NIPH
Norwegian Institute of Public Health

Situational awareness and forecasting

FHI COVID-19 modelling team

5 May 2020

Highlights today:

- We have introduced an additional reproduction number R_2 acting from 20 April, when restrictions started to be lifted. We estimate R_2 to have a mean equal to 0.58 with an interquartile range of (0.34-0.80). The 95% confidence interval is large, namely (0.04-1.16).
- Compared to our estimate of R_2 produced in the last two days, we see that its confidence interval is becoming smaller, because we can use more hospitalisationn data which inform it.
- The estimate of R_2 is still very uncertain, because there is only little information in the hospitalisation data about infections contracted on 20 April and thereafter. Individuals who got infected on 20 April and need hospitalisation, will be admitted to hospital around 2 May. The large confidence interval for R_2 means that there is still insufficient data about R_2, but also indicates that R_2 can be larger than 1, with a probability of ca. 11%.
- We present long term predictions (prevalence, hospitalisation, ventilator treatment) for the next twelve months, under the assumptions that R_2 follows the estimated distribution we have obtained today. Because R_2 might be larger than 1, predictions indicate that there is a probability of the next peak to in the early 2021. We estimate that there is a probability of 2.5% that more than 500 ventilator treatments will be needed simultaneously at peak time.
- In the next three weeks we still predict that the mean hospitalisation will decrease, but uncertainty is quite large. Similarly, we predict that the mean number of patients needing ventilator treatment is decreasing during the next three weeks, but due to the uncertainty, we forecast with small probability that an increase could happen.
- Because in this report we calibrate our model using national hospitalisation data, the predictions at county level can only be taken as an indication. See our regional report, where we use county-wise hospitalisation data, for more reliable regional predictions.

What this report contains:

This report presents results based on a mathematical 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

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.

How we calibrate the model:

The model is fitted to Norwegian COVID-19 hospitalization prevalence data since March 10 until today. We seed new infections into the model using imported COVID-19 cases in Norway from February 26 until March 18.

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 inherent randomness. We present the results in terms of mean values, 95% confidence intervals, median, 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: First, there are uncertainties related to the natural history of SARS-CoV-2, including the importance of asymptomatic and presymptomatic infection. Second, there are uncertainties related to the timing of hospitalization relative to symptom onset, the severity of the COVID-19 infections by age, and the duration of hospitalization and ventilator treatment in ICU. We will update the model assumptions and parameters in accordance with new evidence and local data as they become available. Results can change also significantly. See more details at the end of this report.

The mobility data is updated until May 4. It accounts for the changes in the movement patterns between municipalities that have occurred since start of the epidemic.

We assume three reproduction numbers for Norway:

- R_0 active until March 14;
- R_1 active from March 15 to April 19;
- R_2 active from April 20 until today.

When we forecast beyond today, we use the last reproduction number for the whole future, if not explicitly said otherwise.

The basic reproductive numbers are calibrated to hospitalization data until today. Estimates of R_0, R_1 and R_2 are uncertain, and we use their distribution to guarantee appropriate uncertainty of our predictions. Uncertainties related to the model parameters, as well as the transient period in week 11 and week 17, imply that reported effective reproductive numbers should be interpreted with caution. Because patients admitted to hospital have been infected long before, there is a necessary delay in the estimation of reproductive numbers. We will update the parameters related to permanence in hospital and ICU as soon as NPR data will be linked with MSIS and checked.

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

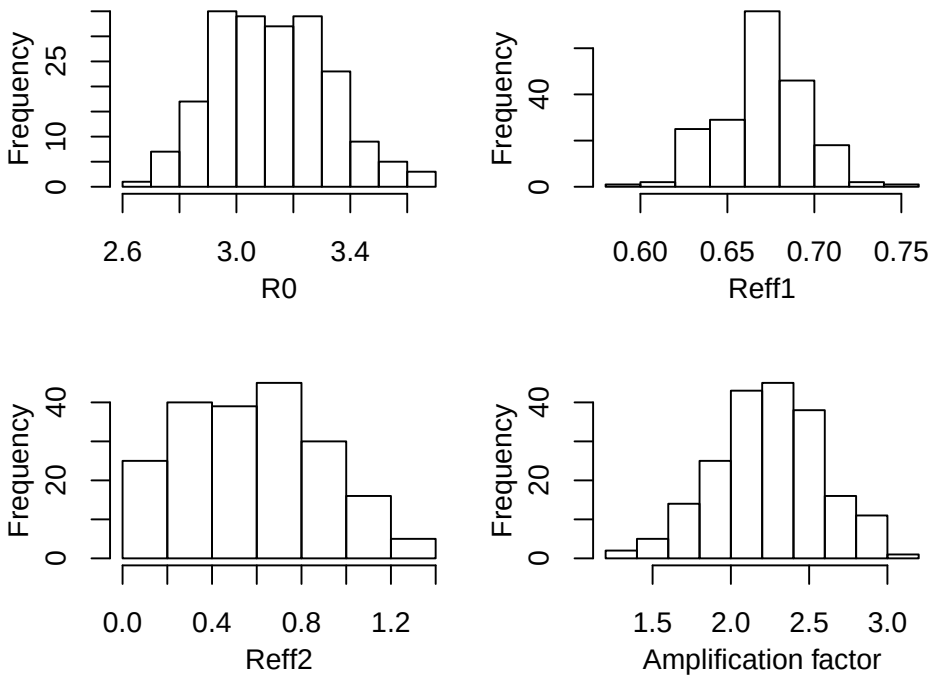
1 Estimated Reproductive Numbers

Calibration of our model with hospitalisation data leads to the following estimates:

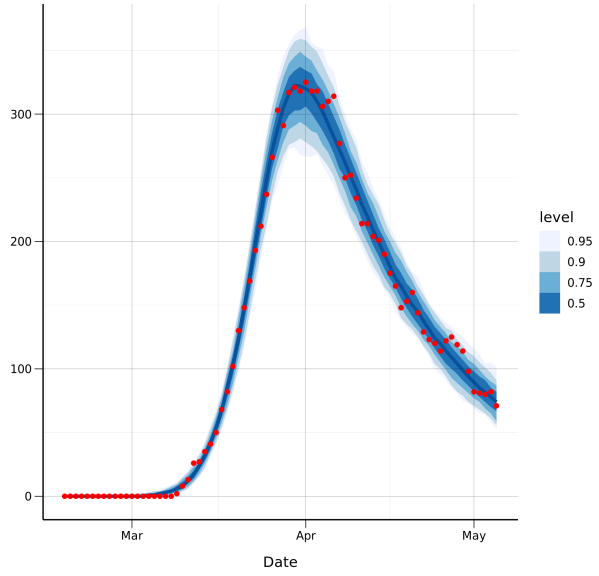
Table 1: Calibration results

Parameter	Mean	Median	Confidence interval (95 %)
Amplification factor	2.24	2.25	(1.55-2.88)
Ro	3.13	3.12	(2.79-3.51)
R1	0.67	0.67	(0.63-0.71)
R2	0.58	0.58	(0.04-1.16)

Estimated densities of these four parameters are plotted below:



Our model estimates the number of hospitalised Covid-19 patients, plotted below with blue median and interquartile bands, which are compared with the actual hospitalisation data, in red. The uncertainty captures the uncertainty in the calibrated parameters in addition to the stochastic elements of our model.



True total number of hospitalisations (red) and predicted values (blue)

2 Estimated cumulative number of infected individuals

Table 2: Estimated cumulative number of infections, 2020-05-05

Region	Total	Symptomatic	No. confirmed	Fraction reported	Min. fraction
Norway	51200 (46632; 55956)	31391 (28521; 34136)	7903	15%	14%
Agder	3199 (2356; 4267)	1960 (1409; 2615)	332	10%	8%
Innlandet	2633 (1764; 3469)	1603 (1086; 2124)	447	17%	13%
Møre og Romsdal	1029 (684; 1502)	638 (428; 913)	123	12%	8%
Nordland	845 (502; 1323)	518 (316; 816)	115	14%	9%
Oslo	11681 (10234; 13181)	7122 (6235; 8065)	2447	21%	19%
Rogaland	6894 (5350; 8444)	4227 (3281; 5144)	435	6%	5%
Troms og Finnmark	1495 (836; 2581)	910 (515; 1593)	246	16%	10%
Trøndelag	2318 (1593; 3068)	1423 (957; 1896)	501	22%	16%
Vestfold og Telemark	4108 (2893; 5776)	2507 (1766; 3518)	277	7%	5%
Vestland	5628 (4227; 7753)	3440 (2621; 4715)	871	15%	11%
Viken	11370 (9775; 12952)	7043 (6068; 8026)	2109	19%	16%

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

3 Predicted incidence of infected individuals, next three weeks

Predicted incidence (asymptomatic and symptomatic) for Norway per day, with confidence intervals.

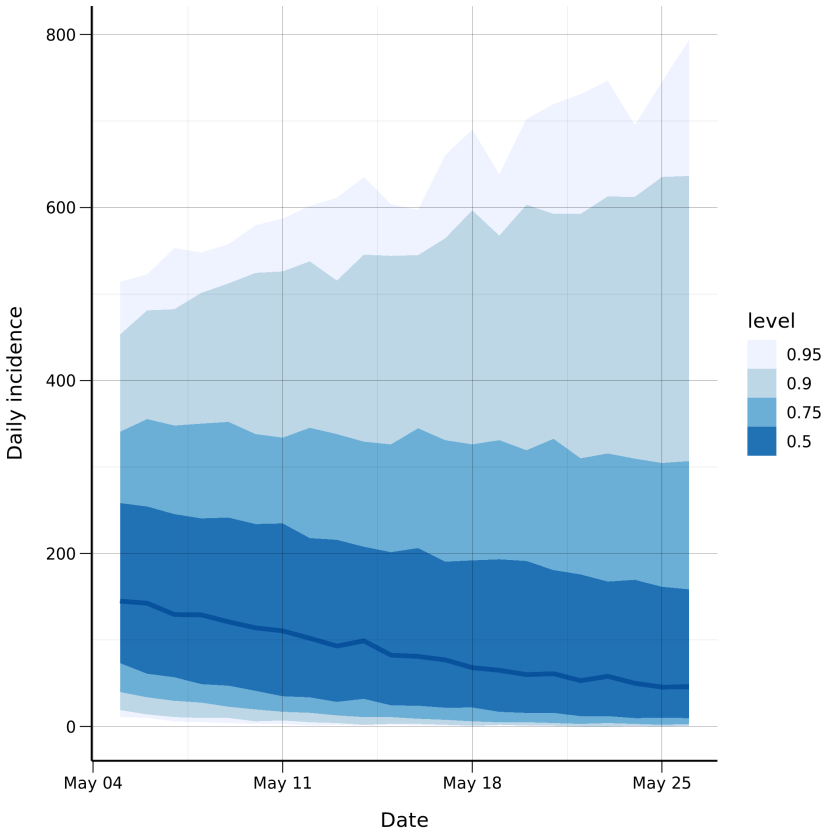


Table 3: Predicted incidence per day.

Region	1 week prediction (12 May)	2 weeks prediction (19 May)	3 weeks prediction (26 May)
Norway	155 (1-601)	143 (1-636)	136 (0-792)
Agder	11 (0-41)	10 (0-47)	9 (0-58)
Innlandet	11 (0-51)	11 (0-55)	10 (0-61)
Møre og Romsdal	4 (0-18)	4 (0-19)	4 (0-22)
Nordland	3 (0-12)	3 (0-16)	3 (0-18)
Oslo	24 (0-93)	22 (0-103)	21 (0-107)
Rogaland	20 (0-81)	19 (0-92)	18 (0-99)
Troms og Finnmark	5 (0-23)	4 (0-22)	4 (0-24)
Trøndelag	8 (0-31)	7 (0-41)	7 (0-42)
Vestfold og Telemark	13 (0-57)	12 (0-66)	12 (0-77)
Vestland	18 (0-75)	17 (0-90)	16 (0-99)
Viken	42 (0-159)	38 (0-178)	37 (0-216)

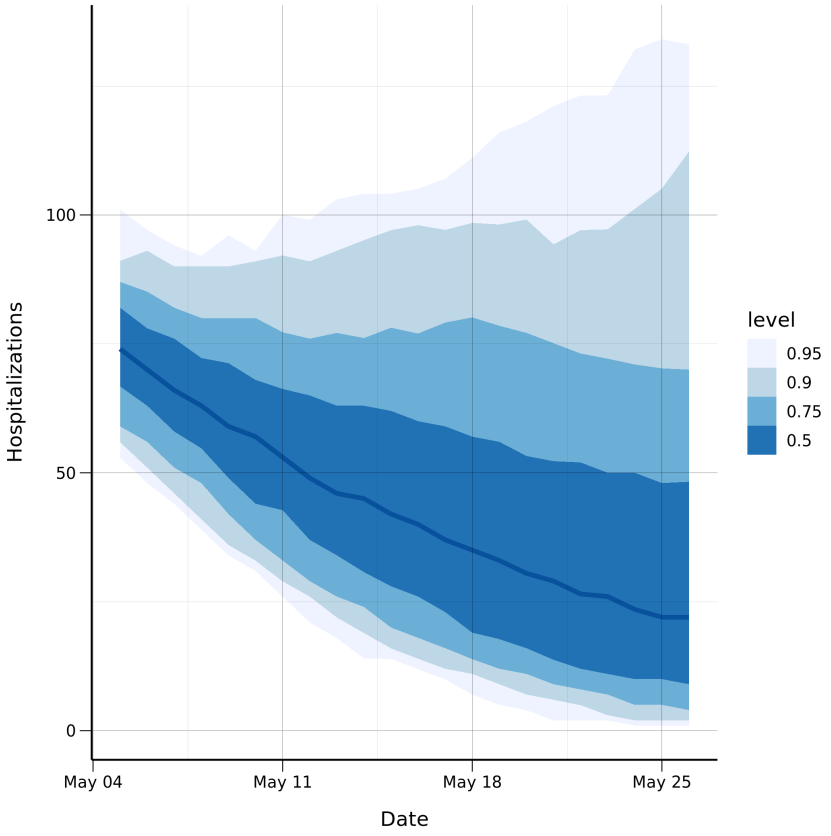
4 Predicted hospitalisation, next three weeks, including patients in ventilator treatment

Table 4: Number of hospitalisation beds occupied by Covid-19 patients.

Region	1 week prediction (12 May)	2 weeks prediction (19 May)	3 weeks prediction (26 May)
Norge	53 (19-102)	40 (6-114)	34 (1-133)
Agder	3 (0-11)	3 (0-10)	2 (0-10)
Innlandet	4 (0-11)	3 (0-12)	3 (0-14)
Møre og Romsdal	1 (0-5)	1 (0-5)	1 (0-5)
Nordland	1 (0-5)	1 (0-4)	1 (0-3)
Oslo	9 (2-23)	6 (0-19)	5 (0-22)
Rogaland	6 (0-16)	5 (0-16)	4 (0-16)
Troms og Finnmark	1 (0-6)	1 (0-6)	1 (0-7)
Trøndelag	2 (0-9)	2 (0-9)	2 (0-9)
Vestfold og Telemark	5 (0-14)	4 (0-12)	3 (0-13)
Vestland	6 (0-16)	5 (0-17)	4 (0-16)
Viken	12 (2-30)	10 (0-32)	9 (0-38)

Yesterday's real value for Norway: 71

Predicted daily number of COVID-19 patients in hospital in Norway (95% confidence intervals and interquartile range), next three weeks, including patients ventilator treatment.



Similar table and figure for each county (fylke) available on request.

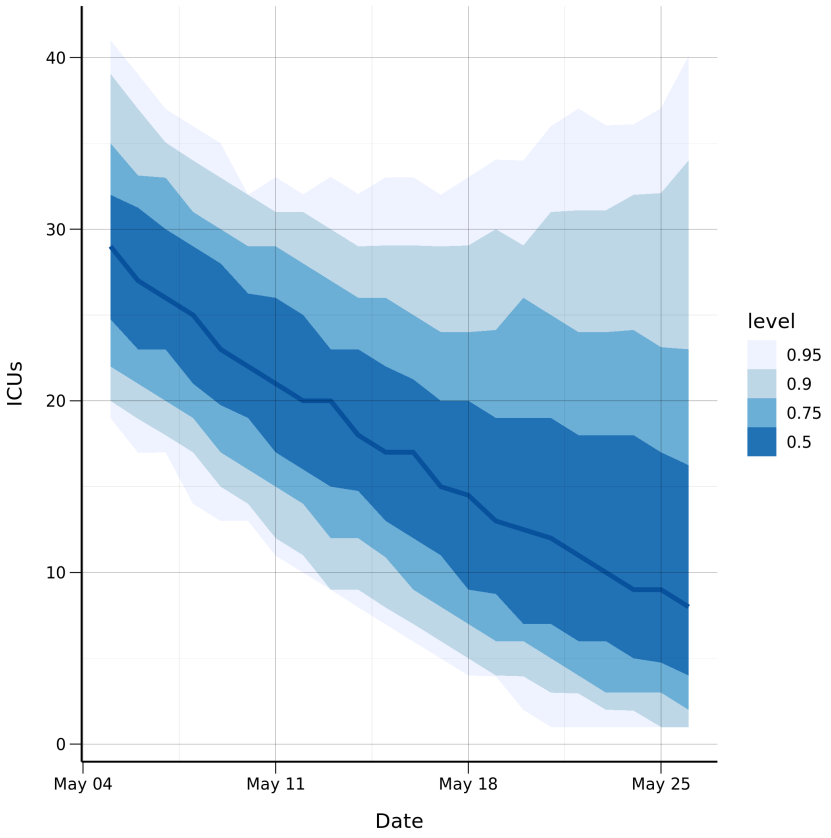
5 Predicted number of patients in ventilator treatment: next three weeks

Table 5: Number of ICU beds occupied by Covid-19 patients.

Region	1 week prediction (12 May)	2 weeks prediction (19 May)	3 weeks prediction (26 May)
Norge	21 (10-32)	15 (4-34)	12 (1-40)
Agder	1 (0-4)	1 (0-3)	1 (0-3)
Innlandet	2 (0-4)	1 (0-4)	1 (0-5)
Møre og Romsdal	1 (0-2)	0 (0-2)	0 (0-2)
Nordland	0 (0-2)	0 (0-2)	0 (0-1)
Oslo	3 (1-8)	2 (0-6)	1 (0-6)
Rogaland	2 (0-7)	2 (0-5)	1 (0-5)
Troms og Finnmark	1 (0-2)	0 (0-2)	0 (0-2)
Trøndelag	1 (0-4)	1 (0-3)	1 (0-3)
Vestfold og Telemark	2 (0-5)	1 (0-4)	1 (0-4)
Vestland	2 (0-6)	2 (0-6)	1 (0-6)
Viken	5 (1-11)	4 (0-10)	3 (0-12)

Yesterday's real value for Norway: 27

Predicted daily number of COVID-19 patients in ventilator treatment in Norway (95% confidence intervals and interquartile range), next three weeks.



Similar table and figure for each county (fylke) available on request.

6 Predicted prevalence of infectious individuals, next three weeks:

Predicted daily prevalence of asymptomatic, presymptomatic and symptomatic individuals, aggregated, whole Norway, (95% confidence interval).

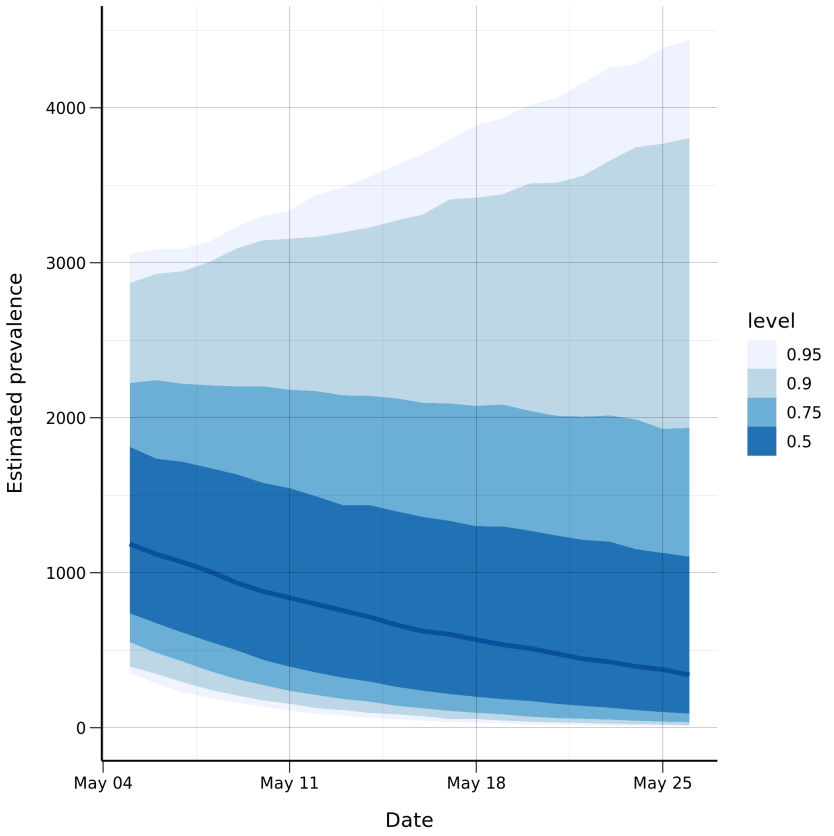
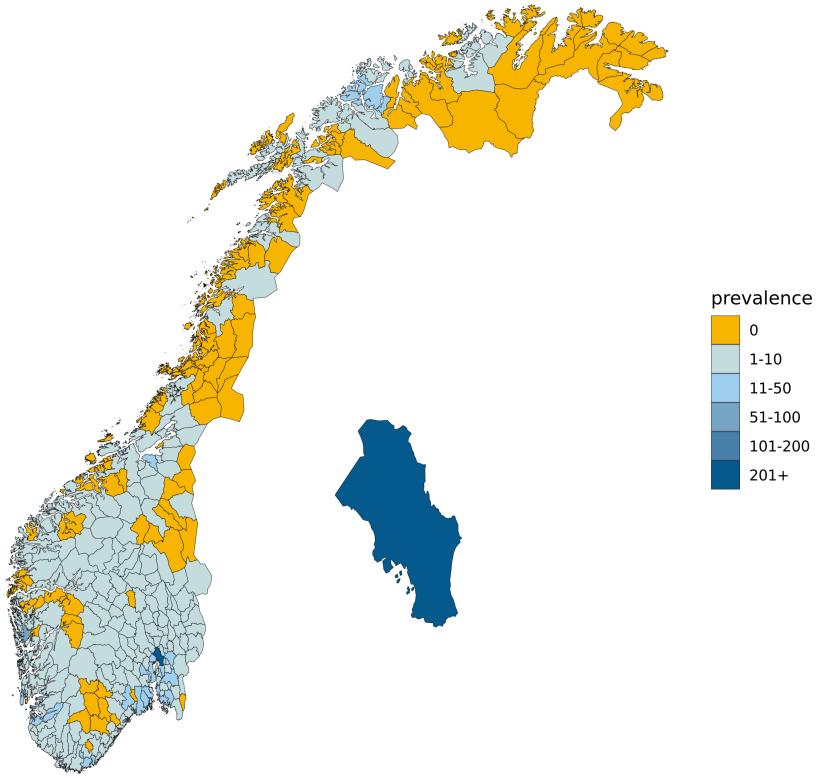


Table 6: Predicted prevalence. Number of infectious individuals (asymptomatic plus pre-symptomatic plus symptomatic) per day. Means and 95 perc. CI for three weeks prediction.

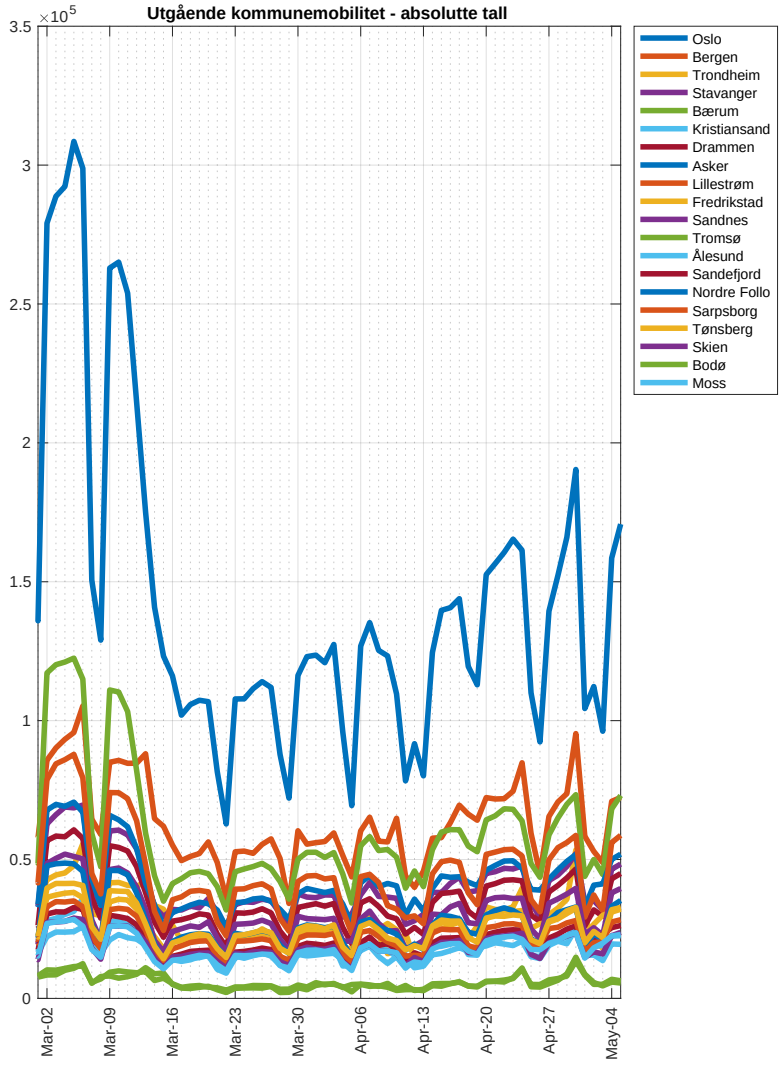
Region	Mean, 12 May	Mean, 19 May	Mean, 26 May	low CI, 26 May	high CI, 26 May
Norway	1065	931	864	8	4430
Agder	68	61	58	0	300
Innlandet	76	66	62	0	357
Møre og Romsdal	25	22	21	0	116
Nordland	18	17	15	0	76
Oslo	165	145	132	1	673
Rogaland	137	120	110	1	581
Troms og Finnmark	30	26	24	0	120
Trøndelag	54	47	44	0	218
Vestfold og Telemark	86	75	71	0	430
Vestland	121	106	100	0	566
Viken	289	251	233	1	1222

Map of predicted prevalence. Number of infectious individuals (asymptomatic plus presymptomatic plus symptomatic) today in each municipality.



7 Mobility between municipalities

Number of trips out from each municipality during each day, based on Telenor mobility data. We have observed a large reduction in inter-municipality mobility in week 11 (around March 11), with a minimum reached on Tuesday 17 March. The reduction with respect to the weeks before (week 10, which we use as reference) is on average 50%. Thereafter, we observe a slight increasing trend: in Oslo, for example, out-mobility has increased of roughly 2% per day in the three weeks 12, 13 and 14. Weekends have a lower mobility, indicating that there is still commuting-to-job during weekdays. On Tuesday April 14th, after Easter, nationwide mobility was only reduced by 38% compared to week 10. On Monday April 20th, when kindergarten started to re-open, the nationwide reduction was only 23% compared to week 10. The nationwide mobility experienced a 27% reduction on Monday April 27 compared to week 10, which is the week where grades 1 to 4 in elementary school re-opened.

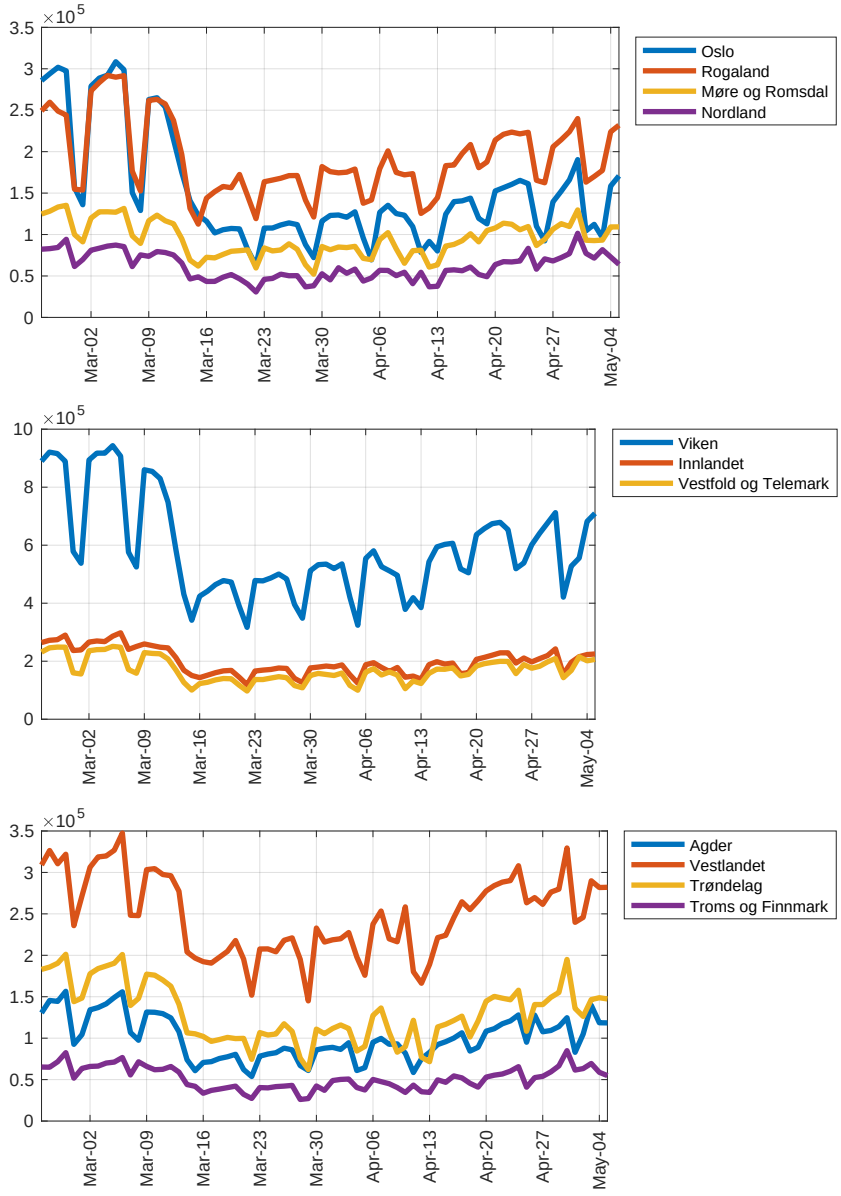


Percentage reduction in total mobility out from each municipality: Monday April 27th is compared to Monday March 2nd (last Monday before restrictions); Tuesday April 28st is compared to Tuesday March 3rd, etc. until Monday May 4th is compared to Monday March 2nd.

	Man_27	Tirs_28	Ons_29	Tors_30	Fre_01	Man_04	Tirs_05
Hele Norge	27,3%	25,3%	22,3%	15,5%	44,9%	19,6%	20,5%
Oslo	50,0%	47,3%	43,2%	38,3%	65,1%	43,2%	40,9%
Bergen	23,6%	21,6%	21,0%	0,4%	44,5%	17,3%	19,8%
Trondheim	29,5%	26,8%	21,0%	-11,8%	47,9%	25,8%	26,4%
Stavanger	32,5%	32,9%	31,0%	24,0%	50,1%	26,0%	26,9%
Bærum	49,8%	46,0%	42,3%	40,1%	61,8%	41,8%	39,2%
Kristiansand	27,8%	27,8%	26,3%	17,2%	55,5%	19,8%	21,7%
Drammen	32,5%	30,4%	25,4%	23,2%	54,7%	24,2%	23,1%
Asker	36,6%	33,7%	28,6%	26,7%	51,0%	26,2%	25,7%
Lillestrøm	36,7%	35,7%	34,7%	33,2%	63,2%	28,8%	30,5%
Fredrikstad	24,5%	23,2%	19,4%	15,1%	39,3%	14,6%	13,8%
Sandnes	29,4%	28,9%	27,6%	22,4%	54,2%	21,8%	21,5%
Tromsø	36,8%	23,3%	12,7%	-36,7%	30,1%	30,3%	34,7%
Ålesund	14,4%	13,9%	17,6%	-4,4%	40,2%	11,9%	18,5%
Sandefjord	28,5%	25,8%	19,7%	20,1%	43,6%	16,2%	15,8%
Nordre Follo	41,2%	36,2%	34,4%	32,1%	60,4%	30,6%	27,3%
Sarpsborg	23,8%	26,5%	21,7%	20,1%	49,0%	16,7%	18,7%
Tønsberg	29,8%	30,1%	23,7%	20,9%	50,8%	19,6%	21,0%
Skien	26,6%	22,8%	19,0%	18,3%	48,1%	17,5%	13,5%
Bodø	35,1%	29,6%	25,5%	-16,8%	28,6%	33,0%	37,7%
Moss	26,6%	24,2%	18,6%	16,8%	44,2%	16,6%	16,4%

Percentage reduction in total mobility out from each county: Monday April 27th is compared to Monday March 2nd (last Monday before restrictions); Tuesday April 28st is compared to Tuesday March 3, etc. until Monday May 4th is compared to Monday March 2nd.

	Man_27	Tirs_28	Ons_29	Tors_30	Fre_01	Man_04	Tirs_05
Oslo	50,0%	47,3%	43,2%	38,3%	65,1%	43,2%	40,9%
Rogaland	24,7%	24,4%	23,3%	17,2%	44,1%	18,1%	18,2%
Møre og Romsdal	11,2%	11,2%	13,9%	-2,2%	29,2%	8,9%	14,3%
Nordland	16,0%	13,6%	10,6%	-16,3%	9,5%	10,1%	23,4%
Viken	32,7%	30,1%	26,3%	24,5%	53,6%	23,7%	22,6%
Innlandet	25,7%	22,5%	18,0%	15,3%	48,0%	16,2%	16,6%
Vestfold og Telemark	25,5%	23,9%	17,8%	16,7%	42,3%	14,6%	14,0%
Agder	19,7%	20,2%	19,4%	16,4%	46,8%	11,6%	13,5%
Vestlandet	14,6%	13,3%	12,5%	-0,8%	31,0%	8,0%	11,5%
Trøndelag	20,9%	18,9%	17,1%	-2,4%	32,4%	16,3%	19,9%
Troms og Finnmark	18,1%	10,5%	4,8%	-19,4%	19,8%	10,8%	17,3%


×10^5
3.5
3
2.5
2
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1
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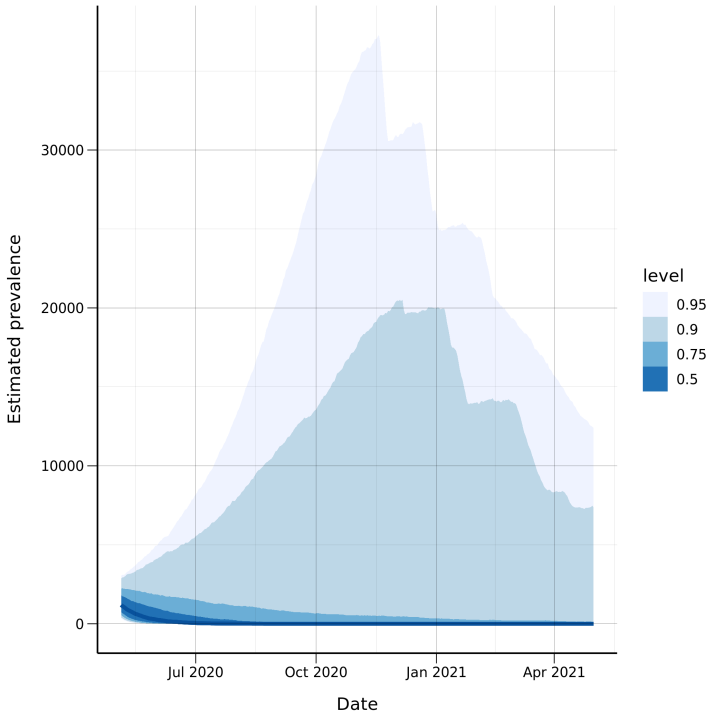
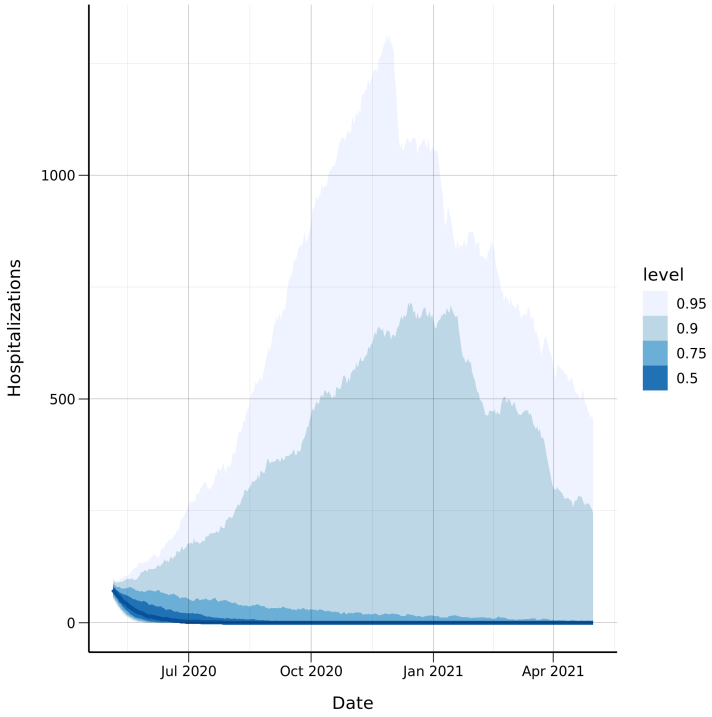
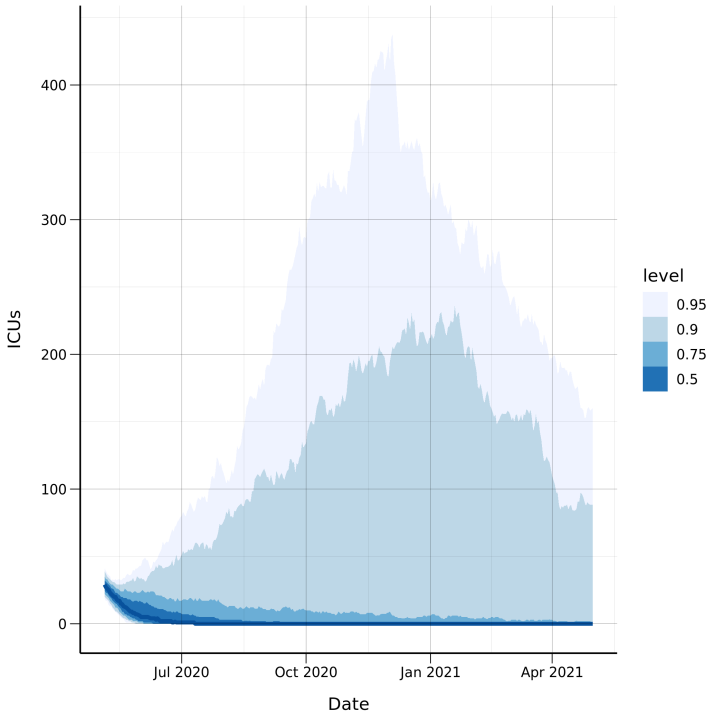
0
Mar-02
Mar-09
Mar-16
Mar-23
Mar-30
Apr-06
Apr-13
Apr-20
Apr-27
May-04
Oslo
Rogaland
Møre og Romsdal
Nordland
×10^5
10
8
6
4
2
0
Viken
Innlandet
Vestfold og Telemark
×10^5
Agder
Vestlandet
Trøndelag
Troms og Finnmark

8 Long-term prediction results

Predicted daily number of COVID-19 patients in hospital and receiving ventilator treatment in Norway until the end April, 2021, in addition to prevalence. The figures are made using 200 candidate models, where the reproductive numbers are varying according to their estimated uncertainty.
The confidence intervals reflected on the plots are two tailed around the median, and therefore the upper 95 % level shows the 97.5 % boundary.



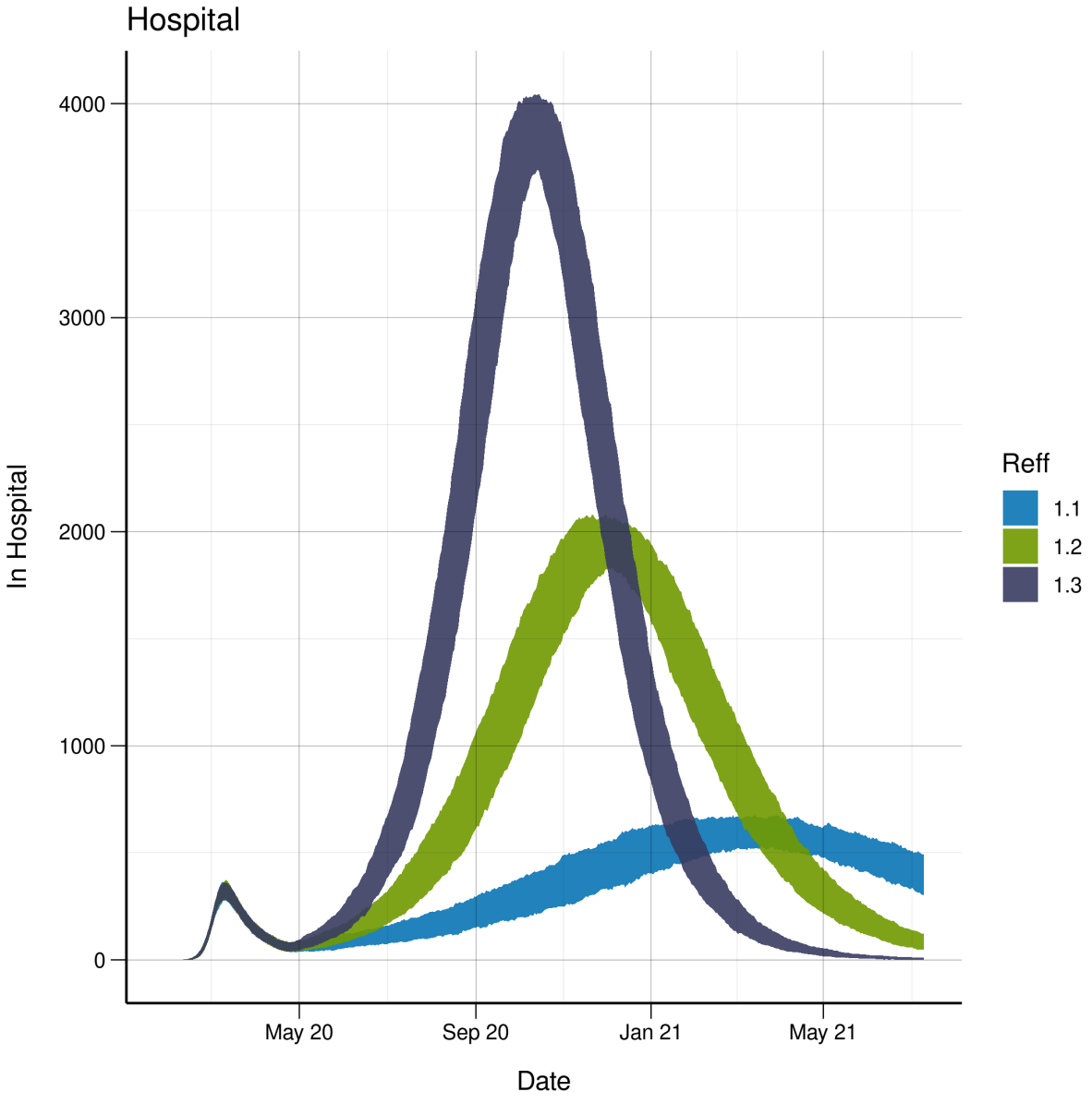


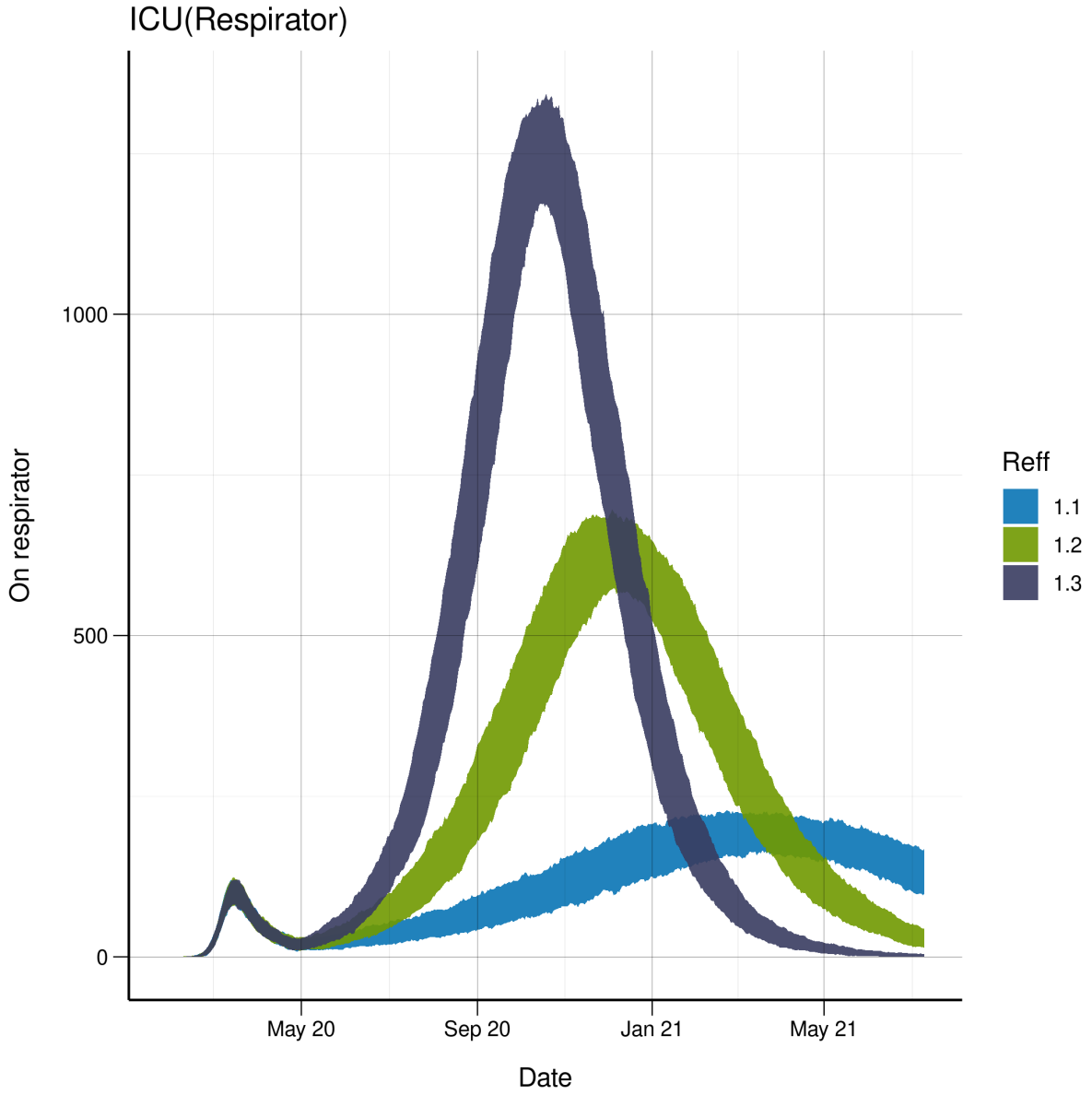


We estimate the probability of a surge capacity need above **1000 ICU** beds to be equal to **1.5 %**. The probability of a surge capacity need above **500 ICU** beds is **2.5 %**.

9 Long-term scenario results

Here we show how the epidemic will develop, from 4. May, under three assumed scenarios. We assume that until 3. May we follow our estimated reproductions numbers, but from 4. May we fix a new effective reproductive number. We show three cases, with this effective reproduction number equal to 1.1, 1.2 or 1.3. We show the daily number of covid-19 patients in hospital (including with ventilator treatment) and the daily number of patients with ventilator treatment. In the table below we also show the number of totally infected individuals under these three scenarios. We indicate the number of patients estimated to need hospitalisation and ventilator treatment in total and at peak time. We show 95% confidence intervals. The reproduction number determines the prevalence and incidence at the peak, while the number in ICU and in hospital is in addition strongly dependent on probability of being hospitalised and the probability of needed ventilator treatment.





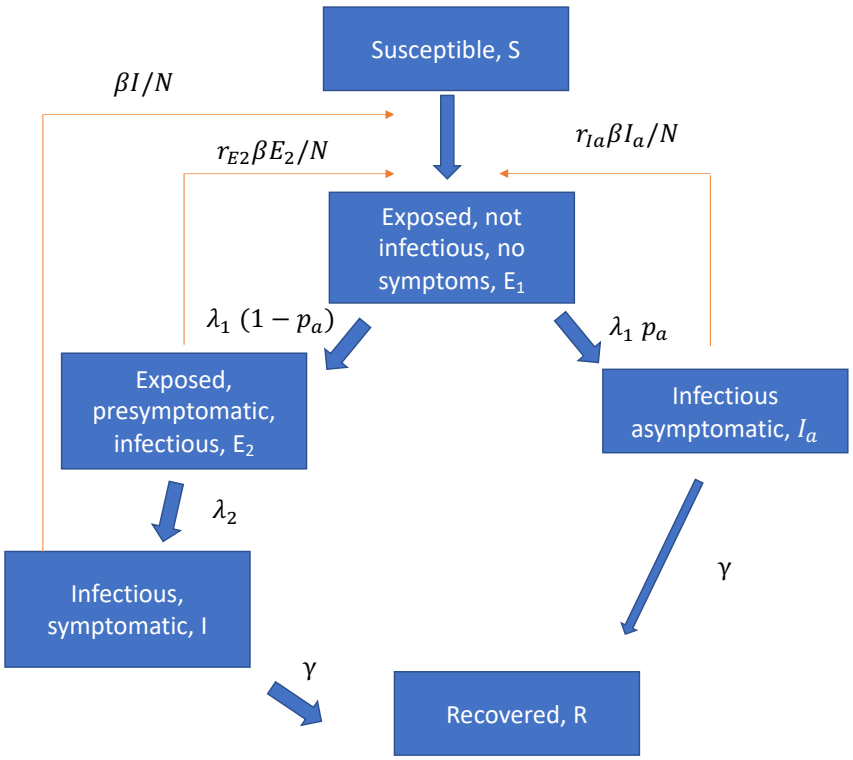
	Reff=1.1	**Reff=1.2**	**Reff=1.3**
Total Infected	917.000(882.000 - 948.000)	1.680.000(1.660.000 - 1.700.000)	2.270.000(2.260.000 - 2.290.000)
Total Hospital	17.900(17.200 - 18.500)	32.000(31.600 - 32.400)	43.000(42.600 - 43.400)
Total on respirator	5.150(4.930 - 5.370)	9.260(9.090 - 9.450)	12.400(12.300 - 12.600)
Hospital at Peak	444(410 - 477)	1.380(1.310 - 1.440)	2.690(2.600 - 2.780)
Respirator at Peak	218(200 - 237)	664(630 - 703)	1.290(1.230 - 1.350)

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.

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 is assumed 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: Susceptibles (S), Exposed, infected, but not infectious (E), Presymptomatic infected (E2), Symptomatic infected (I), Asymptomatic infected (Ia), and Recovered, either immune or dead (R). A schematic overview of the model is shown below:



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 at 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. We follow closely the development in the mobility matrices, and weekend patterns will be introduced if needed.

Healthcare utilization

Based on the estimated daily incidence data from the model and the population age structure in each municipality, we calculated the hospitalization using a weighted average. The hospitalization is assumed delayed relative to 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.

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, until 18th March. 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 others missed. This is called amplification factor.

Reproduction number and calibration

We assume a first reproduction number R_0 until March 14, a second reproduction number R_1 until April 19 and a third reproduction number R_2 thereafter. This last reproduction number is used in the future. The change points follow the change of restrictions introduced. We estimate the reproduction numbers so that the predicted number of hospitalized individuals is closest to the true number of hospitalized individuals, from March 10 until today. We use a method called sequential ABC which tests thousands of combinations of R_0, R_1, R_2 and the amplification factor, to determine the 200 ones that lead to the best fits of hospitalisations. The algorithm is described in Engebretsen et al. (2020) https://www.medrxiv.org/content/10.1101/2020.03.11.20033555v1.

Update notes: what is new in this report.

Here we list aspects of the model or of the input parameters which have changed compared to previous reports, and we explain the reason for these changes. Some changes will have big effects on some of our estimates.

– 14 April: **Hospitalisation risk:** Our model requires the specification of the proportion of symptomatic and asymptomatic patients requiring hospitalisation. Previously we used estimates from Verity et al. (2020) based on Chinese data, adapted to the Norwegian demography, and to the reduced mobility of elderly patients living in elderly homes. We summarised this proportion to be 5.6%. Under these assumptions, our model estimates a cumulative number of infected individuals of ca. 14.000. As we have had ca 135 confirmed deaths in Norway, this corresponds to an Infection Fatality Ratio (IFT) of roughly 1%. However, international studies indicate that the IFT should be around 0.3% (https://www.cebm.net/covid-19/global-covid-19-case-fatality-rates/). We therefore calibrate our model to this IFT (in addition to calibrate the model to the hospitalisation data), by adjusting the hospitalisation risk in our model, reducing it by a third, to 1.85%. The effect of this change is visible on the estimated cumulative number of infected individuals, which is now approximately 45.000. A further effect of this change is that the reproductive numbers are different, with R_0 larger and R_{eff} smaller than before, when we had a higher hospitalisation risk.

– 14 April: **Change point for the reproductive number:** On March 12, a number of contact restrictions were implemented. During that week 11, mobility was reduced significantly, and appears to stabilize on Monday March 16th. Between the 11th and 16th of March we expect a reduction of the reproduction rate. We model this change as a sudden jump from a first reproduction rate R_0 to a second and lower reproduction rate R_{eff}, through a change in the model parameter β. We have chosen Monday March 15 as the changepoint for the reproductive number because it gives the best fit to the hospitalisation data. If we move the changepoint to March 14, or assume a

continuous linear reduction during week 11, the fit deteriorates. We also notice that the best changepoint depends on the assumed time between symptoms appearance and hospitalisation, which is assumed to have mean 8 days in this report. The optimal changepoint also depends on the assumed hospitalisation risk.

– 20 April: **Change in parameter estimation method:** We use sequential ABC instead of iterative parameter calibration. Estimation of the reproduction numbers and of the amplification factor in the seeding of the epidemic at the start is done using Approximate Bayesian Computation (ABC), as described in Engebretsen et al. (2020)[1]. Sequential ABC avoids to calibrate R_0 first on part of the data and then, given the best values of such R_0, to find the best fitting R_{eff}, which might not lead to optimal estimation and is based on more ad-hoc choices. We also do not weigh the last part of the data more than the rest. Sequential ABC takes more time to run: therefore the daily report might use only the hospitalisation until yesterday.

– 3 May: **New reproduction number active from 20 April:** We introduce a new change point in the reproduction numbers, so that R_1 is active until 19 April and R_2 from 20 April. This is the day the kindergarten reopened. On 27 April also part of primary school reopened, and we will see if a further change point will be useful to fit the data best.

[1] https://www.medrxiv.org/content/10.1101/2020.03.11.20033555v1

Parameters used today

Table 7: Assumptions I

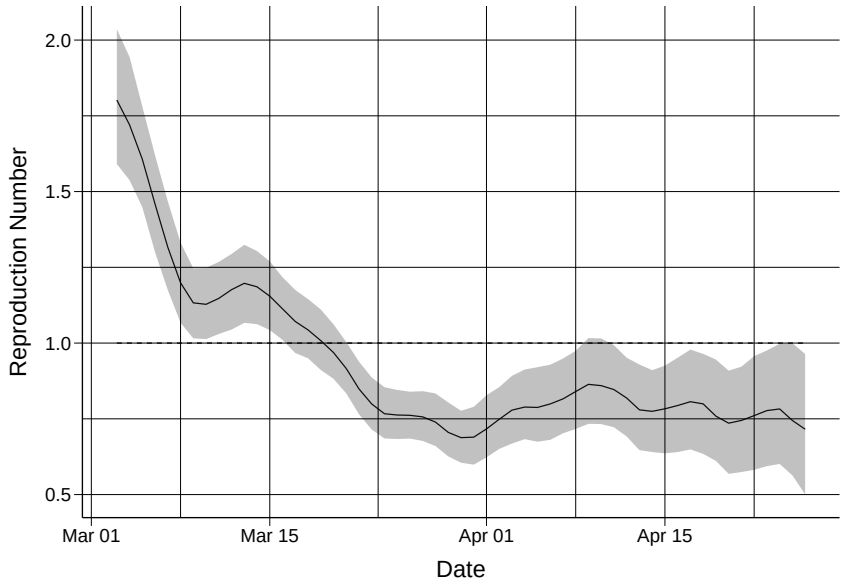
Assumptions	Mean	Distribution	Reference
Seeding			
Scaling factor on imported cases	Min. 1.32 1st Qu. 2.03 Median 2.25 Mean 2.24 3rd Qu. 2.46 Max. 3.04	random	Calibrated to hospitalizations
Telenor coverage	48%		https://ekomstatistikken.nkom.no/
Model parameters			
Exposed period ($1/\lambda_1$)	3 days	Exponential	Fraser et al. Not published
Pre-symptomatic period ($1/\lambda_2$)	2 days	Exponential	Fraser et al. Not published
Symptomatic infectious period ($1/\gamma$)	5 days	Exponential	Fraser et al. Not published
Asymptomatic, infectious period ($1/\gamma$)	5 days	Exponential	Fraser et al. Not published
Infectiousness asympt. (r_{I_a})	0.1	Fixed	Fraser et al. Not published
Infectiousness presymp (r_{E_2})	1.25	Fixed	Fraser et al. Not published
Prob. asymptomatic infection (p_a)	0.4		Fraser et al. Not published
R_0, until March 14	Min. 2.66 1st Qu. 2.97 Median 3.12 Mean 3.12 3rd Qu. 3.27 Max. 3.69	random	Calibrated to hospitalizations
R_1, from 15 March until 19 April	Min. 0.59 1st Qu. 0.66 Median 0.67 Mean 0.67 3rd Qu. 0.69 Max. 0.75	random	Calibrated to hospitalizations
R_2, from 20 April until today	Min. 0.006 1st Qu. 0.34 Median 0.58 Mean 0.58 3rd Qu. 0.80 Max. 1.38	random	Calibrated to hospitalizations

Table 8: Assumptions II

Assumptions	Mean	Distribution	Reference
Healthcare			
Time sympt. onset to hospitalisation	8 days	Poisson	
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	 0.00% 0.013% 0.37% 1.13% 1.43% 2.73% 3.93% 5.53% 5.33%	Fixed	Verity et al 2020 corrected for: % of elderly living in of elderly living in Norway (last two age groups). Also corrected by 1/3 to account for severity in comparison with the expected fatality rate.
% hospitalized patients requiring ICU 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	 5% 5% 5% 5% 6.3% 12.2% 27.4% 43.2% 70.9%	Fixed	Verity et al 2020
Overall hospitalization risk	1.9%	Fixed	Verity et al 2020 (adapted to Norwegian population)
Normal hospitalization length	8 days	Poisson	Ferguson et al 2020
Time in hospital before ICU	4 days	Poisson	Ferguson et al 2020, Expert opinion
Time in ICU	12 days	Poisson	Ferguson et al 2020, Expert opinion
Mobile phone mobility			
Until May 4	Measured Telenor mobility		
Data used in the predictions	May 4	Fixed	Corrected to preserve population

Supplementary analysis: Instantaneous Reproduction Number based on lab-confirmed cases only, EpiEstim

The following results are based on confirmed cases and should be interpreted very carefully due to the multiple changes in testing criteria during this period. During the early part of the period, testing was mainly based on travel to areas with an ongoing outbreak, while since the middle of March testing has been for people with an acute respiratory infection.From early may the testing criteria have been expanded to less severe symptoms. The reproduction numbers estimated by this method gives a similar conclusion to the analysis based on the metapopulation model above.
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 method to estimate the instantaneous reproduction number smoothed over a sliding window of 3 days. For the results to be comparable to the analysis above we estimate the date of infection for each confirmed case by first estimating the date of onset and the subtracting 5 days for the incubation period. We estimate the date of onset from the empirical delay between onset and testing from the early 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 for. The displayed results are the combined results from all these 100 simulated epi-curves. The serial interval was assumed at 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 should be interpreted with caution as indicated by increasing credible intervals.



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