

# Situational awareness and forecasting for Norway

FHI COVID-19 modelling team

**Week 11, 24 March 2021**

## Highlights:

- **National epidemiological situation:** Our models indicate that in the present situation, the prevalence of cases and hospitalisations continue to increase due to the exponential phase of the epidemic, governed by a high effective reproduction number. In our changepoint model, the effective reproduction number  $R$  acting from March 2nd until today is estimated to be 1.3 (median, 95% CI 1.18-1.46). Looking back in time since Christmas, the effective reproduction number was estimated to be below 0.7 until January 21; it then started to increase but remained below 1 until February 7. Then the increase was twice as rapid, to 1.39 (1.26-1.51) until March 1. Since then, the reproduction number has remained stable. The SMC model estimates the 7-days averaged effective reproduction number during week 10, to be 1.21 (mean, 95% CI 0.93-1.57). The SMC model indicates a peak between week 7 and 8 and a decrease during the last week of February, followed by week 9 with a stable reproduction number, with then a decrease in the last week 10. The trend appears currently decreasing, though with high uncertainty. The changepoint model and the SMC agree in estimating the same level of the effective reproduction number. Still the SMC, which reacts to recent data more rapidly, indicates a recent decreasing trend. These estimates include the interventions implemented on March 2, but not the ones implemented in Oslo and Viken at the beginning of week 11, which our models will be able to capture fully after Easter.

Since the start of the epidemic, we estimate that in total, 166.000 (95% CI 144.000- 193.000) persons in Norway have been infected. The current estimate of the detection probability is stably around ~62%.

- **Changes introduced this week: updated risk of hospitalisation.** According to literature, the B.1.1.7 variant results in a higher probability to hospitalisation for infected symptomatic individuals, estimated to be up to 60% increase. We have, therefore, increased these probabilities in our models. We assume that the B1.1.7 variant started to be observable 1 January and increased logistically until today, when it is dominating in Oslo and some other regions of Norway, but probably not everywhere. To balance this heterogeneity, we used an increase of 3% in January and an increase of 23% in February and in March. Correcting hospitalisation probabilities in this way may lead to a decrease of estimated reproduction numbers, and a better fit to hospital data.

In the regional model, the correction is done slightly differently, as we here apply one hospitalisation risk per region per day. Hence here we can gradually include the 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.

- **Changes introduced this week: Long term predictions include vaccination plans.** Here we use the individual-based model, which we have been running especially in the study of alternative interventions and vaccination strategies. We make a 12-month scenario starting from today with estimates from the national changepoint model and assume that transmissibility stays the same in the future as today. We assume vaccine deliveries in the future as in the "nøktern" (sober) scenario.
- **National forecasting:** During the next three weeks, we expect the situation to continue to worsen in terms of daily incidence of positive cases and new hospitalisations. In one week, on March 28, we

estimate ca 2500 new cases per day (median; 95% CI 1800-3900), and a prevalence (total number of presently infected individuals in Norway) of 14.000 (median; 95% CI 10.000-20.000). Compared to our estimates for March 28 made one week ago, these numbers are smaller, an indication that the speed of the increase has diminished. The number of COVID-19 patients in hospital (daily prevalence) on March 28 is estimated to be 260 (median 95% CI 196-334), and the number of patients on ventilator treatment is estimated to be 44 (median 95% CI 26-60); the corresponding predictions in three weeks (April 11) are 417 (95% CI 283 - 628) and 68 (95% CI 42 - 100). Long term predictions, now including vaccination plans, shows a peak in late May/June under the "nøkter" vaccination plan and if transmissibility continues as now. 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:** The estimated reproduction number in Oslo since March 2 is 1.31 (CI 1.03-1.59). Between February 5 and March 1 it is estimated to be 1.64 (1.5-1.78), which indicates a reduction of transmissibility in Oslo after the interventions were introduced on March 2. Most cases in Oslo are due to the B.1.1.7 variant, so that we do not expect a further growth of reproduction number induced by the increase of the B.1.1.7. The effect of the additional interventions decided on March 12, cannot be seen yet in our estimates and might lead, together with more efficient contact tracing, to a further reduction of the reproduction number. In Viken we estimate the reproduction number since February 22 to be 1.49 (1.3-1.65). We have not moved the changepoint to a more recent one, because there is no evidence in the data of an important change of transmissibility in the county as a whole. Reproduction number in Viken between February 5 and February 21 was 1.19 (1-1.38). Regarding the other counties, we estimate the reproduction number in Rogaland since February 20 to be as high as 2.1 but with very large uncertainty (1.36-2.85). In Vestfold og Telemark we obtain 1.62 (1.2-2) since February 22. Nordland and Troms og Finnmark have similar estimates 1.09 and 1.2 respectively, with rather large uncertainty too. Vestland is just around 1, see table 4 for the other counties. Our models will not be 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 380 (mean, 95% CI 210 -677) on 28 March and on April 11 to be 640 (95% CI 300-1300). Hospital prevalence in one week is estimated to be 51 (median; 95% CI 27-83), and in three weeks 70 (median; 95% CI 11-350, large uncertainty). The situation is worsening.

- **Telenor mobility data, local mobility and foreign visitors:** Inter-municipality mobility, measured as outgoing mobility of mobile phones from each municipality, is stable, though at low levels in Oslo, Viken, Vestfold og Telemark. In the other counties mobility is only slightly less than mid December. Mobility in Troms og Finnmark is high. The number of foreign visitors to Norway has stabilised to a high level, with a slight decrease in the last weeks.

## 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 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 interquartile 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
3.17/3.18(2.42-3.94)	From Feb 17 to Mar 14
0.5/0.5(0.38-0.59)	From Mar 15 to Apr 19
0.59/0.58(0.19-0.93)	From Apr 20 to May 10
0.65/0.65(0.18-1.06)	From May 11 to Jun 30
0.89/0.89(0.17-1.56)	From Jul 01 to Jul 31
1.09/1.1(0.83-1.4)	From Aug 01 to Aug 31
0.91/0.91(0.71-1.13)	From Sep 01 to Sep 30
1.28/1.28(1.09-1.49)	From Oct 01 to Oct 25
1.31/1.31(1.06-1.57)	From Oct 26 to Nov 04
0.79/0.79(0.73-0.86)	From Nov 05 to Nov 30
1.08/1.08(1.03-1.13)	From Dec 01 to Jan 03
0.6/0.6(0.5-0.7)	From Jan 04 to Jan 21
0.85/0.86(0.72-1)	From Jan 22 to Feb 07
1.39/1.39(1.26-1.51)	From Feb 08 to Mar 01
1.3/1.3(1.18-1.46)	From Mar 02

Median/Mean (95% credible intervals)

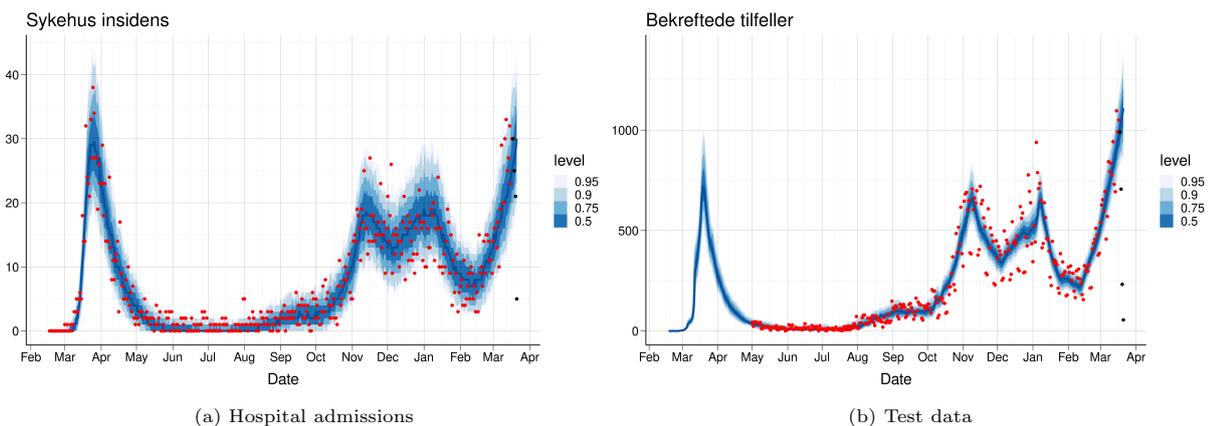


Figure 1: A comparison of true data (red) and predicted values (blue) for hospital admissions and test data. The last four data points (black) are assumed to be affected by reporting delay. B) Comparison of our simulated number of positive cases, with blue median and interquartile bands to the actual 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.

### 1.1 National SMC-model: Estimated daily reproduction numbers

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.

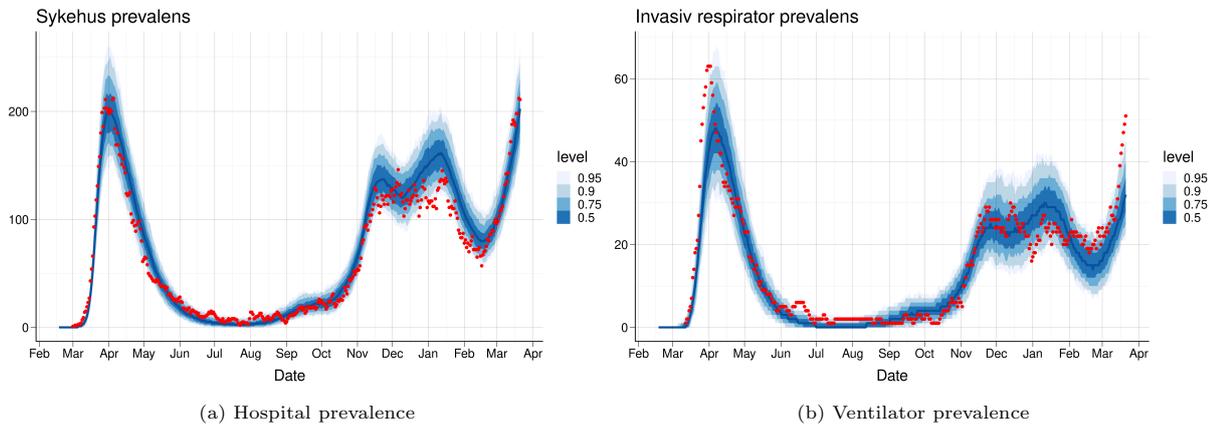


Figure 2: A comparison of true data (red) and predicted values (blue) for hospital and respirator prevalence.

### 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 of a delay in reporting tests, the data contain information on the transmissibility until a week before the end of the data (today).

The parameters  $\pi_0$  and  $\pi_1$  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

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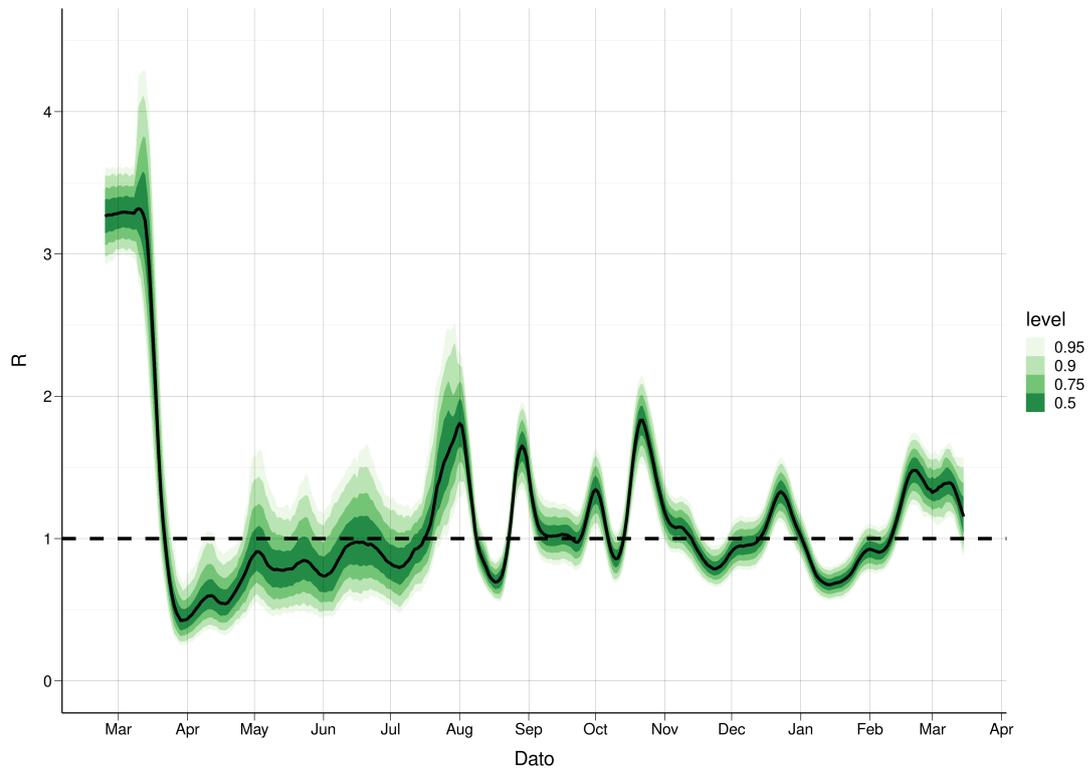


Figure 3:  $R(t)$  estimates using a Sequential Monte Carlo approach calibrated to hospitalisation incidence and test data. The large uncertainty during the last 7 days reflects the lack of available data due to the transmission delay, test delay, time between symptoms onset and hospitalisation. The 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

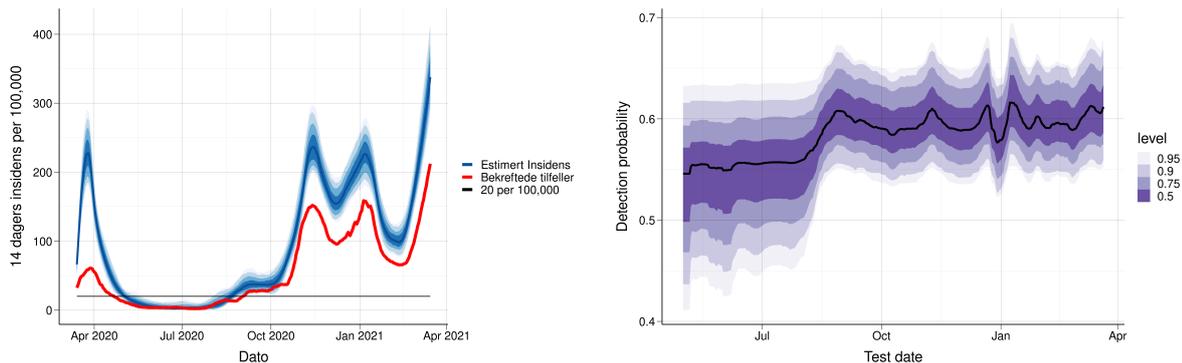
The national changepoint model estimates the total number of infections and the symptomatic cases that have occurred (Table 2).

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, 2021-03-21

Region	Total	No. confirmed	Fraction reported	Min. fraction
Norway	165971 (143559; 192501)	86939	52%	45%

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 4). 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 (Mar 28)	2 week prediction (Apr 04)	3 week prediction (Apr 11)
Prevalence	14266/14091 (10251-20398)	18020/17485 (11695-28249)	22751/21717 (13861-38664)
Daily incidence	2561/2506 (1791-3872)	3235/3129 (2063-5250)	4080/3884 (2349-7132)
Hospital beds	261/260 (196-334)	333/332 (232-445)	417/409 (283-628)
Ventilator beds	43/44 (26-60)	55/55 (35-75)	68/68 (42-100)

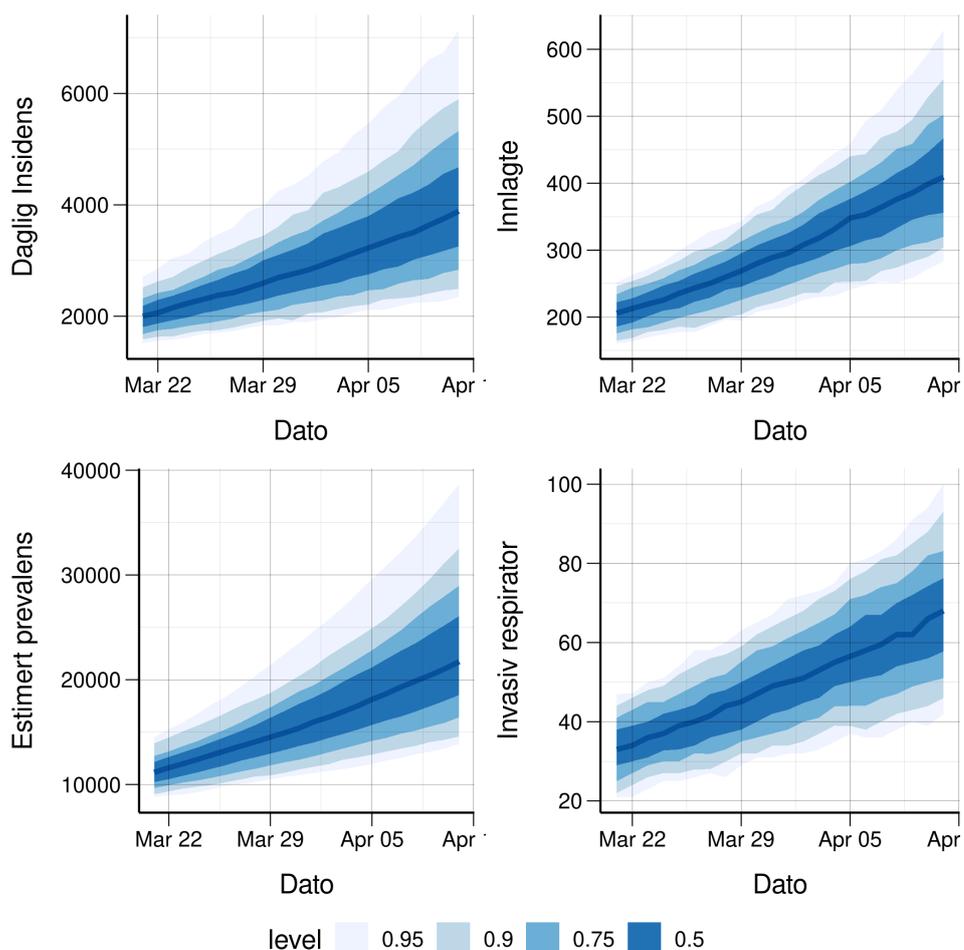


Figure 5: National 3 week predictions for incidence (top left), prevalence (bottom left), hospital beds (top right) and ventilator beds (bottom right)

## 4 National long-term scenarios with vaccination: Prevalence, Hospital beds and Ventilator beds

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).

On 11 March 2021, the rollout of the AstraZeneca vaccine was suspended by NIPH following the news of a death after vaccination. At the same time, NIPH and the Norwegian Medicines Agency started an investigation to clarify a potential connection between the AstraZeneca vaccine and serious side effects. It is currently unknown if the AstraZeneca vaccine will continue in the Norwegian covid-19 vaccination program. This decision may also influence the use of the other vector-vaccine from Janssen. For this reason, we present three scenarios: Scenario PMAJ including all four vaccines from Pfizer, Moderna, AstraZeneca and Janssen; Scenario PMJ excluding the AstraZeneca vaccine; Scenario PM including only the mRNA vaccines from Pfizer and Moderna.

The initial conditions in the municipalities are set following the results of the regional situational awareness model. The results are based on 100 simulations using the current average national reproduction number (Table 1) from our changepoint model; no seasonal effect with lower transmission during the summer period is included.

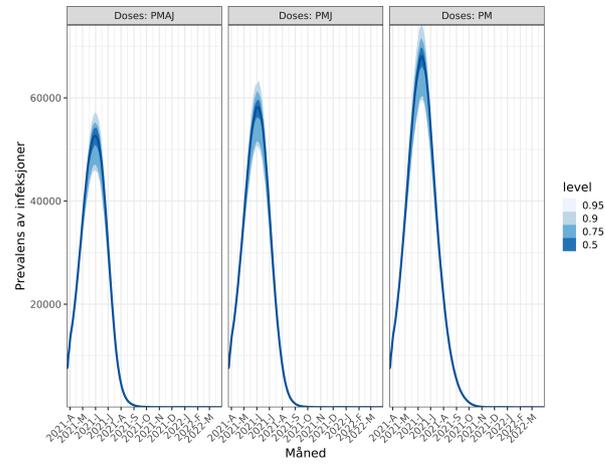
We use data from the Norwegian Immunisation Registry (SYSVAK) on the number of vaccinations carried out up to 22 March 2021. Vaccine deliveries in the future are based on the Norwegian Institute of Public Health’s realistic (“nøktern”) scenario, updated 19 March 2021. The vaccine uptake is assumed to be 90% in all age groups 16 years and above. We assume 6 weeks interval between the first and second dose for the mRNA vaccines and 12 weeks interval for the AstraZeneca vaccine. The following vaccine efficacy (VE) is used 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. People who are vaccinated and get infected are assumed to transmit 40% less than those who have not been vaccinated.

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>.

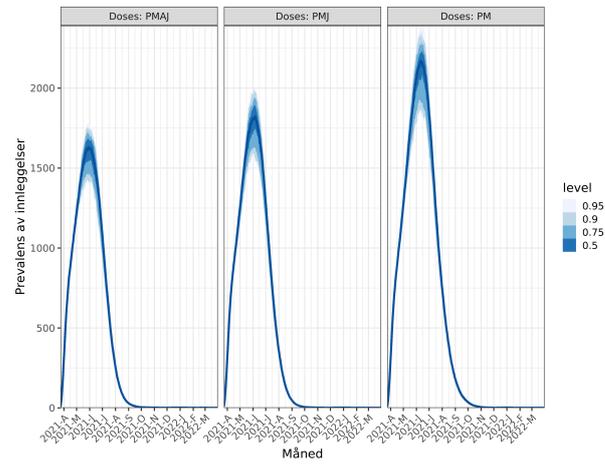
Table 4: Estimated peak prevalence of infections, hospitalisations and ventilator beds

	PMAJ scenario	PMJ scenario	PM scenario
Prevalence	52206 (45903-57398)	57557 (50270-63591)	67359 (59348-74288)
Hospital beds	1649 (1453-1824)	1838 (1609-2029)	2175 (1892-2433)
Ventilator beds	229 (194-260)	254 (219-293)	299 (256-341)

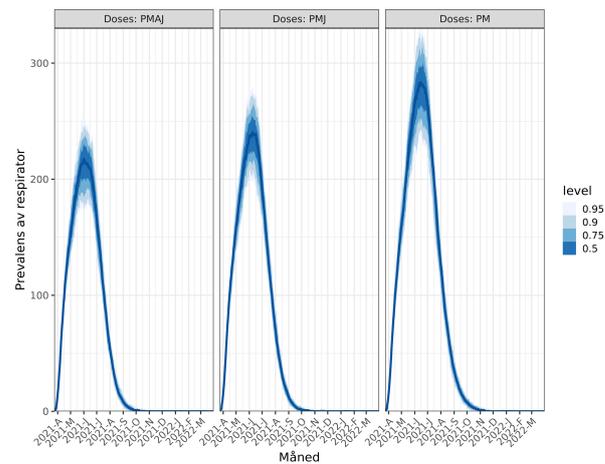
Given the current epidemiological situation and assuming no change in the interventions or seasonal effects, the epidemic is expected to peak in late May to early June. None of the scenarios exceed a surge capacity need of **500 ICU** ventilator beds (Table 4).



(a)



(b)



(c)

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

## **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 5). 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 interquartile 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 5: Estimated current regional reproduction numbers

R	Parameter	County	From	Pr(R>1)
1.31 (1.03-1.59)	R9	Oslo	2021-03-02	0.99
2.1 (1.36-2.85)	R8	Rogaland	2021-02-20	1
0.8 (0.16-1.45)	R7	Møre og Romsdal	2021-02-05	0.27
1.09 (0.46-1.73)	R10	Nordland	2021-02-20	0.62
1.47 (1.3-1.65)	R9	Viken	2021-02-22	1
0.63 (0.23-1.02)	R9	Innlandet	2021-02-05	0.03
1.62 (1.2-2)	R9	Vestfold og Telemark	2021-02-22	1
0.85 (0.32-1.45)	R8	Agder	2021-02-20	0.29
0.95 (0.64-1.26)	R9	Vestland	2021-02-05	0.4
0.61 (0.09-1.17)	R7	Trøndelag	2021-02-05	0.08
1.2 (0.34-1.98)	R8	Troms og Finnmark	2021-02-20	0.7

Mean and 95% credible intervals

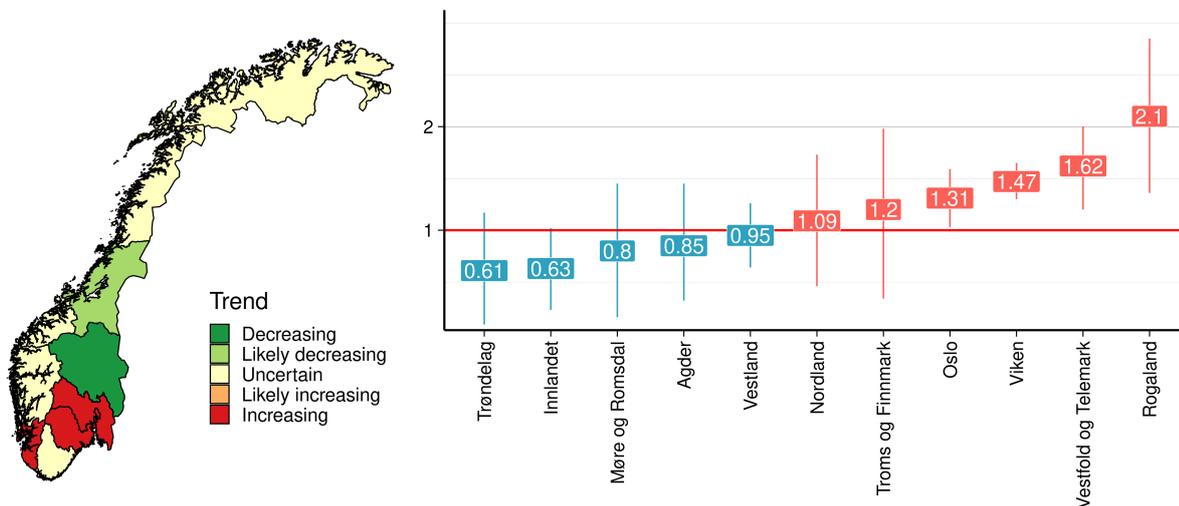
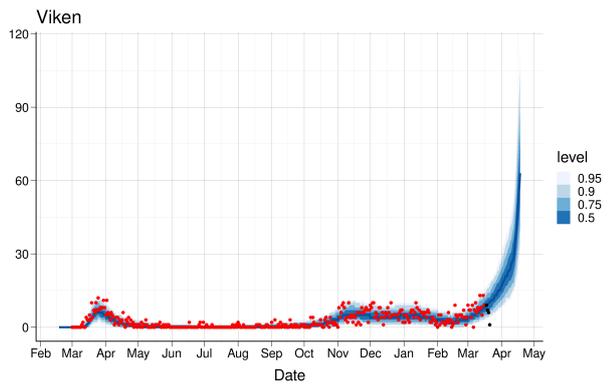
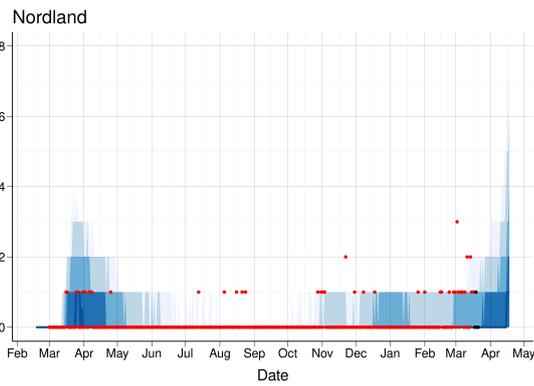
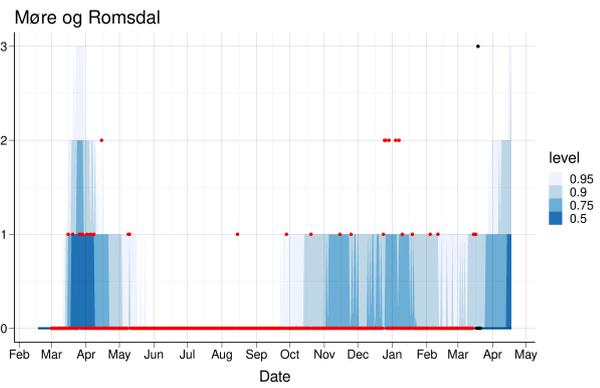
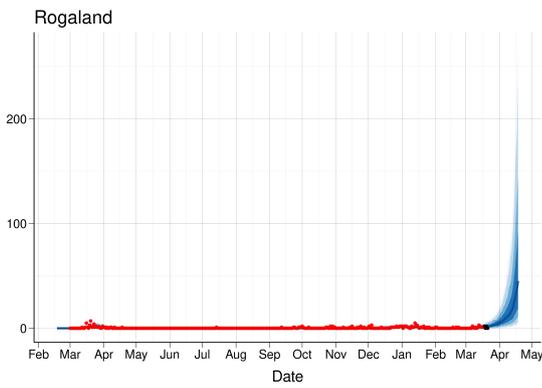
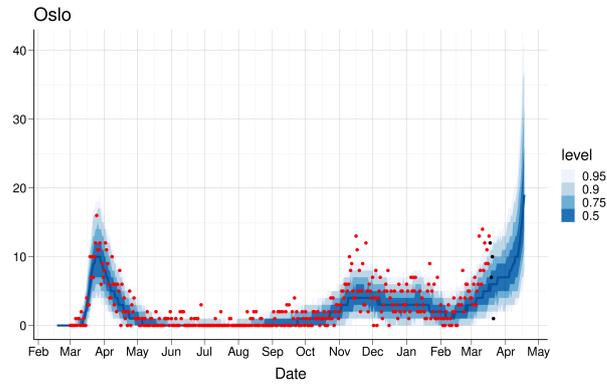
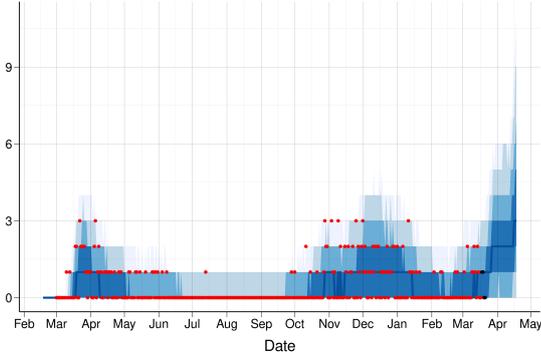


Figure 7: The map shows the direction of the trend in incidence in the counties based on the latest reproduction numbers shown in the other chart. The trend is increasing if the probability that the latest reproduction number is above one is above 95%, the trend is likely increasing if this probability 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%.

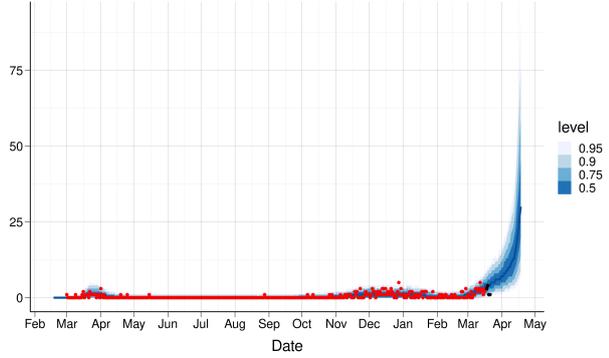
**Estimated vs observed hospital incidence data by county:**



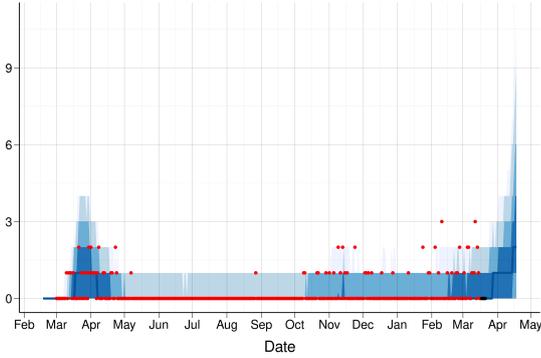
Innlandet



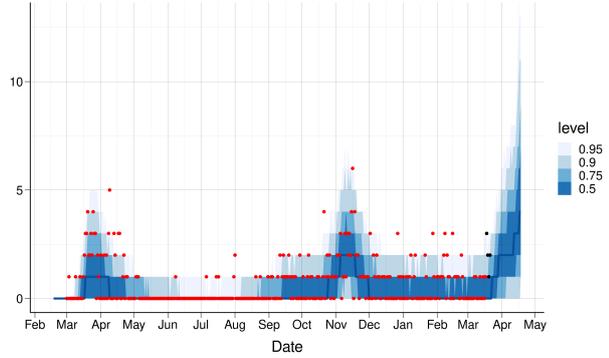
Vestfold og Telemark



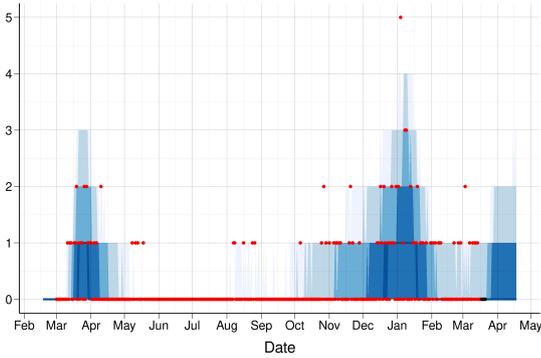
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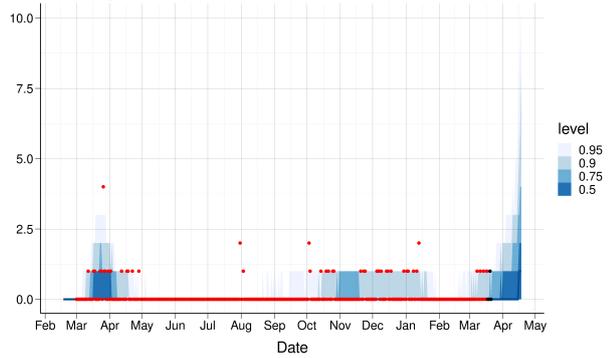
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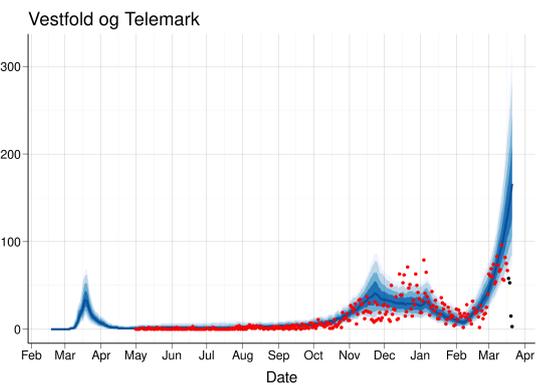
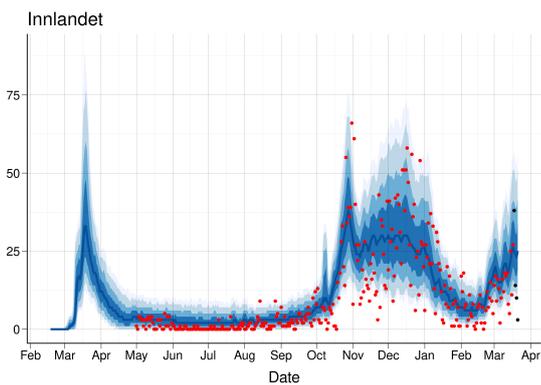
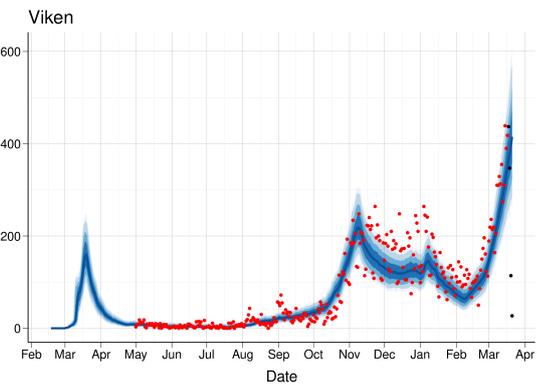
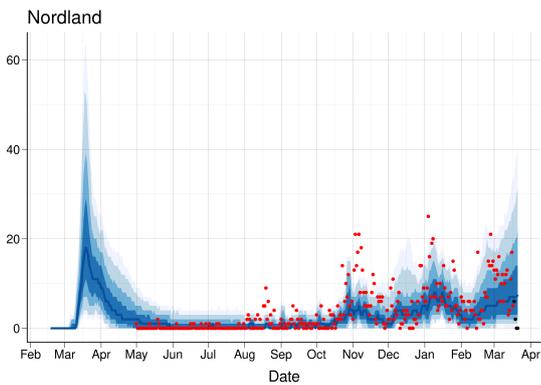
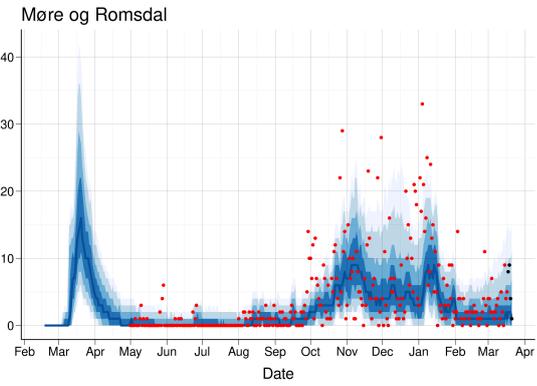
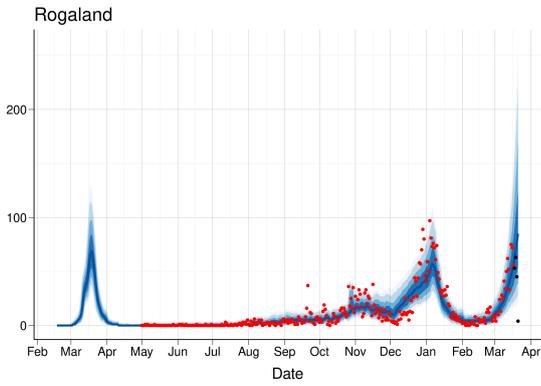
Trøndelag

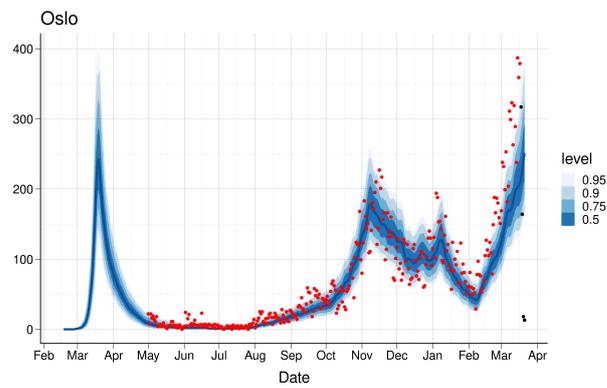
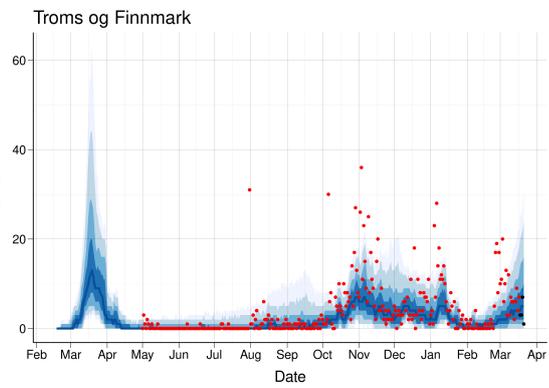
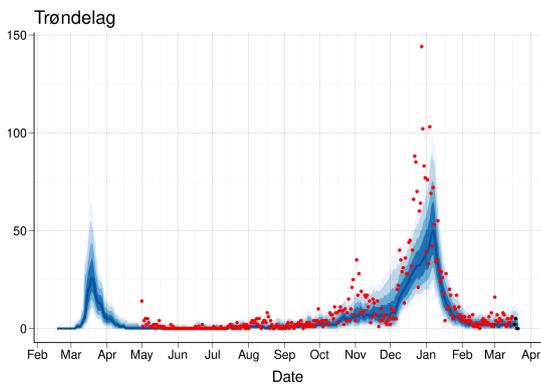
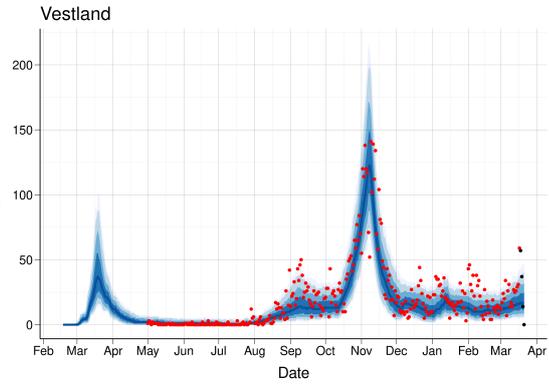
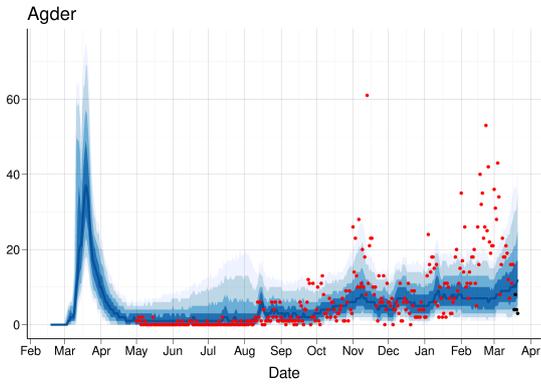


Troms og Finnmark



**Estimated and observed lab-confirmed test data by county:**





## 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 6), daily incidence (table 7) and prevalence (table 8) for each county.

Table 6: Estimated cumulative number of infections, 2021-03-21

Region	Total	No. confirmed	Fraction reported	Min. fraction
Oslo	13997 (9915; 19080)	11327	81%	59%
Rogaland	3132 (1581; 5924)	1994	64%	34%
Møre og Romsdal	419 (193; 1003)	446	106%	44%
Nordland	774 (286; 1801)	635	82%	35%
Viken	19027 (13371; 26182)	13289	70%	51%
Innlandet	1841 (1105; 2873)	947	51%	33%
Vestfold og Telemark	5612 (3334; 8582)	2570	46%	30%
Agder	1086 (551; 2082)	1300	120%	62%
Vestland	1773 (935; 3165)	1692	95%	53%
Trøndelag	1207 (583; 2115)	1095	91%	52%
Troms og Finnmark	363 (165; 897)	433	119%	48%

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

Table 7: Predicted incidence per day: Median/Mean (CI)

Region	1 week prediction (28 Mar)	2 weeks prediction (04 Apr)	3 weeks prediction (11 Apr)
Agder	41/46 (13-114)	47/57 (11-160)	66/83 (15-242)
Innlandet	85/89 (39-166)	75/82 (29-182)	83/92 (30-206)
Møre og Romsdal	9/12 (2-40)	8/13 (0-50)	7/14 (0-68)
Nordland	20/26 (4-80)	22/33 (3-119)	25/44 (2-180)
Oslo	383/398 (210-677)	489/525 (242-985)	640/699 (306-1351)
Rogaland	310/404 (71-1239)	636/910 (104-3288)	1262/1956 (134-7434)
Troms og Finnmark	18/24 (3-78)	22/35 (2-147)	27/53 (2-240)
Trøndelag	16/18 (4-42)	11/14 (1-47)	9/13 (0-54)
Vestfold og Telemark	340/366 (138-724)	522/574 (175-1320)	772/882 (209-2215)
Vestland	78/82 (34-153)	85/93 (31-197)	106/121 (31-303)
Viken	986/1006 (618-1558)	1340/1378 (774-2210)	1806/1873 (976-3256)

Table 8: 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	28 Mar	04 Apr	11 Apr	low CI, 11 Apr	high CI, 11 Apr
Agder	244/271	280.5/328	420/502	127	1324
Innlandet	576/595	493/529	556/606	249	1245
Møre og Romsdal	65/78	56/79	48.5/86	8	355
Nordland	118.5/148	129/184	150/243	26	908
Oslo	2082/2161	2669.5/2823	3401.5/3718	1651	7260
Rogaland	1446/1836	2961.5/4117	5968.5/8900	742	32496
Troms og Finnmark	98/127	122/182	159.5/277	23	1153
Trøndelag	120/130	93/110	94/118	29	338
Vestfold og Telemark	1762.5/1878	2708.5/2947	4075.5/4541	1169	11006
Vestland	476/494	525.5/565	692.5/786	247	1851
Viken	5328.5/5430	7218/7455	9786.5/10099	5387	16652

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

Below is shown the estimated short-term forecasting of expected hospital prevalence (table 9) and patients on ventilator treatment for each county (table 10).

Table 9: Number of hospitalisation beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (28 Mar)	2 weeks prediction (04 Apr)	3 weeks prediction (11 Apr)
Agder	4/5 (0-13)	6/7 (1-19)	7/9 (1-24)
Innlandet	9/11 (3-22)	14/15 (4-31)	17/17 (4-37)
Møre og Romsdal	1/1 (0-5)	1/2 (0-7)	1/2 (0-10)
Nordland	2/3 (0-10)	2/3 (0-13)	3/4 (0-18)
Oslo	51/52 (27-83)	58/60 (32-100)	70/73 (34-129)
Rogaland	17/21 (4-56)	36/45 (7-135)	73/101 (11-353)
Troms og Finnmark	1/1 (0-7)	1/2 (0-10)	2/4 (0-16)
Trøndelag	1/2 (0-6)	2/3 (0-9)	2/3 (0-11)
Vestfold og Telemark	39/41 (15-76)	52/56 (20-108)	77/84 (26-178)
Vestland	7/8 (1-19)	13/14 (4-28)	16/18 (4-40)
Viken	89/92 (53-140)	125/127 (76-198)	174/177 (100-286)

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

Region	1 week prediction (28 Mar)	2 weeks prediction (04 Apr)	3 weeks prediction (11 Apr)
Agder	0/1 (0-3)	1/1 (0-4)	1/1 (0-4)
Innlandet	1/1 (0-4)	2/2 (0-6)	3/3 (0-8)
Møre og Romsdal	0/0 (0-1)	0/0 (0-2)	0/0 (0-2)
Nordland	0/0 (0-2)	0/1 (0-3)	0/1 (0-3)
Oslo	9/9 (3-16)	10/11 (4-19)	12/13 (4-23)
Rogaland	2/3 (0-8)	5/6 (0-17)	9/13 (1-42)
Troms og Finnmark	0/0 (0-1)	0/0 (0-2)	0/1 (0-3)
Trøndelag	0/0 (0-1)	0/0 (0-2)	0/1 (0-3)
Vestfold og Telemark	6/6 (1-13)	8/9 (2-18)	12/13 (3-27)
Vestland	1/1 (0-4)	2/2 (0-5)	2/3 (0-8)
Viken	14/14 (6-24)	19/20 (10-32)	27/27 (14-46)

Table 11: Trend analysis for the last 14 days

County	Average daily increase last 14 days		Doubling Time (days)	
	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 11 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 1.40; 1.45 and 1.50 from today, respectively. In these scenarios we assume no change to the reproductive numbers in the other counties. Table 12 and Figure compares these projected scenarios with a projection of the current epidemiological situation in Oslo.

Table 12: 4 week predictions in Oslo: Prevalence and Incidence (mean/median(CI))

Scenario	Prevalence	Incidence
Current	4543/4474 (2902-6615)	857/842 (558-1303)
R=1.40	4861/4802 (3197-7397)	919/911 (616-1396)
R=1.45	5322/5217 (3519-7892)	1012/991 (670-1510)
R=1.50	5747/5682 (3784-8614)	1095/1082 (704-1621)

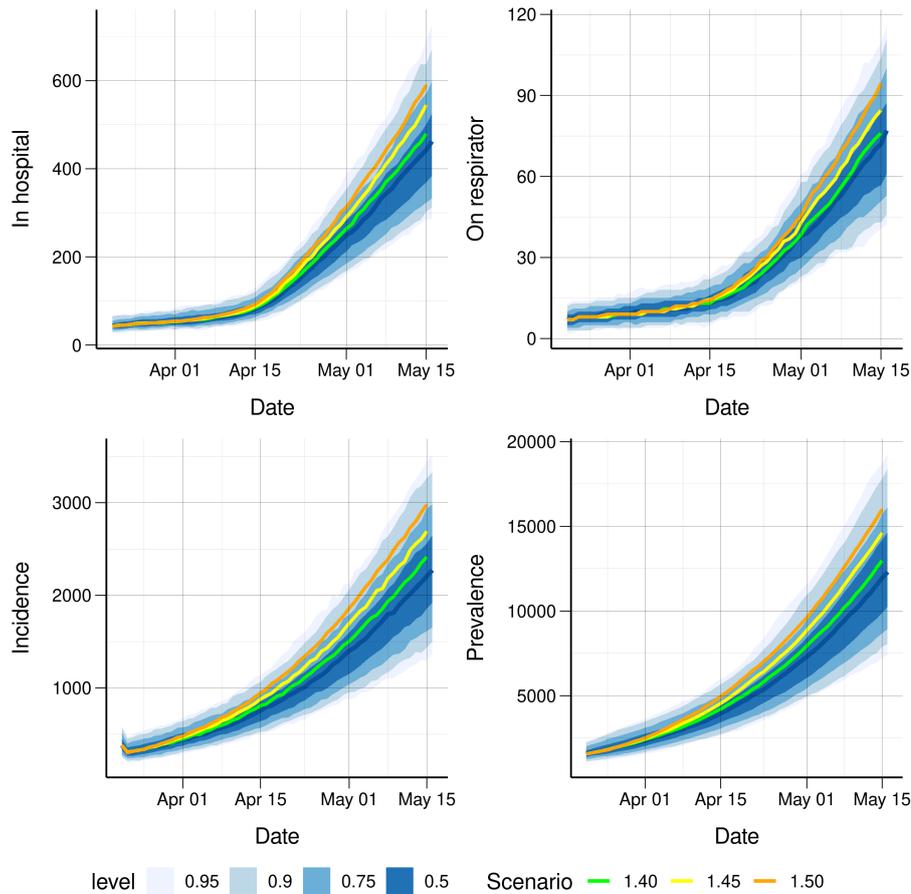


Figure 18: Future predictions for Oslo assuming the reproductive number will remain constant vs alternative scenarios. Confidence intervals correspond to "current scenario". Parameters showed are: Hospitalisations (top left), On respirator (top right), Incidence (bottom left) and Prevalence (bottom right).

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

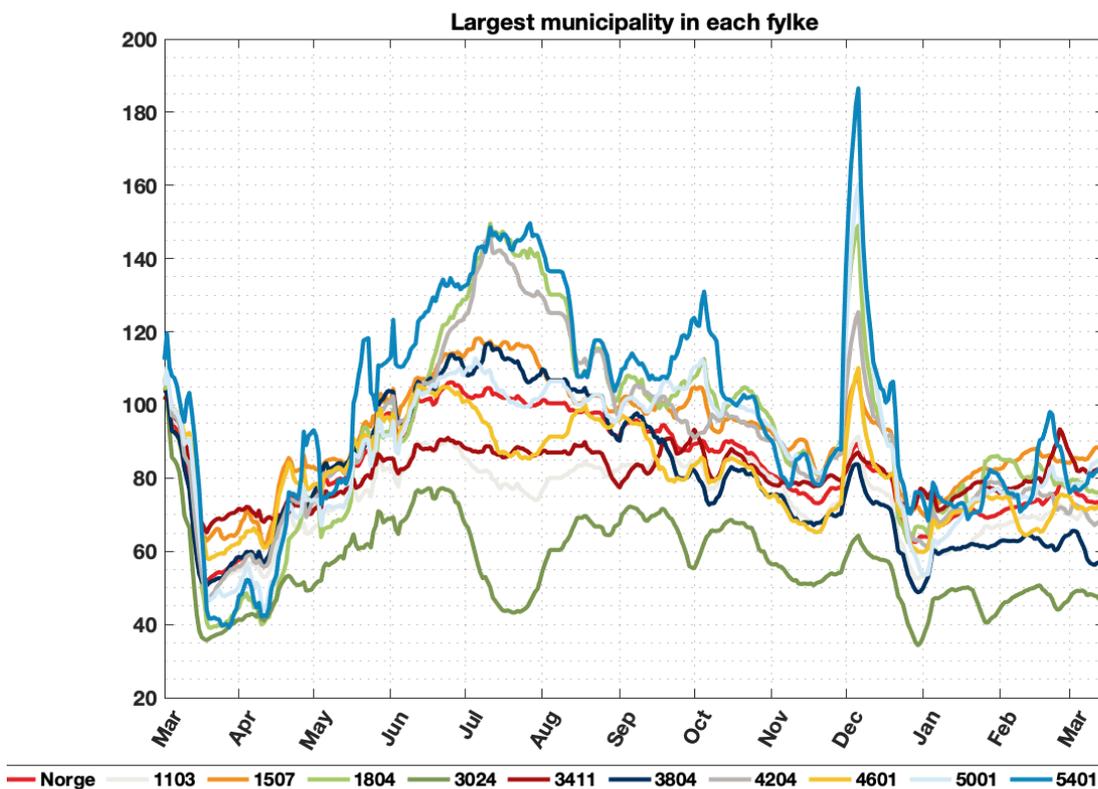


Figure 19: Mobility for selected municipalities since March 2020: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

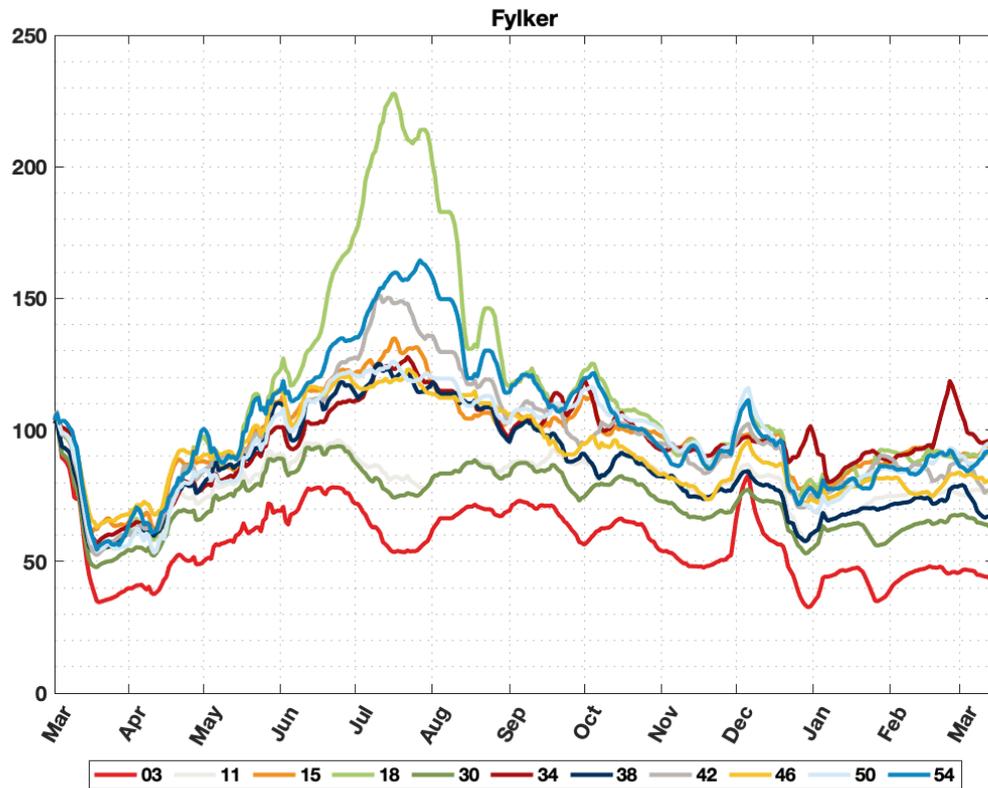


Figure 20: Mobility for fylker since March 2020: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

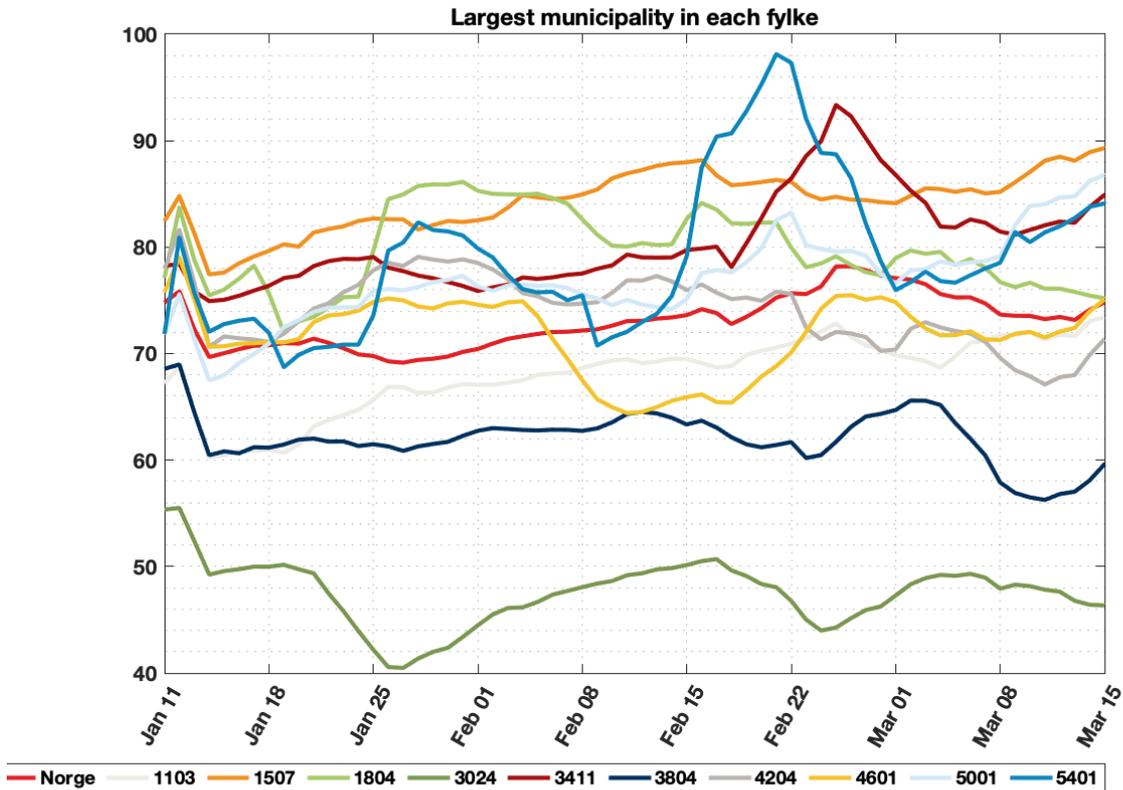


Figure 21: Zoom: Mobility from January 11, 2021 and onwards: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

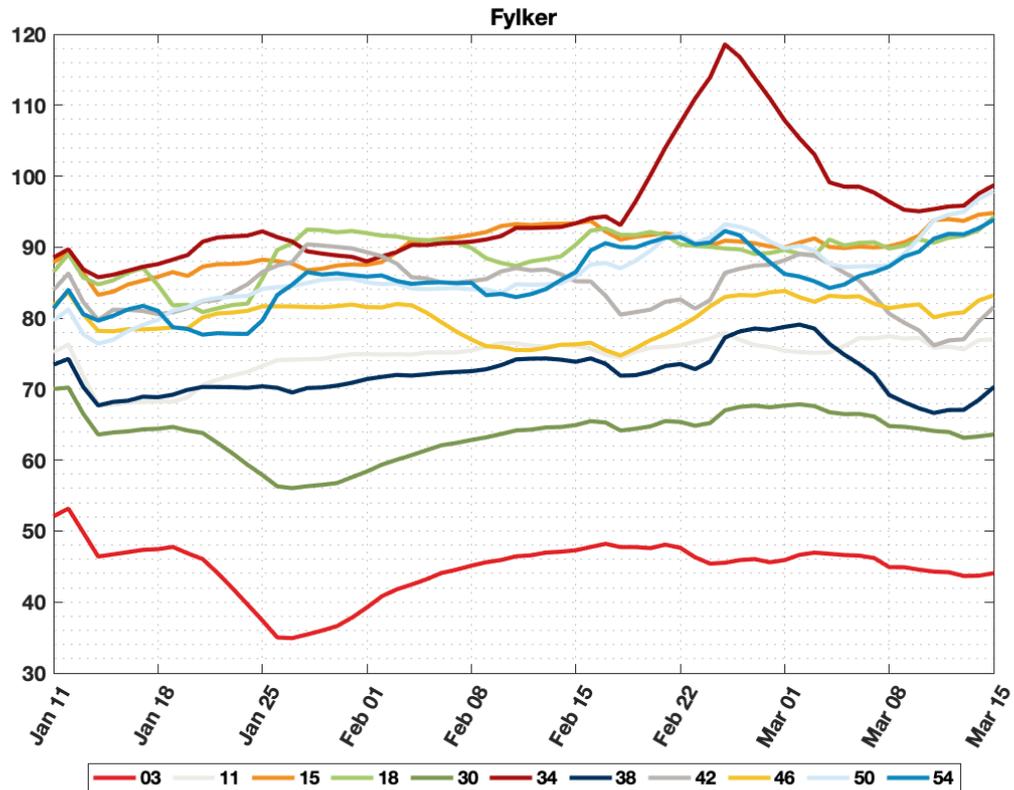


Figure 22: Zoom: Mobility from January 11, 2021 and onwards, per fylker: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finnmark (54).

	8	9	10	11	12
Norge	73.6	75.7	77.1	73.7	74.8
Stavanger	69.5	70.9	69.8	71.7	73.4
Ålesund	88.0	86.1	84.1	85.2	89.3
Bodø	82.7	80.0	79.0	76.7	75.2
Bærum	50.1	46.8	47.3	47.9	46.3
Ringsaker	79.7	86.4	86.8	81.5	84.9
Sandefjord	63.4	61.7	64.7	57.9	59.6
Kristiansand	76.0	75.6	70.4	69.6	71.4
Bergen	65.9	70.1	74.8	71.3	75.1
Trondheim	75.1	83.2	76.6	79.2	86.8
Tromsø	79.2	97.3	76.0	78.5	84.1

Table 13: Municipalities

	8	9	10	11	12
Oslo	47.3	47.6	45.9	44.9	44.1
Rogaland	76.1	76.2	75.4	77.4	77.0
Møre og Romsdal	93.4	91.6	90.0	90.1	94.8
Nordland	90.3	90.4	89.6	89.8	94.2
Viken	64.9	65.4	67.7	64.8	63.6
Innlandet	93.4	107.5	107.8	96.4	98.7
Vestfold og Telemark	73.8	73.5	78.8	69.2	70.2
Agder	85.2	82.6	88.2	80.6	81.5
Vestlandet	76.3	78.8	83.8	81.4	83.2
Trøndelag	85.9	91.9	89.8	87.4	97.8
Troms og Finnmark	86.5	91.4	86.2	87.3	93.8

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.

12.1 Foreign roamers on Telenor’s network in Norway

**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 23 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 24 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.

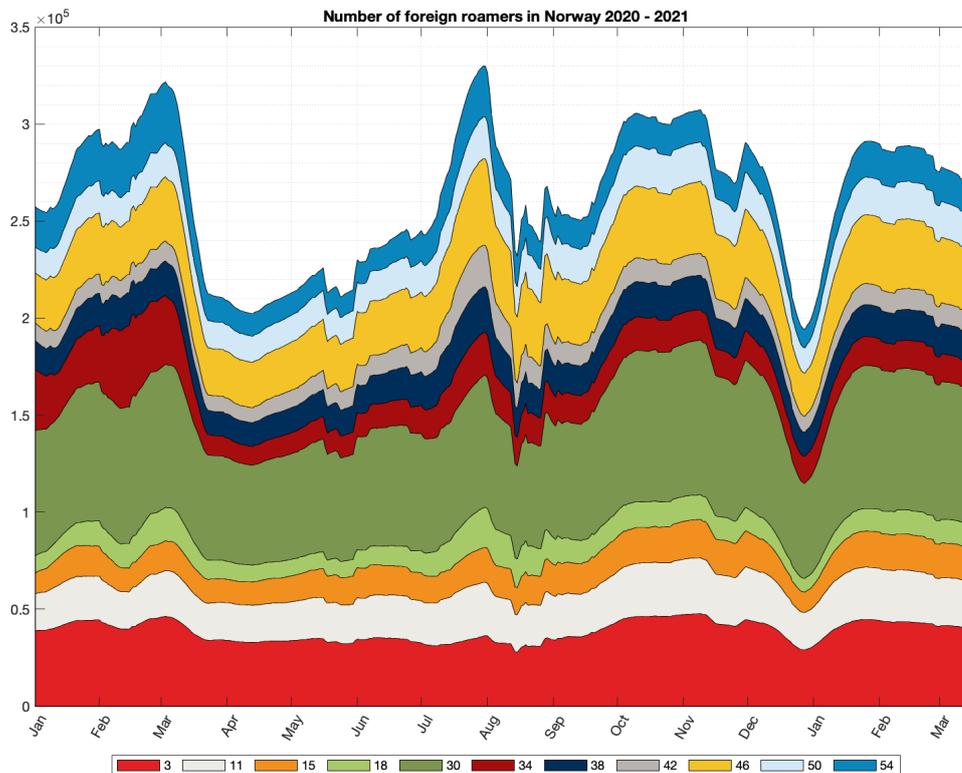


Figure 23: The total number of foreign roamers in Norway broken down on different fylker: Oslo (3), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

12.1 Foreign roamers on Telenor's network in Norway

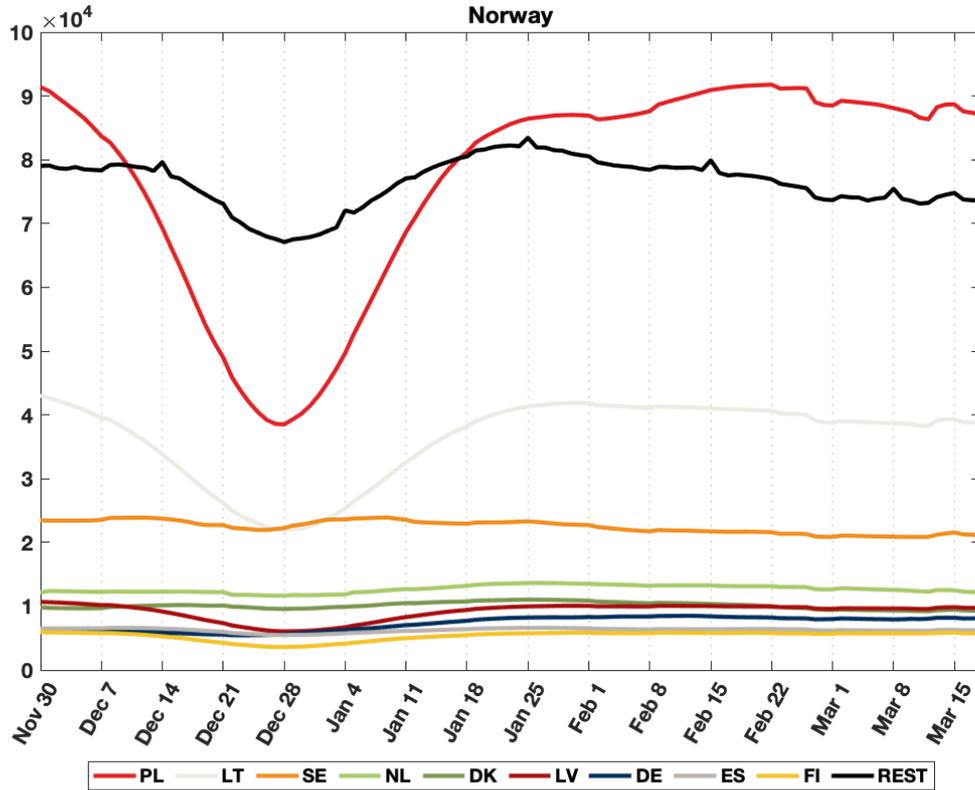
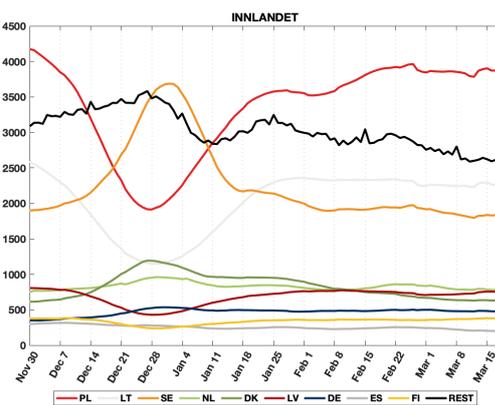
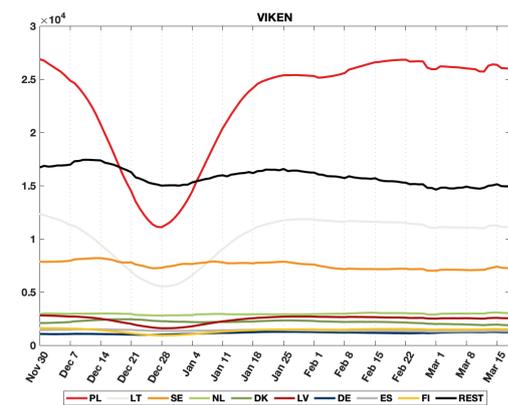
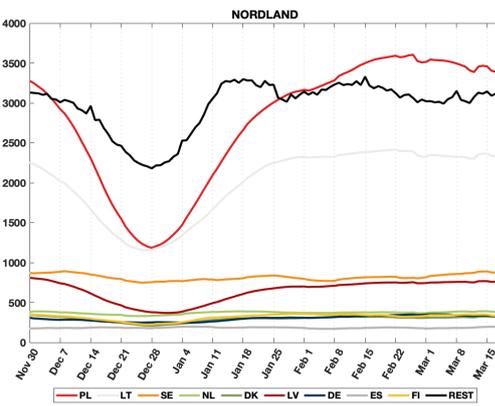
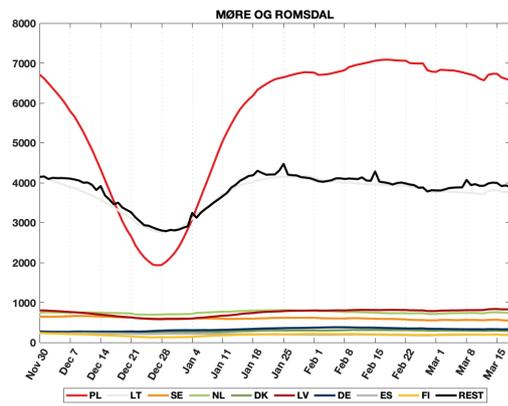
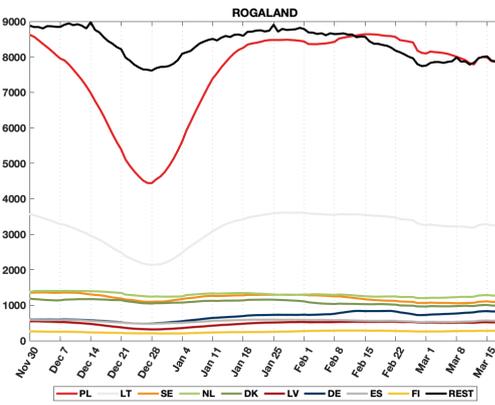
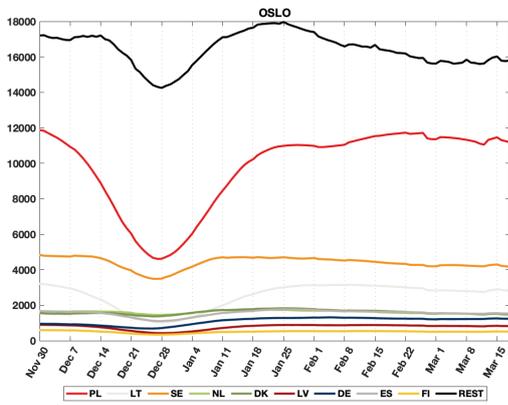


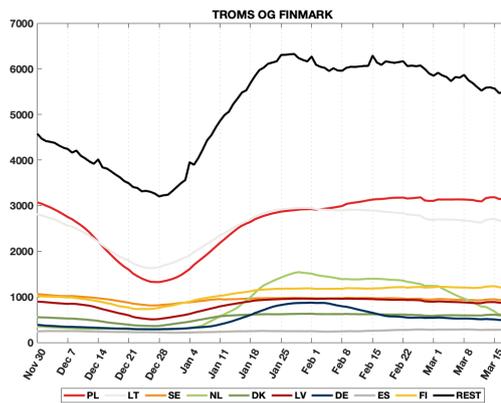
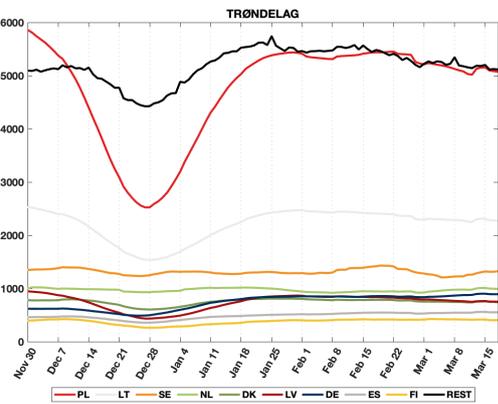
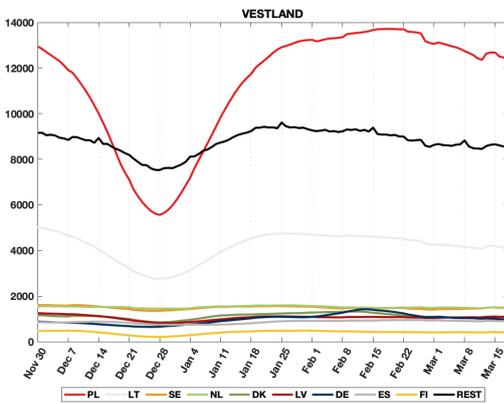
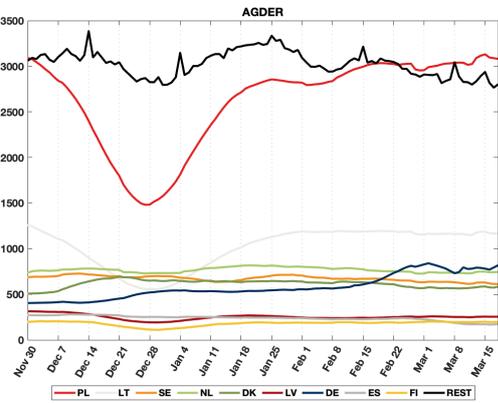
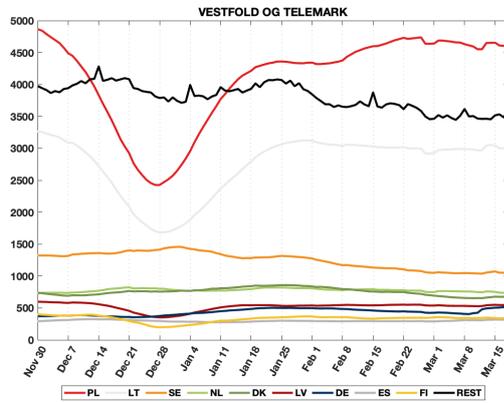
Figure 24: National overview of total number of foreign, visiting roamers from Poland, Lithuania, Sweden, Netherlands, Denmark, Latvia, Germany, Spain, Finland and the rest of the world.

12.2 Foreign roamers per county (fylke) in Norway

12.2 Foreign roamers per county (fylke) in Norway



## 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 27.

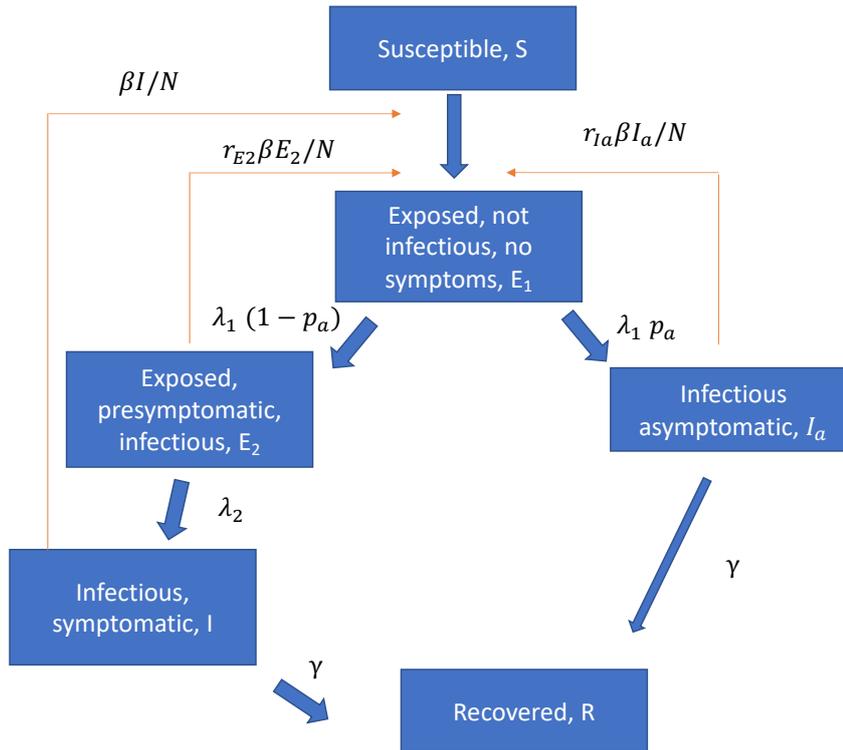


Figure 27: Schematic overview of the model.

### 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

### 13.3 Healthcare utilisation

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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

### 13.6 Specifications for the national changepoint model

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success probability  $\pi_t$ , 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  $\pi_0$  and  $\pi_1$  are two parameters that we estimate, assuming positivity of  $\pi_1$ . 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 28, 29 and 30 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.

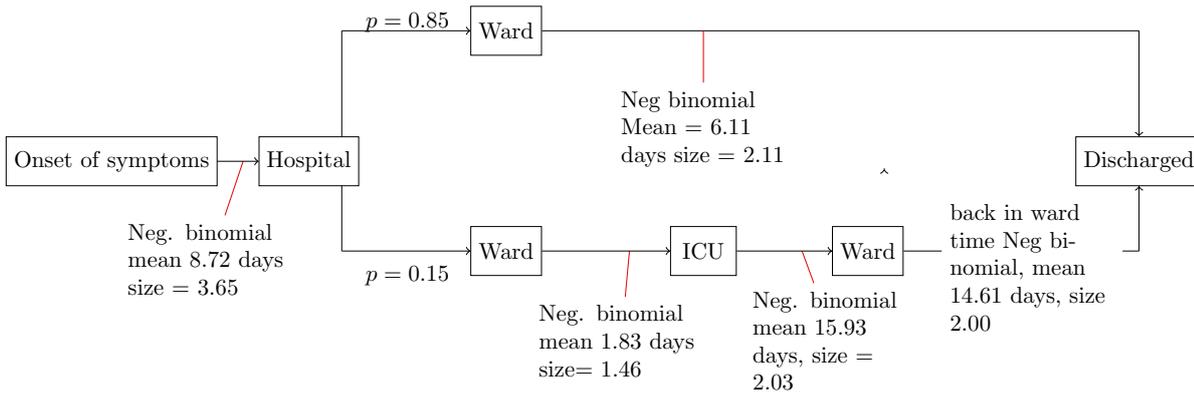


Figure 28: Hospital assumptions and parameters used before 1 June 2020

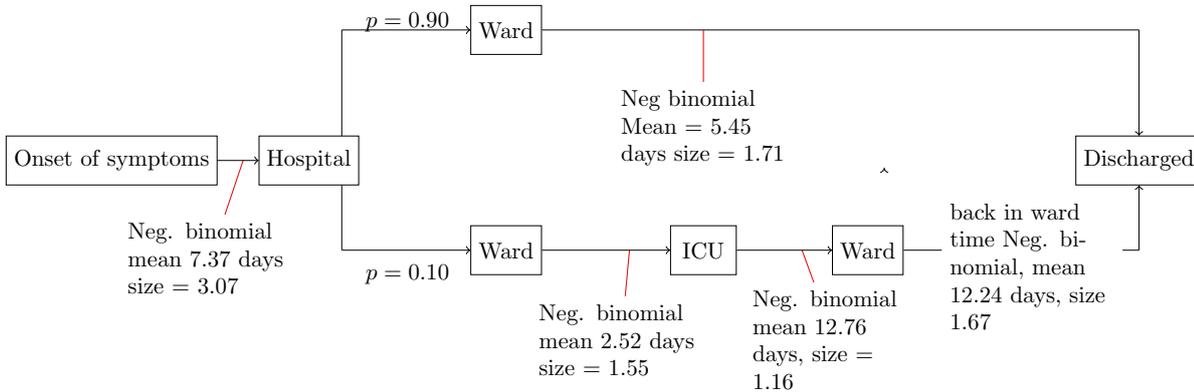


Figure 29: Hospital assumptions and parameters used between 1 June 2020 and 1 January 2021

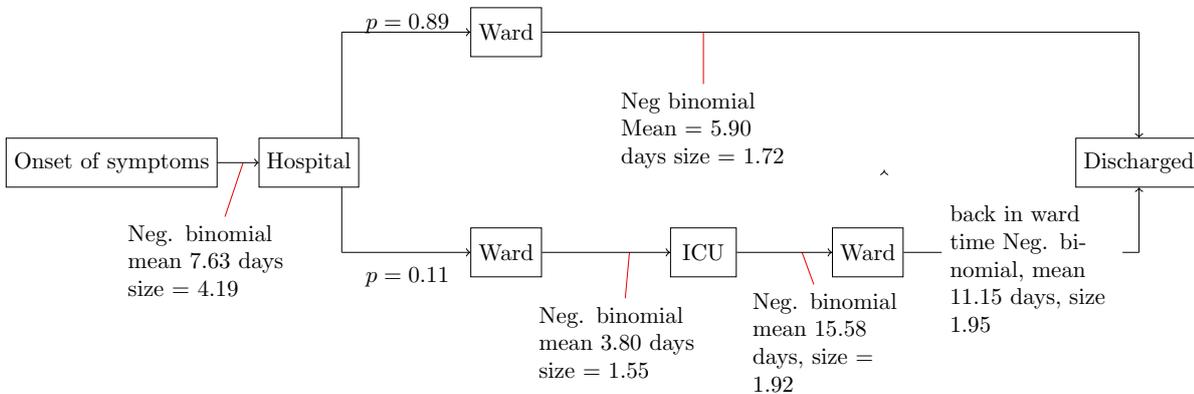


Figure 30: Hospital assumptions and parameters used from 1 January 2021

Table 15: Estimated parameters

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Period
R0s	2.357	2.882	3.172	3.177	3.421	4.251	Until March 14
R1s	0.314	0.46	0.497	0.497	0.535	0.646	From 15 March to 19 April
R2s	0.04	0.42	0.591	0.581	0.724	1.223	From 20 April to 10 May
R3s	0.049	0.468	0.652	0.649	0.819	1.315	From 11 May to 30 June
R4s	0.069	0.632	0.888	0.888	1.144	1.701	From 01 July to 31 July
R5s	0.653	1.012	1.095	1.097	1.181	1.594	From 01 August to 31 August
R6s	0.589	0.834	0.913	0.914	0.986	1.212	From 01 September to 30 September
R7s	1.035	1.217	1.279	1.283	1.344	1.533	From 01 October to 25 October
R8s	0.988	1.217	1.309	1.31	1.395	1.682	From 26 October to 04 November
R9s	0.72	0.768	0.791	0.793	0.815	0.879	From 05 November to 30 November
R10s	1.017	1.058	1.079	1.079	1.098	1.137	From 01 December to 03 January
R11s	0.462	0.568	0.602	0.602	0.635	0.724	From 04 January to 21 January
R12s	0.668	0.822	0.85	0.857	0.901	1.03	From 22 January to 07 February
R13s	1.228	1.337	1.386	1.386	1.43	1.552	From 08 February to 01 March
R14s	1.094	1.253	1.295	1.303	1.36	1.56	From 02 March
AMPs	1.004	1.705	1.974	2.037	2.339	3.378	-
$\pi_0$	-0.612	-0.044	0.168	0.118	0.282	0.573	-
$\pi_1$	4.0e-08	8.5e-06	1.8e-05	2.2e-05	3.4e-05	9.4e-05	-
delays	1	2	3	2.925	4	4	-

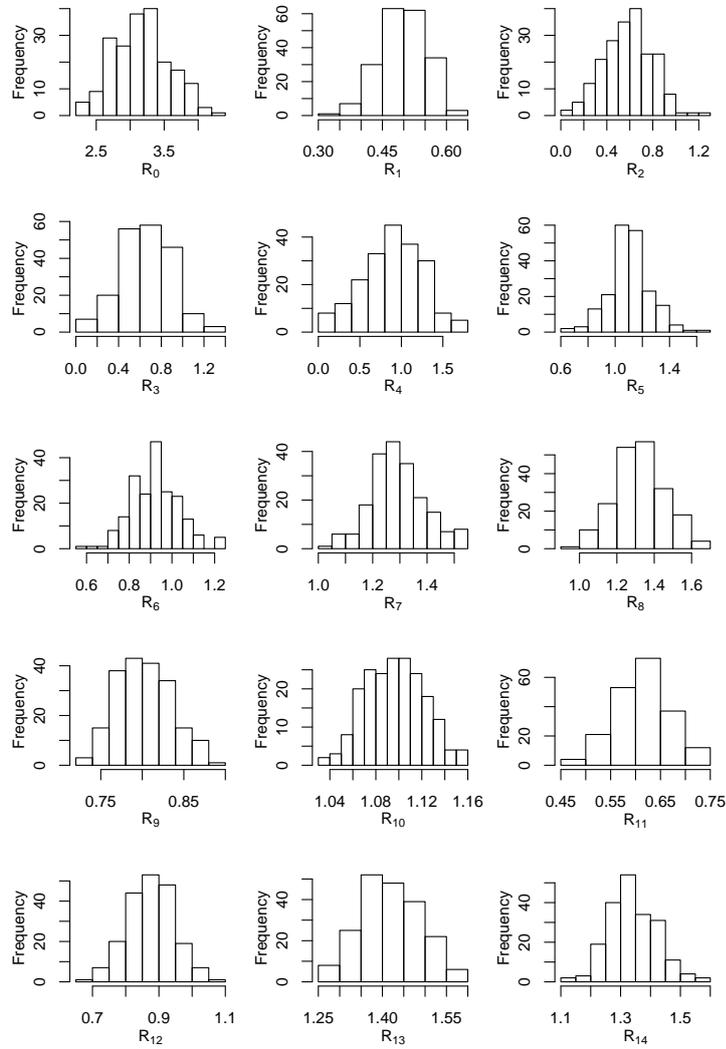


Figure 31: Estimated densities of the reproduction numbers. National model

Table 16

R	Parameter	County	From	To	Pr(R>1)
5.61 (4.98-6.02)	R0	Oslo	2020-02-17	2020-03-14	1
3.52 (2.78-4.12)	R0	Rogaland	2020-02-17	2020-03-14	1
3.22 (1.71-4.65)	R0	Møre og Romsdal	2020-02-17	2020-03-14	1
3.29 (1.14-5.69)	R0	Nordland	2020-02-17	2020-03-14	0.98
3.6 (2.7-4.3)	R0	Viken	2020-02-17	2020-03-14	1
2.94 (1.44-4.82)	R0	Innlandet	2020-02-17	2020-03-14	0.99
3.43 (2-4.6)	R0	Vestfold og Telemark	2020-02-17	2020-03-14	1
2.73 (1.65-3.75)	R0	Agder	2020-02-17	2020-03-14	1
2.83 (1.86-4.12)	R0	Vestland	2020-02-17	2020-03-14	1
3.87 (2.38-5.16)	R0	Trøndelag	2020-02-17	2020-03-14	1
2.66 (1.56-3.92)	R0	Troms og Finnmark	2020-02-17	2020-03-14	1
0.6 (0.5-0.74)	R1	Oslo	2020-03-15	2020-04-19	0
0.48 (0.16-1.01)	R2	Oslo	2020-04-20	2020-07-24	0.03
1.31 (1.22-1.41)	R3	Oslo	2020-07-25	2020-09-30	1
1.49 (1.41-1.56)	R4	Oslo	2020-10-01	2020-11-04	1
1.03 (0.96-1.1)	R5	Oslo	2020-11-05	2020-12-14	0.79
1.32 (1.15-1.51)	R6	Oslo	2020-12-15	2021-01-03	1
0.76 (0.66-0.87)	R7	Oslo	2021-01-04	2021-02-04	0
1.64 (1.5-1.78)	R8	Oslo	2021-02-05	2021-03-01	1
1.31 (1.03-1.59)	R9	Oslo	2021-03-02		0.99
0.05 (0.01-0.12)	R1	Rogaland	2020-03-15	2020-04-19	0
0.8 (0.4-1.11)	R2	Rogaland	2020-04-20	2020-08-31	0.17
0.83 (0.62-1.03)	R3	Rogaland	2020-09-01	2020-11-04	0.04
0.72 (0.28-1.11)	R4	Rogaland	2020-11-05	2020-11-30	0.07
1.35 (1.11-1.6)	R5	Rogaland	2020-12-01	2021-01-03	1
0.32 (0.08-0.54)	R6	Rogaland	2021-01-04	2021-01-31	0
0.85 (0.28-1.41)	R7	Rogaland	2021-02-01	2021-02-19	0.31
2.1 (1.36-2.85)	R8	Rogaland	2021-02-20		1
0.38 (0.09-0.64)	R1	Møre og Romsdal	2020-03-15	2020-04-19	0
0.64 (0.29-0.98)	R2	Møre og Romsdal	2020-04-20	2020-09-14	0.02
0.74 (0.33-1.05)	R3	Møre og Romsdal	2020-09-15	2020-11-04	0.05
0.53 (0.11-1.12)	R4	Møre og Romsdal	2020-11-05	2020-12-14	0.05
0.7 (0.04-1.4)	R5	Møre og Romsdal	2020-12-15	2021-01-03	0.23
0.35 (0.03-0.72)	R6	Møre og Romsdal	2021-01-04	2021-02-04	0
0.8 (0.16-1.45)	R7	Møre og Romsdal	2021-02-05		0.27
0.53 (0.12-0.89)	R1	Nordland	2020-03-15	2020-04-19	0
0.79 (0.51-1.07)	R2	Nordland	2020-04-20	2020-07-24	0.06
0.52 (0.02-1.44)	R3	Nordland	2020-07-25	2020-08-14	0.1
0.62 (0.25-1.01)	R4	Nordland	2020-08-15	2020-10-04	0.04
0.66 (0.25-1.11)	R5	Nordland	2020-10-05	2020-11-04	0.06
0.45 (0.02-1.21)	R6	Nordland	2020-11-05	2020-12-14	0.07
0.84 (0.04-1.63)	R7	Nordland	2020-12-15	2021-01-03	0.33
0.48 (0.12-0.85)	R8	Nordland	2021-01-04	2021-02-04	0
1.53 (0.63-2.4)	R9	Nordland	2021-02-05	2021-02-19	0.86
1.09 (0.46-1.73)	R10	Nordland	2021-02-20		0.62
0.29 (0.15-0.41)	R1	Viken	2020-03-15	2020-04-19	0
0.84 (0.4-1.13)	R2	Viken	2020-04-20	2020-07-24	0.23
1.08 (0.96-1.18)	R3	Viken	2020-07-25	2020-10-09	0.94
1.46 (1.38-1.53)	R4	Viken	2020-10-10	2020-11-04	1
0.8 (0.72-0.89)	R5	Viken	2020-11-05	2020-11-30	0
0.94 (0.86-1.01)	R6	Viken	2020-12-01	2021-01-03	0.06
0.81 (0.72-0.9)	R7	Viken	2021-01-04	2021-02-04	0
1.19 (1-1.38)	R8	Viken	2021-02-05	2021-02-21	0.97
1.47 (1.3-1.65)	R9	Viken	2021-02-22		1

Mean and 95% credible intervals

Table 17

R	Parameter	County	From	To	Pr(R>1)
0.49 (0.09-0.82)	R1	Innlandet	2020-03-15	2020-04-19	0
0.96 (0.67-1.18)	R2	Innlandet	2020-04-20	2020-07-24	0.44
0.84 (0.58-1.04)	R3	Innlandet	2020-07-25	2020-10-09	0.08
1.62 (1.01-2.1)	R4	Innlandet	2020-10-10	2020-10-24	0.98
0.52 (0.18-0.94)	R5	Innlandet	2020-10-25	2020-11-04	0.01
0.85 (0.39-1.13)	R6	Innlandet	2020-11-05	2020-12-14	0.21
0.53 (0.05-1.01)	R7	Innlandet	2020-12-15	2021-01-03	0.03
0.44 (0.12-0.78)	R8	Innlandet	2021-01-04	2021-02-04	0
0.63 (0.23-1.02)	R9	Innlandet	2021-02-05		0.03
0.19 (0.07-0.31)	R1	Vestfold og Telemark	2020-03-15	2020-04-19	0
0.94 (0.56-1.23)	R2	Vestfold og Telemark	2020-04-20	2020-07-24	0.38
0.76 (0.49-0.94)	R3	Vestfold og Telemark	2020-07-25	2020-10-09	0.01
0.81 (0.51-1.12)	R4	Vestfold og Telemark	2020-10-10	2020-11-04	0.09
1.15 (0.37-1.7)	R5	Vestfold og Telemark	2020-11-05	2020-11-19	0.72
0.85 (0.61-1.06)	R6	Vestfold og Telemark	2020-11-20	2021-01-03	0.07
0.56 (0.3-0.82)	R7	Vestfold og Telemark	2021-01-04	2021-02-04	0
1.61 (1.04-2.2)	R8	Vestfold og Telemark	2021-02-05	2021-02-21	0.98
1.62 (1.2-2)	R9	Vestfold og Telemark	2021-02-22		1
0.37 (0.09-0.58)	R1	Agder	2020-03-15	2020-04-19	0
0.89 (0.46-1.29)	R2	Agder	2020-04-20	2020-07-31	0.35
0.74 (0.39-1.14)	R3	Agder	2020-08-01	2020-09-19	0.06
0.88 (0.4-1.34)	R4	Agder	2020-09-20	2020-10-09	0.24
0.83 (0.4-1.52)	R5	Agder	2020-10-10	2020-11-04	0.22
0.53 (0.1-0.9)	R6	Agder	2020-11-05	2021-01-03	0
0.92 (0.75-1.07)	R7	Agder	2021-01-04	2021-02-19	0.15
0.85 (0.32-1.45)	R8	Agder	2021-02-20		0.29
0.42 (0.16-0.65)	R1	Vestland	2020-03-15	2020-04-19	0
0.8 (0.56-1.04)	R2	Vestland	2020-04-20	2020-07-24	0.04
1.38 (1.12-1.65)	R3	Vestland	2020-07-25	2020-09-04	1
0.94 (0.77-1.11)	R4	Vestland	2020-09-05	2020-10-09	0.27
1.68 (1.52-1.81)	R5	Vestland	2020-10-10	2020-11-04	1
0.41 (0.15-0.65)	R6	Vestland	2020-11-05	2020-11-30	0
0.59 (0.12-1)	R7	Vestland	2020-12-01	2021-01-03	0.03
0.76 (0.53-1.04)	R8	Vestland	2021-01-04	2021-02-04	0.05
0.95 (0.64-1.26)	R9	Vestland	2021-02-05		0.4
0.24 (0.01-0.51)	R1	Trøndelag	2020-03-15	2020-04-19	0
0.61 (0.25-0.96)	R2	Trøndelag	2020-04-20	2020-08-31	0.01
0.59 (0.11-1.05)	R3	Trøndelag	2020-09-01	2020-11-04	0.04
0.9 (0.26-1.51)	R4	Trøndelag	2020-11-05	2020-11-30	0.4
1.29 (0.98-1.54)	R5	Trøndelag	2020-12-01	2021-01-03	0.95
0.33 (0.11-0.54)	R6	Trøndelag	2021-01-04	2021-02-04	0
0.61 (0.09-1.17)	R7	Trøndelag	2021-02-05		0.08
0.17 (0.02-0.38)	R1	Troms og Finnmark	2020-03-15	2020-04-19	0
0.74 (0.06-1.18)	R2	Troms og Finnmark	2020-04-20	2020-09-14	0.26
0.75 (0.26-1.19)	R3	Troms og Finnmark	2020-09-15	2020-11-04	0.15
0.57 (0.05-1.25)	R4	Troms og Finnmark	2020-11-05	2020-11-30	0.09
0.45 (0.02-0.96)	R5	Troms og Finnmark	2020-12-01	2021-01-03	0.02
0.16 (0.01-0.36)	R6	Troms og Finnmark	2021-01-04	2021-02-04	0
1.05 (0.22-1.89)	R7	Troms og Finnmark	2021-02-05	2021-02-19	0.54
1.2 (0.34-1.98)	R8	Troms og Finnmark	2021-02-20		0.7
1.26 (1.05-1.53)	AMP factor	All			-

Mean and 95% credible intervals

Table 18: Assumptions

Assumptions	Mean	Distribution	Reference
<b>Mobile Mobility Data</b>			
Telenor coverage	48%		<a href="https://ekomstatistikken.nkom.no/">https://ekomstatistikken.nkom.no/</a>
Data updated	March 20th		
Data used in the predictions	March 18th	Fixed	Corrected to preserve population
<b>Model parameters</b>			
Exposed period ( $1/\lambda_1$ )	3 days	Exponential	<a href="#">Feretti et al 2020</a>
Pre-symptomatic period ( $1/\lambda_2$ )	2 days	Exponential	<a href="#">Feretti et al 2020</a>
Symptomatic infectious period ( $1/\gamma$ )	5 days	Exponential	<a href="#">Feretti et al 2020</a>
Asymptomatic, infectious period ( $1/\gamma$ )	5 days	Exponential	<a href="#">Feretti et al 2020</a>
Infectiousness asympt. ( $r_{I_a}$ )	0.1	Fixed	<a href="#">Feretti et al 2020</a>
Infectiousness presymp ( $r_{E_2}$ )	1.25	Fixed	<a href="#">guided by Feretti et al 2020</a>
Prob. asymptomatic infection ( $p_a$ )	0.4		<a href="#">Feretti et al 2020</a>
<b>Healthcare</b>			
Time sympt. onset to hospitalisation	8.87 days (before August 1st)/ 7.40 (After August 1st)	Neg. binomial	
Fraction asymptomatic infections	40%	Fixed	<a href="#">Mizumoto et al 2020</a> 20% for the old population, Diamond Princess
% symptomatic and asymptomatic infections requiring hospitalization:			<a href="#">Salje et al 2020</a> corrected for: % of elderly living in elderly homes in Norway (last two age groups) and corrected for presence among positive tested since May 1.
0-9 years	0.1%	Fixed	
10 - 19 years	0.1%		
20 - 29 years	0.5%		
30 - 39 years	1.1%		
40 - 49 years	1.4%		
50 - 59 years	2.9%		
60 - 69 years	5.8%		
70 - 79 years	9.3%		
80+ years	22.3%		
% hospitalized patients requiring ICU			
Feb - July	15.1%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
August -	8.5%		
Probability that an admission has been reported on Monday			
From Sunday	32%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
From Saturday	49%		
From Friday	68%		
From Thursday	86%		
Probability that an admission has been reported			
From one day before	53%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
From two days before	77%		
From three days before	82%		
From four days before	91%		
Probability that a positive laboratory test has been reported			
From one day before	6.7%	Fixed	Estimated from MSIS
From two days before	59%		
From three days before	90%		
From four days before	97%		
Probability that a negative laboratory test has been reported			
From one day before	16%	Fixed	Estimated from MSIS
From two days before	74%		
From three days before	92%		
From four days before	98%		

## 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 32. 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.

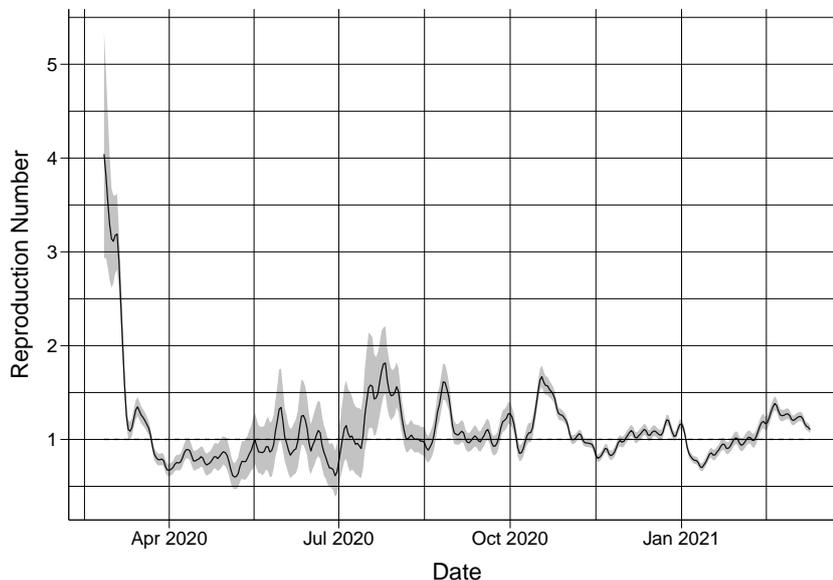


Figure 32: Reproduction number estimated using the R package EpiEstim.

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