-2.3, 5.3) %	-1 (-2.7, 0.8) %	49 (-29.6, 13.4)	-71.7 (-25.6, 90.1)

9 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.

10 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 20 shows an overview of the mobility since March 2020 for the largest municipalities in each county, and Figure 21 shows the total mobility out from all municipalities in each county, including Oslo. Figure 22 and 23, zooms in on mobility from January 11 2021, for municipalities and counties, respectively.

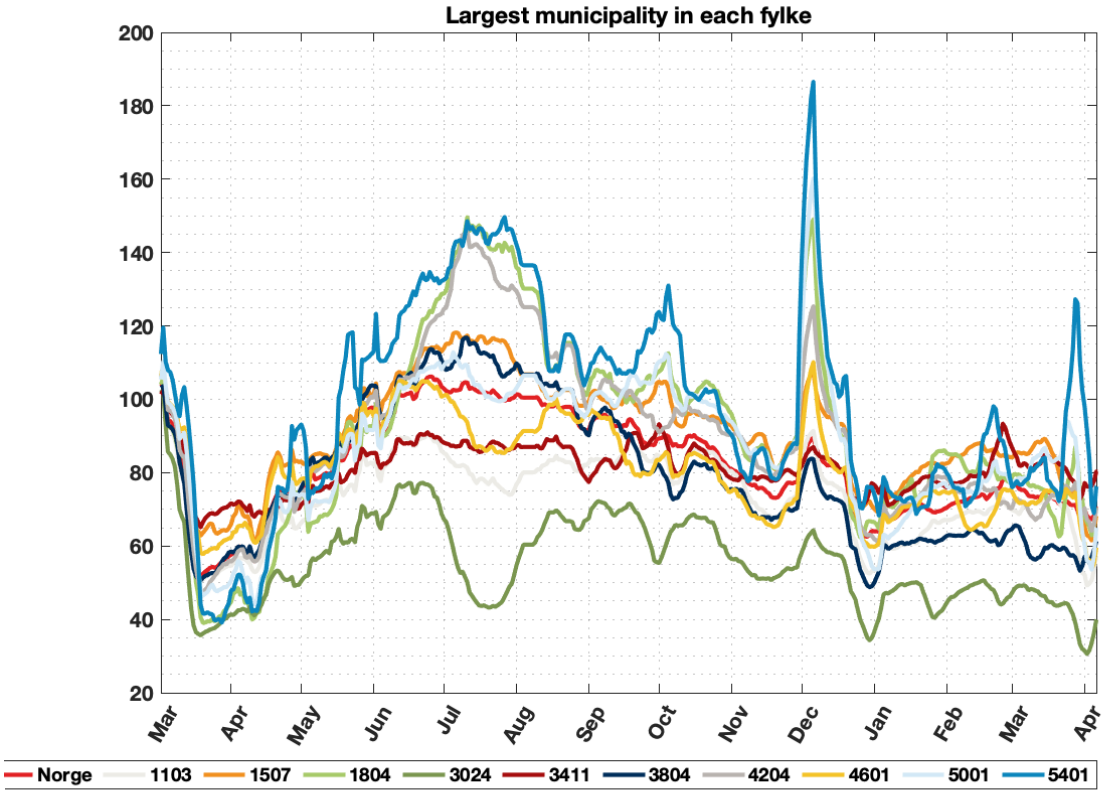


Figure 20: Mobility for selected municipalities since March 2020: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

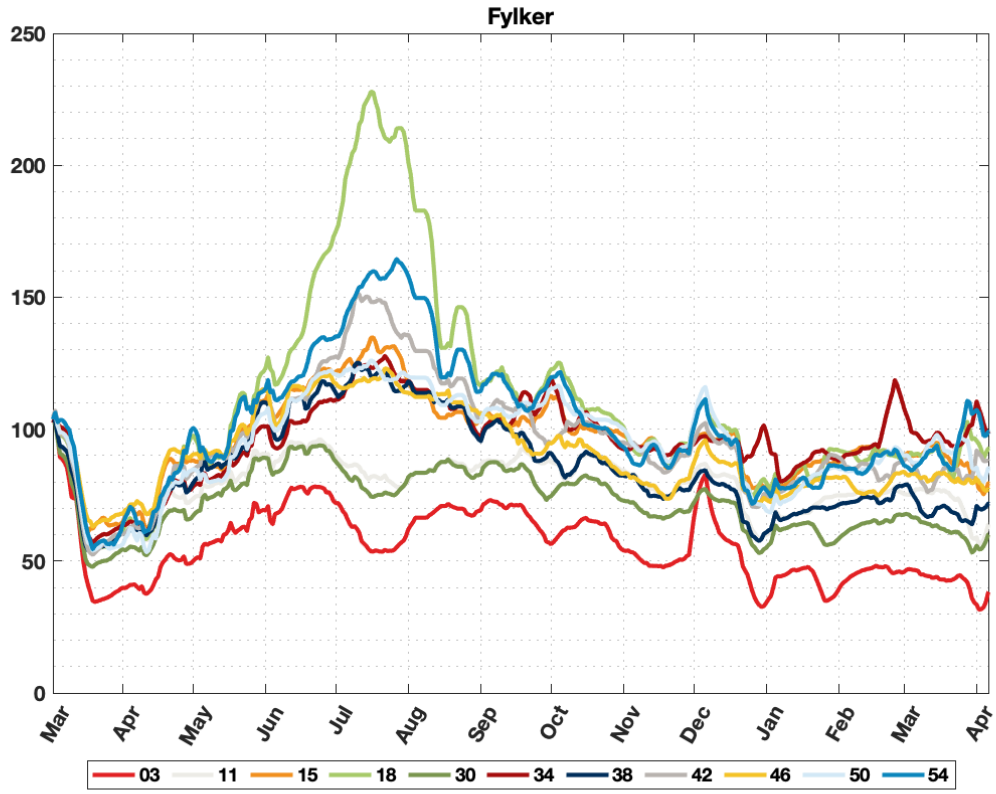


Figure 21: Mobility for fylker since March 2020: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

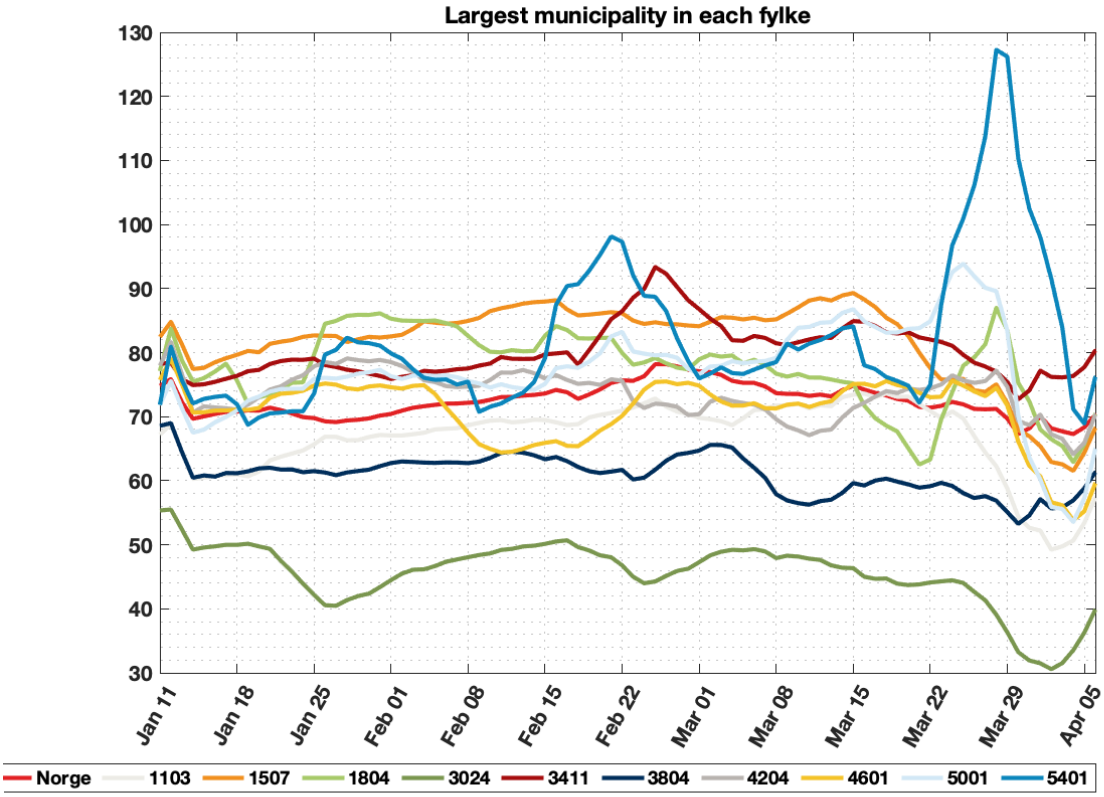


Figure 22: Zoom: Mobility from January 11, 2021 and onwards: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

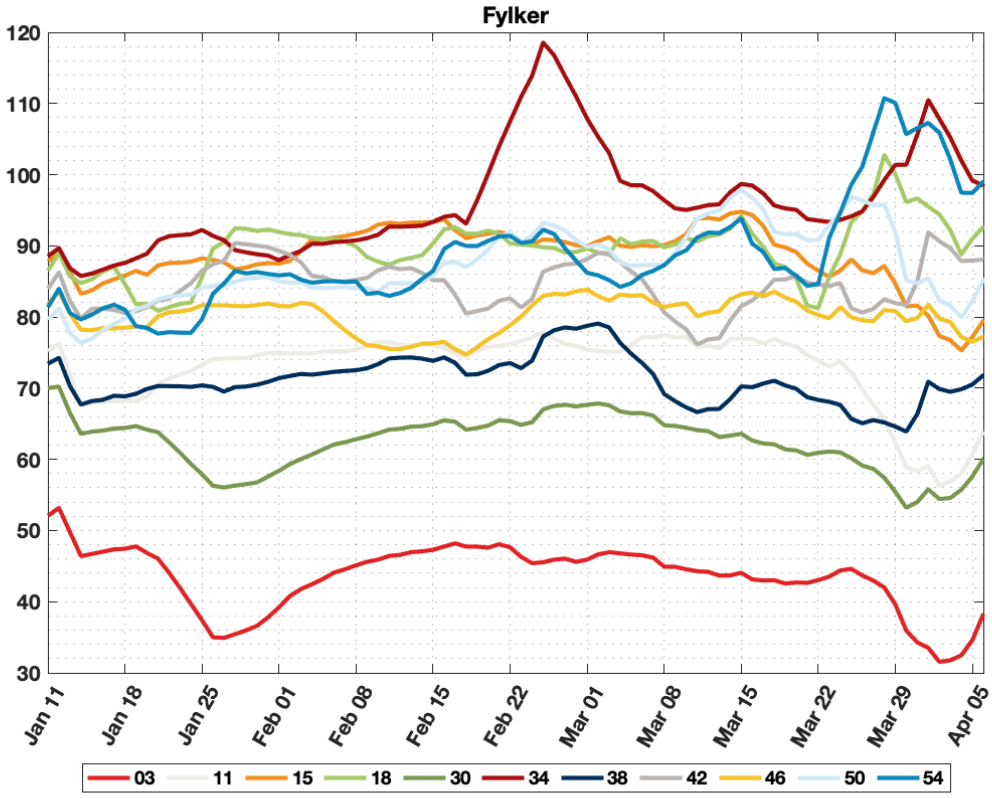


Figure 23: Zoom: Mobility from January 11, 2021 and onwards, per fylker: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finnmark (54).

	12	13	14	15	16
Norge	74.8	71.4	69.7	68.3	68.1
Stavanger	73.4	70.9	58.8	53.4	62.6
Ålesund	89.3	77.6	72.1	64.4	71.7
Bodø	75.2	63.3	83.5	65.7	74.8
Bærum	46.3	44.1	36.3	36.3	44.0
Ringsaker	84.9	82.0	75.4	77.7	75.4
Sandefjord	59.6	59.1	55.1	58.8	59.1
Kristiansand	71.4	74.4	74.7	65.9	70.2
Bergen	75.1	73.0	71.7	55.2	67.8
Trondheim	86.8	84.9	83.4	57.3	71.8
Tromsø	84.1	75.0	126.2	68.9	80.4

Table 13: Municipalities

	12	13	14	15	16
Oslo	44.1	43.0	39.6	34.6	41.1
Rogaland	77.0	73.8	62.4	60.6	68.0
Møre og Romsdal	94.8	86.5	84.7	77.2	79.7
Nordland	94.2	81.2	100.1	91.0	89.4
Viken	63.6	60.9	55.4	57.6	58.8
Innlandet	98.7	93.5	101.4	99.2	84.6
Vestfold og Telemark	70.2	68.3	64.6	70.5	67.9
Agder	81.5	84.6	82.0	87.9	79.3
Vestlandet	83.2	80.3	80.8	76.5	77.3
Trøndelag	97.8	90.8	91.9	82.2	81.4
Troms og Finnmark	93.8	84.6	110.1	97.4	92.9

Table 14: Counties

Weekly mobility for Norway and selected municipalities is displayed in Table 13 and mobility for counties is displayed in Table 14. 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.

10.1 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 24 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 25 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.

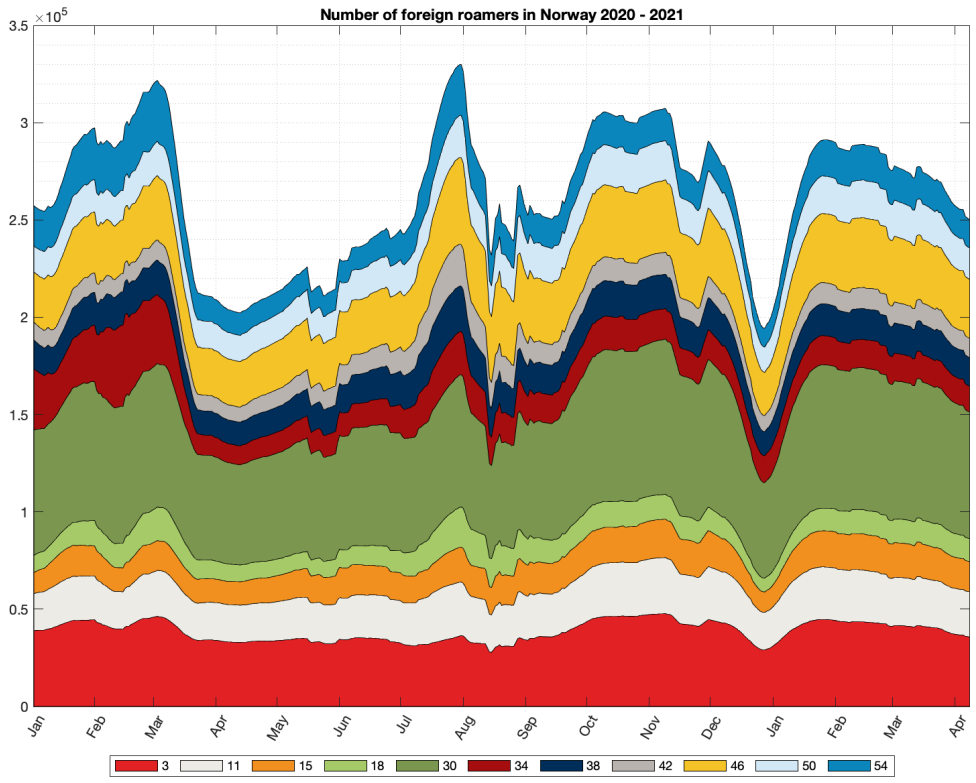


Figure 24: The total number of foreign roamers in Norway broken down on different fylker: Oslo (3), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

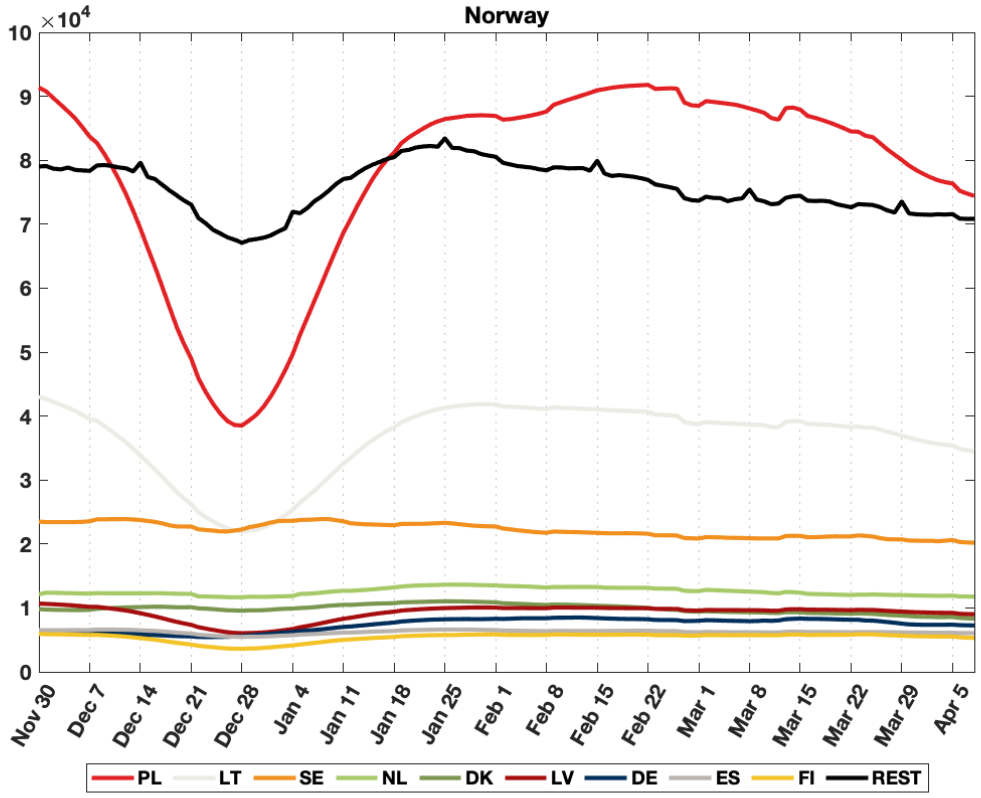
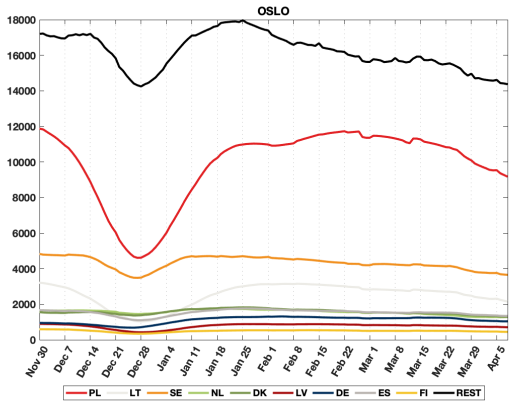
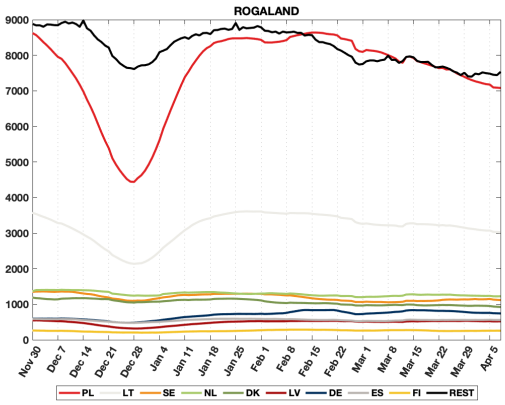
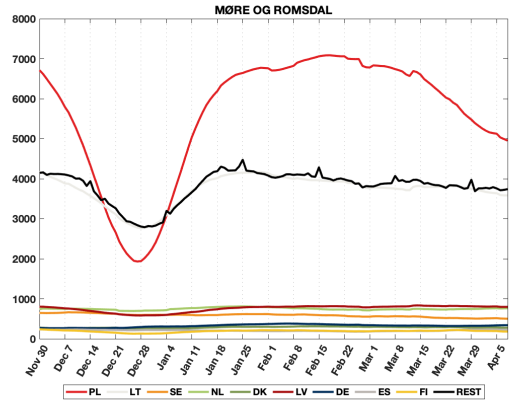


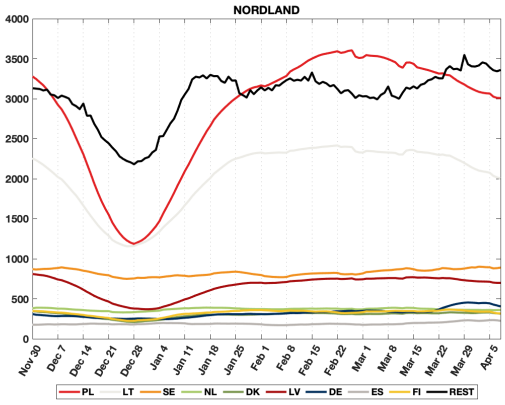
Figure 25: National overview of total number of foreign, visiting roamers from Poland, Lithuania, Sweden, Netherlands, Denmark, Latvia, Germany, Spain, Finland and the rest of the world.

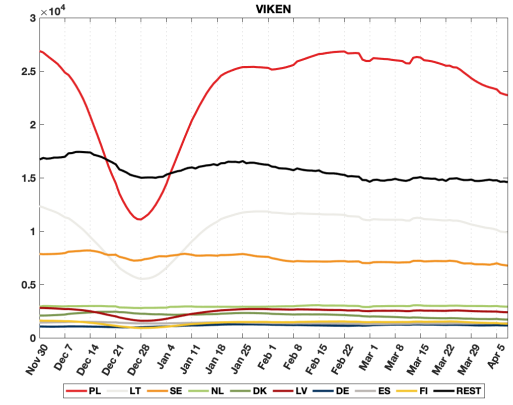
10.2 Foreign roamers per county (fylke) in Norway

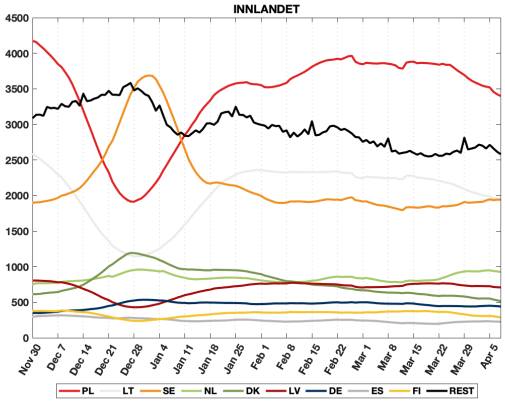




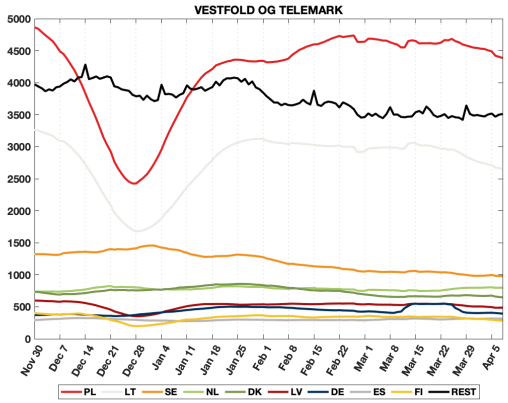


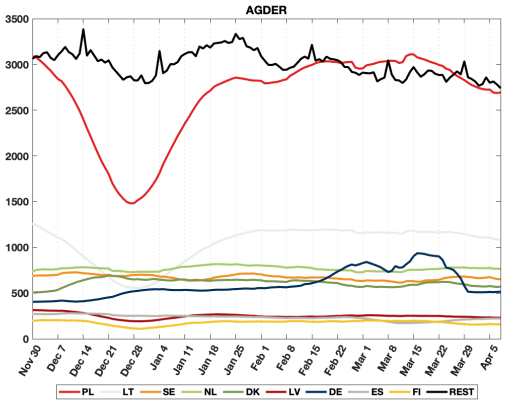


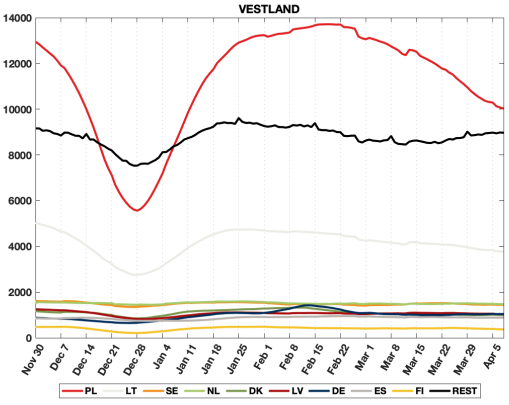


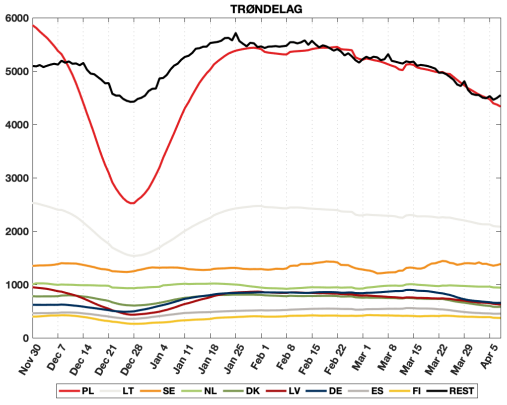


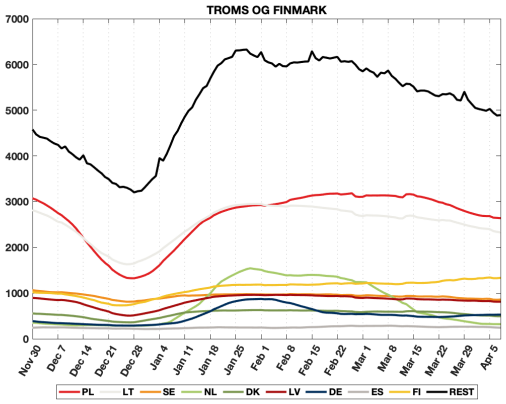
10.2 Foreign roamers per county (fylke) in Norway











11 Methods

11.1 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.

11.1.1 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 28.

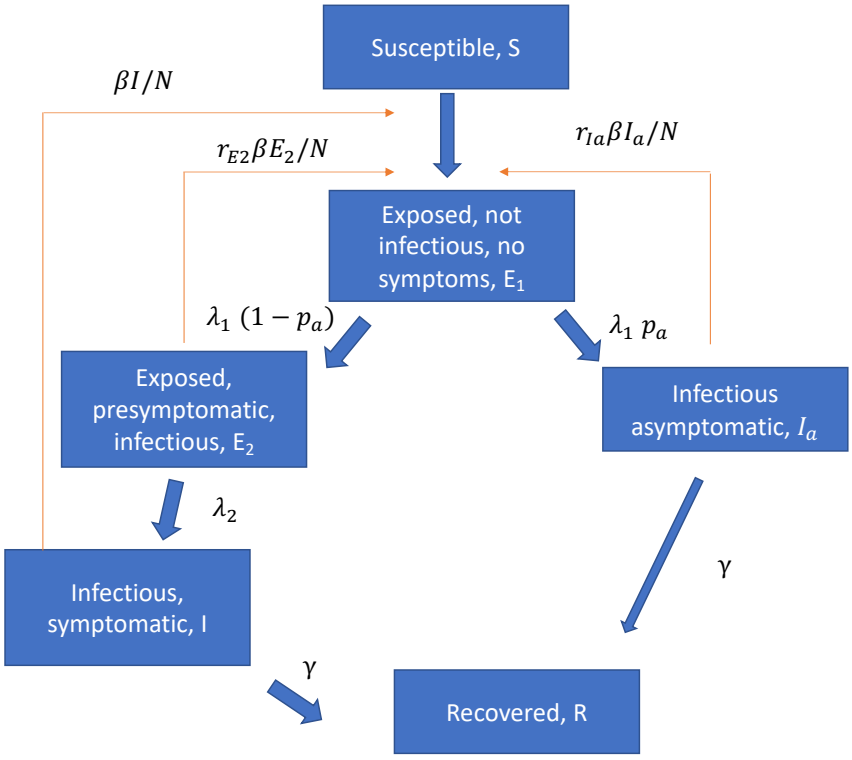


Figure 28: Schematic overview of the model.

11.2 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.

11.3 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.

11.4 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.

11.5 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.

11.5.1 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 11.3, using the parameters provided in Section 12, 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.

11.5.2 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.

11.6 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.

11.7 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.

12 Parameters used today

Figures 29 to 34 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.

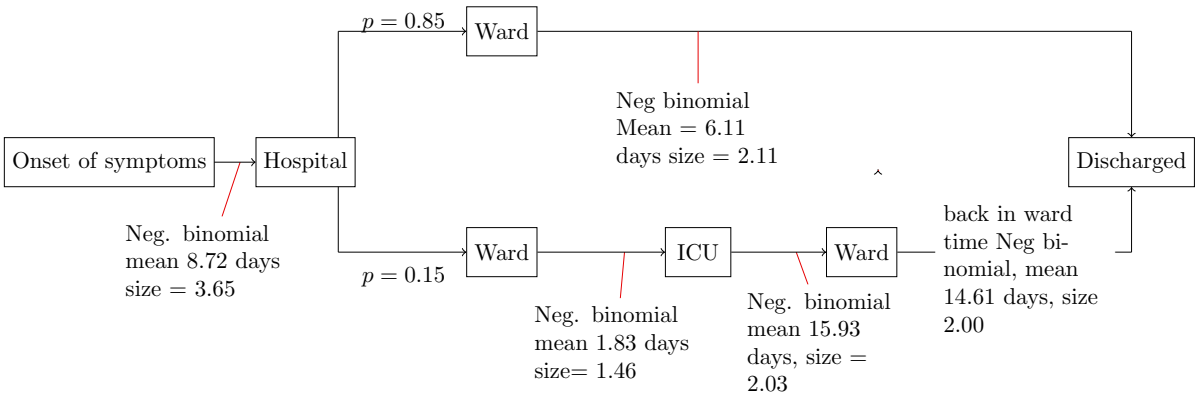


Figure 29: Hospital assumptions and parameters used before 1 June 2020

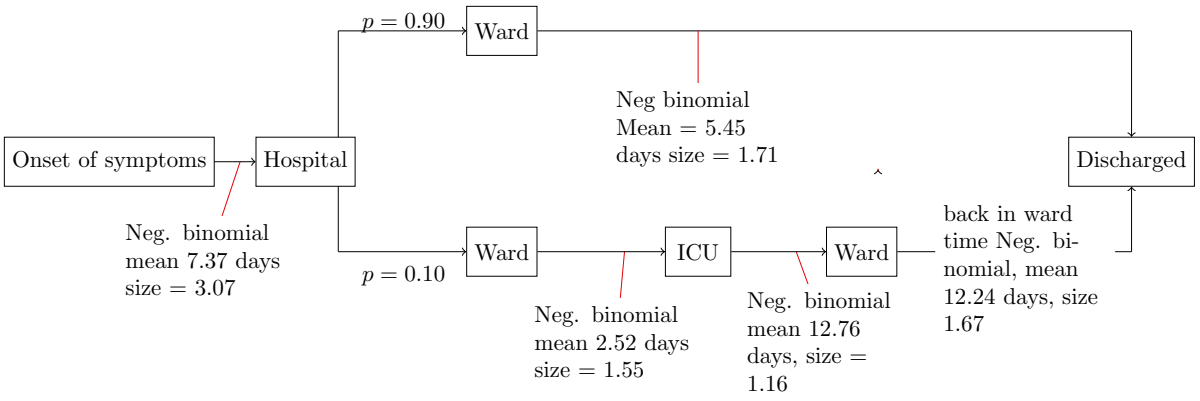


Figure 30: Hospital assumptions and parameters used between 1 June 2020 and 1 January 2021

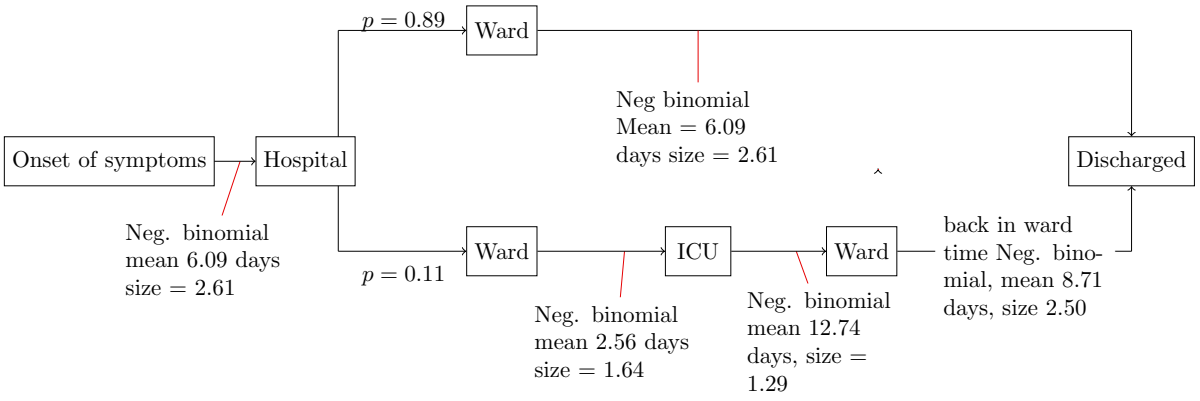


Figure 31: Hospital assumptions and parameters used between 1 January 2021 and 1 March 2021 for those living in Oslo

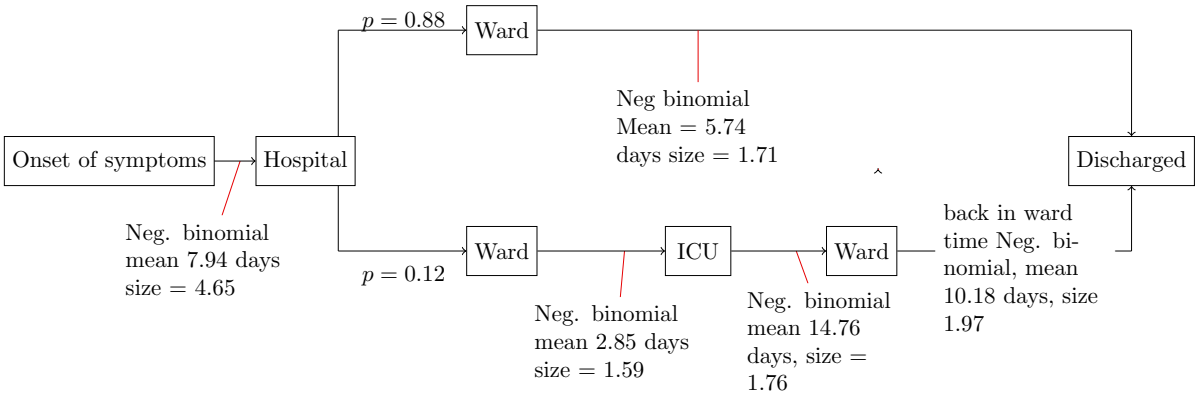


Figure 32: Hospital assumptions and parameters used between 1 January 2021 and 1 March 2021 for those not living in Oslo

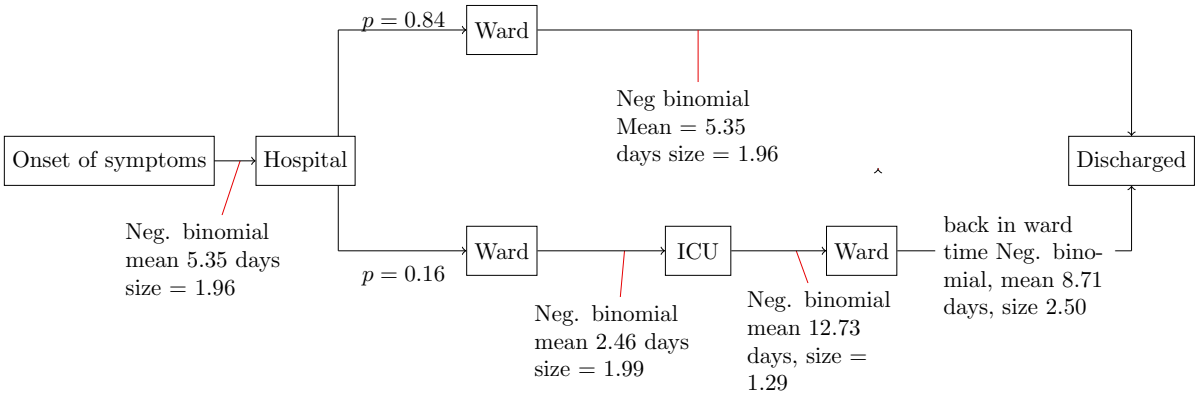


Figure 33: Hospital assumptions and parameters used from 1 March 2021 for those living in Oslo

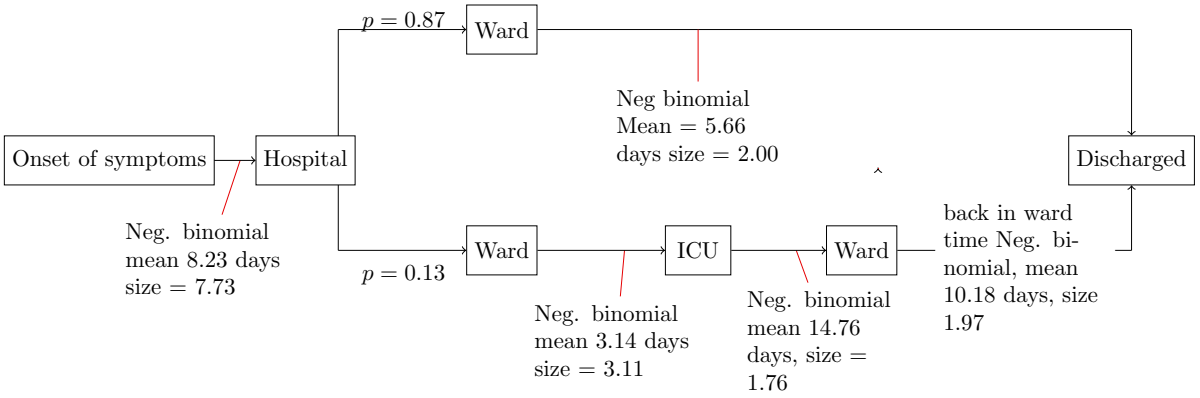


Figure 34: Hospital assumptions and parameters used from 1 March 2021 for those not living in Oslo

Table 15: Estimated parameters

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Period
R0s	2.307	2.97	3.268	3.26	3.557	4.277	Until March 14
R1s	0.386	0.477	0.505	0.509	0.543	0.666	From 15 March to 19 April
R2s	0.172	0.635	0.755	0.751	0.862	1.182	From 20 April to 10 May
R3s	0.065	0.528	0.657	0.642	0.748	1.054	From 11 May to 30 June
R4s	0.015	0.792	1.057	1.023	1.252	1.76	From 01 July to 31 July
R5s	0.658	0.922	1.01	1.039	1.135	1.551	From 01 August to 31 August
R6s	0.69	0.876	0.954	0.946	1.011	1.205	From 01 September to 30 September
R7s	0.968	1.191	1.255	1.251	1.313	1.49	From 01 October to 25 October
R8s	0.945	1.205	1.291	1.309	1.401	1.788	From 26 October to 04 November
R9s	0.709	0.788	0.809	0.811	0.837	0.901	From 05 November to 30 November
R10s	1.014	1.054	1.067	1.069	1.085	1.151	From 01 December to 03 January
R11s	0.459	0.578	0.62	0.616	0.659	0.762	From 04 January to 21 January
R12s	0.569	0.729	0.786	0.793	0.858	1.037	From 22 January to 07 February
R13s	1.308	1.436	1.476	1.485	1.533	1.69	From 08 February to 01 March
R14s	0.995	1.056	1.093	1.093	1.13	1.194	From 02 March to 24 March
R15s	0.638	0.784	0.839	0.841	0.9	1.027	From 25 March
AMPs	1.012	1.621	1.972	2.025	2.376	3.589	-
π_0	-0.704	-0.048	0.143	0.101	0.283	0.663	-
π_1	2.8e-07	1.1e-05	2.3e-05	2.5e-05	3.4e-05	9.0e-05	-
delays	0	2	3	2.465	3	4	-

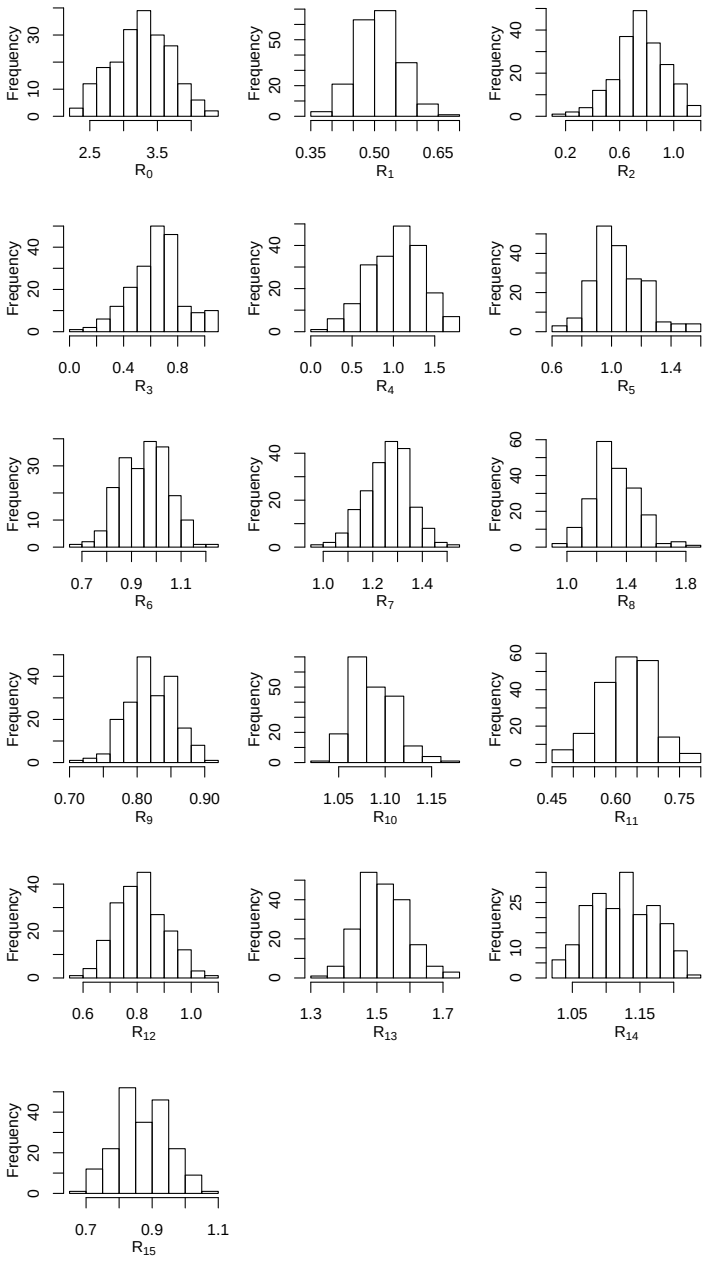


Figure 35: Estimated densities of the reproduction numbers. National model

Table 16

R	Parameter	County	From	To	Pr(R>1)
5.58 (4.98-6.08)	R0	Oslo	2020-02-17	2020-03-14	1
3.5 (2.76-4.21)	R0	Rogaland	2020-02-17	2020-03-14	1
3.18 (1.35-4.91)	R0	Møre og Romsdal	2020-02-17	2020-03-14	0.99
3.47 (1.14-5.88)	R0	Nordland	2020-02-17	2020-03-14	0.98
3.58 (2.89-4.2)	R0	Viken	2020-02-17	2020-03-14	1
2.97 (1.43-4.5)	R0	Innlandet	2020-02-17	2020-03-14	0.99
3.3 (1.7-4.47)	R0	Vestfold og Telemark	2020-02-17	2020-03-14	1
2.75 (1.82-3.8)	R0	Agder	2020-02-17	2020-03-14	1
2.89 (1.86-4.03)	R0	Vestland	2020-02-17	2020-03-14	1
3.94 (2.35-5.35)	R0	Trøndelag	2020-02-17	2020-03-14	1
2.72 (1.57-3.93)	R0	Troms og Finnmark	2020-02-17	2020-03-14	1
0.61 (0.48-0.75)	R1	Oslo	2020-03-15	2020-04-19	0
0.52 (0.16-0.92)	R2	Oslo	2020-04-20	2020-07-24	0.01
1.32 (1.23-1.42)	R3	Oslo	2020-07-25	2020-09-30	1
1.5 (1.43-1.57)	R4	Oslo	2020-10-01	2020-11-04	1
1.03 (0.97-1.1)	R5	Oslo	2020-11-05	2020-12-14	0.79
1.34 (1.17-1.57)	R6	Oslo	2020-12-15	2021-01-03	1
0.74 (0.59-0.94)	R7	Oslo	2021-01-04	2021-02-04	0
1.9 (1.43-2.28)	R8	Oslo	2021-02-05	2021-02-21	1
1.54 (1.05-2.09)	R9	Oslo	2021-02-22	2021-03-01	0.99
1.36 (1.17-1.55)	R10	Oslo	2021-03-02	2021-03-16	1
0.97 (0.82-1.12)	R11	Oslo	2021-03-17		0.36
0.06 (0.01-0.13)	R1	Rogaland	2020-03-15	2020-04-19	0
0.79 (0.47-1.12)	R2	Rogaland	2020-04-20	2020-08-31	0.12
0.82 (0.6-1.03)	R3	Rogaland	2020-09-01	2020-11-04	0.05
0.76 (0.35-1.1)	R4	Rogaland	2020-11-05	2020-11-30	0.09
1.34 (1.09-1.59)	R5	Rogaland	2020-12-01	2021-01-03	0.99
0.31 (0.06-0.53)	R6	Rogaland	2021-01-04	2021-01-31	0
0.88 (0.25-1.85)	R7	Rogaland	2021-02-01	2021-02-19	0.3
1.64 (1.33-1.99)	R8	Rogaland	2021-02-20	2021-03-23	1
0.67 (0.15-1.22)	R9	Rogaland	2021-03-24		0.1
0.4 (0.09-0.68)	R1	Møre og Romsdal	2020-03-15	2020-04-19	0
0.62 (0.29-0.96)	R2	Møre og Romsdal	2020-04-20	2020-09-14	0.02
0.75 (0.36-1.07)	R3	Møre og Romsdal	2020-09-15	2020-11-04	0.08
0.56 (0.1-1.11)	R4	Møre og Romsdal	2020-11-05	2020-12-14	0.05
0.69 (0.06-1.43)	R5	Møre og Romsdal	2020-12-15	2021-01-03	0.24
0.18 (0.01-0.55)	R6	Møre og Romsdal	2021-01-04	2021-02-04	0
1.12 (0.63-1.52)	R7	Møre og Romsdal	2021-02-05	2021-03-23	0.71
1.01 (0.13-2.04)	R8	Møre og Romsdal	2021-03-24		0.47
0.46 (0.06-0.88)	R1	Nordland	2020-03-15	2020-04-19	0
0.8 (0.51-1.1)	R2	Nordland	2020-04-20	2020-07-24	0.09
0.6 (0.02-1.59)	R3	Nordland	2020-07-25	2020-08-14	0.16
0.67 (0.27-1.03)	R4	Nordland	2020-08-15	2020-10-04	0.04
0.64 (0.21-1.09)	R5	Nordland	2020-10-05	2020-11-04	0.06
0.32 (0.01-1.02)	R6	Nordland	2020-11-05	2020-12-14	0.03
1.08 (0.19-1.81)	R7	Nordland	2020-12-15	2021-01-03	0.59
0.54 (0.15-0.91)	R8	Nordland	2021-01-04	2021-02-04	0.01
0.85 (0.08-1.93)	R9	Nordland	2021-02-05	2021-02-19	0.34
0.53 (0.08-1.07)	R10	Nordland	2021-02-20	2021-03-23	0.05
0.53 (0.03-1.29)	R11	Nordland	2021-03-24		0.11
0.28 (0.14-0.41)	R1	Viken	2020-03-15	2020-04-19	0
0.82 (0.44-1.12)	R2	Viken	2020-04-20	2020-07-24	0.18
1.08 (0.98-1.18)	R3	Viken	2020-07-25	2020-10-09	0.94
1.47 (1.39-1.54)	R4	Viken	2020-10-10	2020-11-04	1
0.81 (0.74-0.88)	R5	Viken	2020-11-05	2020-11-30	0
0.96 (0.88-1.03)	R6	Viken	2020-12-01	2021-01-03	0.14
0.82 (0.72-0.92)	R7	Viken	2021-01-04	2021-02-04	0
1.33 (1.12-1.53)	R8	Viken	2021-02-05	2021-02-21	1
1.35 (1.26-1.44)	R9	Viken	2021-02-22	2021-03-23	1
0.89 (0.72-1.07)	R10	Viken	2021-03-24		0.13

Mean and 95% credible intervals

Table 17

R	Parameter	County	From	To	Pr(R>1)
0.47 (0.11-0.78)	R1	Innlandet	2020-03-15	2020-04-19	0
0.98 (0.71-1.19)	R2	Innlandet	2020-04-20	2020-07-24	0.48
0.83 (0.61-1.04)	R3	Innlandet	2020-07-25	2020-10-09	0.06
1.62 (1.02-2.11)	R4	Innlandet	2020-10-10	2020-10-24	0.98
0.52 (0.12-0.93)	R5	Innlandet	2020-10-25	2020-11-04	0
0.87 (0.42-1.13)	R6	Innlandet	2020-11-05	2020-12-14	0.22
0.68 (0.12-1.11)	R7	Innlandet	2020-12-15	2021-01-03	0.09
0.22 (0.02-0.49)	R8	Innlandet	2021-01-04	2021-02-21	0
0.49 (0.1-0.93)	R9	Innlandet	2021-02-22	2021-03-23	0.02
0.39 (0.08-0.66)	R10	Innlandet	2021-03-24		0
0.19 (0.06-0.31)	R1	Vestfold og Telemark	2020-03-15	2020-04-19	0
0.92 (0.52-1.23)	R2	Vestfold og Telemark	2020-04-20	2020-07-24	0.33
0.78 (0.52-1.02)	R3	Vestfold og Telemark	2020-07-25	2020-10-09	0.03
0.79 (0.39-1.12)	R4	Vestfold og Telemark	2020-10-10	2020-11-04	0.1
1.12 (0.45-1.75)	R5	Vestfold og Telemark	2020-11-05	2020-11-19	0.67
0.88 (0.66-1.09)	R6	Vestfold og Telemark	2020-11-20	2021-01-03	0.14
0.64 (0.31-0.92)	R7	Vestfold og Telemark	2021-01-04	2021-02-04	0
1.74 (1.12-2.39)	R8	Vestfold og Telemark	2021-02-05	2021-02-21	0.99
0.95 (0.75-1.17)	R9	Vestfold og Telemark	2021-02-22	2021-03-23	0.32
0.42 (0.07-0.8)	R10	Vestfold og Telemark	2021-03-24		0
0.36 (0.08-0.58)	R1	Agder	2020-03-15	2020-04-19	0
0.86 (0.37-1.26)	R2	Agder	2020-04-20	2020-07-31	0.29
0.74 (0.36-1.21)	R3	Agder	2020-08-01	2020-09-19	0.11
0.87 (0.38-1.25)	R4	Agder	2020-09-20	2020-10-09	0.28
0.86 (0.4-1.45)	R5	Agder	2020-10-10	2020-11-04	0.24
0.55 (0.14-0.9)	R6	Agder	2020-11-05	2021-01-03	0
0.83 (0.6-1.05)	R7	Agder	2021-01-04	2021-02-19	0.08
0.64 (0.15-1.09)	R8	Agder	2021-02-20	2021-03-23	0.06
0.51 (0.04-1.27)	R9	Agder	2021-03-24		0.08
0.4 (0.16-0.63)	R1	Vestland	2020-03-15	2020-04-19	0
0.79 (0.56-1.05)	R2	Vestland	2020-04-20	2020-07-24	0.04
1.4 (1.14-1.67)	R3	Vestland	2020-07-25	2020-09-04	1
0.95 (0.79-1.12)	R4	Vestland	2020-09-05	2020-10-09	0.3
1.67 (1.51-1.84)	R5	Vestland	2020-10-10	2020-11-04	1
0.44 (0.18-0.66)	R6	Vestland	2020-11-05	2020-11-30	0
0.52 (0.08-1.05)	R7	Vestland	2020-12-01	2021-01-03	0.04
0.75 (0.34-1.1)	R8	Vestland	2021-01-04	2021-02-04	0.1
0.94 (0.64-1.21)	R9	Vestland	2021-02-05	2021-03-23	0.32
1.4 (0.53-2.42)	R10	Vestland	2021-03-24		0.79
0.26 (0.03-0.55)	R1	Trøndelag	2020-03-15	2020-04-19	0
0.64 (0.29-0.97)	R2	Trøndelag	2020-04-20	2020-08-31	0.02
0.62 (0.23-1.05)	R3	Trøndelag	2020-09-01	2020-11-04	0.06
0.86 (0.26-1.43)	R4	Trøndelag	2020-11-05	2020-11-30	0.34
1.31 (1.01-1.63)	R5	Trøndelag	2020-12-01	2021-01-03	0.98
0.26 (0.04-0.48)	R6	Trøndelag	2021-01-04	2021-02-04	0
0.36 (0.03-0.8)	R7	Trøndelag	2021-02-05	2021-03-23	0
1.31 (0.15-2.71)	R8	Trøndelag	2021-03-24		0.65
0.18 (0.01-0.41)	R1	Troms og Finnmark	2020-03-15	2020-04-19	0
0.7 (0.06-1.22)	R2	Troms og Finnmark	2020-04-20	2020-09-14	0.26
0.76 (0.24-1.2)	R3	Troms og Finnmark	2020-09-15	2020-11-04	0.17
0.5 (0.05-1.14)	R4	Troms og Finnmark	2020-11-05	2020-11-30	0.04
0.4 (0.02-0.96)	R5	Troms og Finnmark	2020-12-01	2021-01-03	0.02
0.32 (0.08-0.57)	R6	Troms og Finnmark	2021-01-04	2021-02-04	0
1.13 (0.32-1.89)	R7	Troms og Finnmark	2021-02-05	2021-02-19	0.65
1.08 (0.21-1.66)	R8	Troms og Finnmark	2021-02-20	2021-03-23	0.67
0.71 (0.08-1.5)	R9	Troms og Finnmark	2021-03-24		0.22
1.29 (1.05-1.53)	AMP factor	All			-

Mean and 95% credible intervals

Table 18: Assumptions

Assumptions	Mean	Distribution	Reference
Mobile Mobility Data			
Telenor coverage	48%		https://ekomstatistikken.nkom.no/
Data updated	April 10th		
Data used in the predictions	April 8th	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 combination of hospitalisation data and test data used in the main analysis are likely a less biased information source for the number of real infections, but since testing-criteria have remained constant over a long period of time, we also expect that using confirmed cases can give a reasonable estimate of the reproduction number in this phase of the epidemic. In this approach we do not take into account changes in the number of tests, for example during holidays, so the results in these periods are likely to under-estimate the reproduction number when the holiday starts and overestimate it when the holiday ends and the number of tests return to it's normal level.

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 4 days nationally and 7 days regionally, see figure 36. 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.

Table 19: Estimated reproduction numbers 7 days ago

Location	Reff
National	0.94(0.9 - 0.99)
Oslo	0.91(0.86 - 0.96)
Rogaland	1.07(0.94 - 1.22)
Møre og Romsdal	0.96(0.73 - 1.2)
Nordland	1.09(0.67 - 1.61)
Viken	0.92(0.88 - 0.96)
Innlandet	1.14(0.94 - 1.36)
Vestfold og Telemark	0.9(0.76 - 1.04)
Agder	1.77(1.39 - 2.22)
Vestland	1.01(0.89 - 1.14)
Trøndelag	1.6(1.24 - 2.02)
Troms og Finnmark	0.57(0.29 - 0.96)

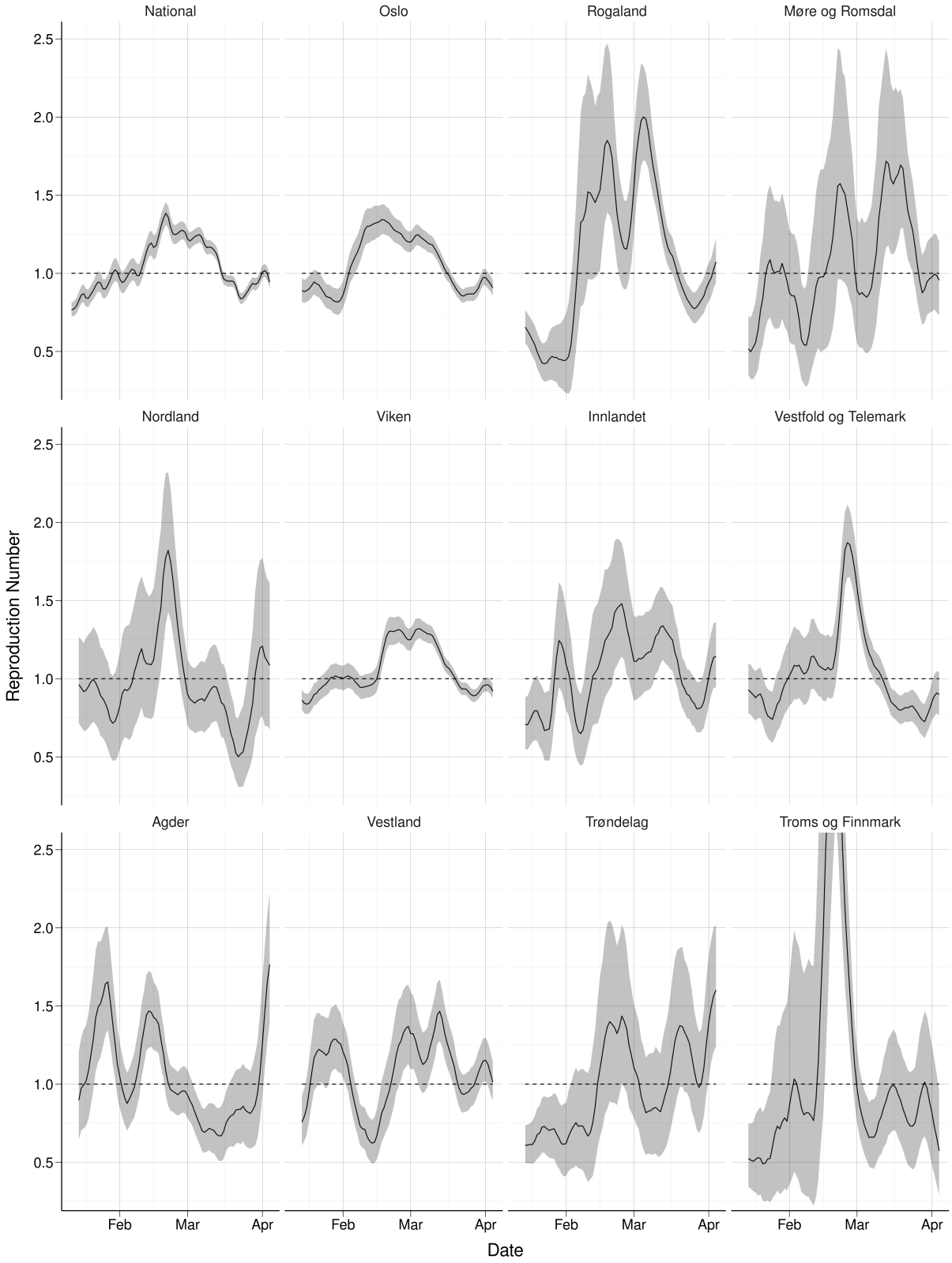


Figure 36: Reproduction number estimated using the R package EpiEstim.

FHI COVID-19 modelling team:

- **Birgitte Freiesleben de Blasio** - Department of Method Development and Analytics. Norwegian Institute of Public Health and Oslo Centre for Biostatistics and Epidemiology, University of Oslo.
- **Francesco Di Ruscio** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Gunnar Øyvind Isaksson Rø** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Solveig Engebretsen** - Norsk Regnesentral.
- **Arnoldo Frigessi** - Oslo Centre for Biostatistics and Epidemiology, University of Oslo and Oslo University Hospital.
- **Alfonso Diz-Lois Palomares** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **David Swanson** - Oslo Centre for Biostatistics and Epidemiology, Oslo University Hospital.
- **Magnus Nygård Osnes** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Anja Bråthen Kristoffersen** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Kenth Engø-Monsen** - Telenor Research.
- **Louis Yat Hin Chan** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Jonas Christoffer Lindstrøm** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Richard White** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Gry Marysol Grøneng** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Chi Zhang** - Department of Method Development and Analytics. Norwegian Institute of Public Health.
- **Jørgen Eriksson Midtbø** - Department of Method Development and Analytics. Norwegian Institute of Public Health.