Coronavirus (COVID-19): Analysis

Coronavirus (COVID-19): modelling the epidemic in Scotland (Issue No. 60)

Background

This is a report on the Scottish Government modelling of the spread and level of Covid-19. This updates the previous publication on modelling of Covid-19 in Scotland published on 8th July 2021. The estimates in this document help the Scottish Government, the health service and the wider public sector plan and put into place what is needed to keep us safe and treat people who have the virus.

This edition of the research findings focuses on the epidemic as a whole, looking at estimates of R, growth rate and incidence as well as local measures of change in the epidemic.

In Scotland, the modelled estimate for R is between 1.1 and 1.4, with the growth rate between 2% and 6% based on the period up to 12th July.

R is an indicator that lags by two to three weeks and therefore does not reflect any behavioural changes that have happened during this time. In particular, the recent decline in the number of new daily cases in Scotland may not yet be fully reflected in the R and growth rate estimates.

Key Points

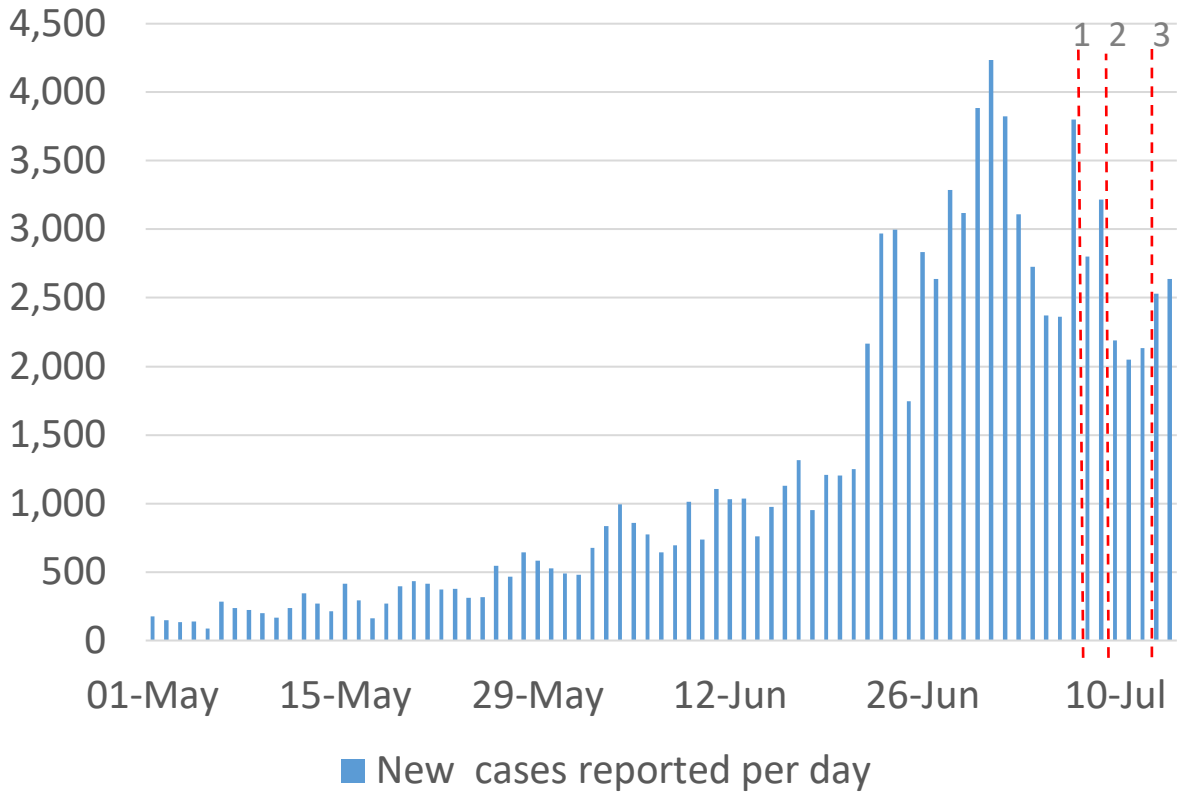
- The reproduction rate R in Scotland is currently estimated as being between 1.1 and 1.4, based on the period up to 12th July. The lower and upper limits have decreased since last week.
- The number of new daily infections for Scotland is estimated as being between 105 and 192, per 100,000 people, based on the period up to 12th June.
- The growth rate for Scotland is currently estimated as being between 2% and 6%, based on the period up to 12th June. The lower and upper limits have decreased since last week.

- Average contacts have decreased by approximately 18% in the last two weeks (comparing surveys pertaining to 17th June - 23rd June and 1st July - 7th July) with a current level of 3.8 daily contacts.
- Contacts within the work and other setting (contacts outside of the school, home and work) have decreased compared to two weeks prior by 37% and 13% respectively. Average contacts within the home setting have remained at similar levels over the same period.
- Mean contacts across all age groups have shown a reduction in comparison to two weeks prior with those aged between 18-29 reporting the largest decrease of 37%.
- Those who do not work from home have more contacts than those who work from home.
- The biggest decrease in interactions is seen between those aged 18-49 with those under 18, decreasing by at least 55%.
- There has been a reduction in the proportion of participants visiting the workplace, decreasing from 18% to 14%, and also a decrease in those visiting a health care facility, decreasing from 21% to 18% in the last two weeks.
- Based on the increase in cases in the last few weeks, hospital beds and ICU are projected to rise – for how long this continues is uncertain.
- Modelled rates of positive tests per 100K using data to 12th July indicate that, for the week commencing 25th July 2021, there are 26 local authorities with at least a 75% probability of exceeding 100 cases per 100k.
- Of these, 4 local authorities (Angus, Edinburgh, Midlothian and West Lothian) have at least a 75% probability of exceeding 300 cases per 100k. There are no local authorities with at least a 75% probability of exceeding 500 cases per 100k.
- Overall, wastewater Covid-19 levels continued to rise rapidly in the last week, reaching the highest levels observed. Increases are seen in a broad range of local authorities. Unlike recent weeks, wastewater Covid-19 values significantly exceeded levels suggested by case rates.
- At Hatton, which covers Dundee, wastewater levels in the last week rose to extremely high levels, substantially higher than in January. While this displays a large amount of variability, this shows a clear departure from case trends and represents the highest levels recorded in a major site.

Recent increase in cases

Figure 1 shows the number of cases reported in Scotland between May and July 2021. The vertical dashed lines indicate the cut off points for each of the modelling inputs; after these dates, the number of cases is not incorporated into the outputs.

Figure 1: Cases reported in Scotland to 14th July 2021.



This report covers the period up to 7th July for contact patterns (indicated by dashed line 1). Wastewater data is provided to 9th July (dashed line 2). The estimates of R, incidence, growth rates, the modelled rates of positive tests per 100k, and the medium term projections by the Scottish Government of infections, hospitalisations and ICU beds use data to 12th July (dashed line 3).

Overview of Scottish Government Modelling

Modelling outputs are provided here on the current epidemic in Scotland as a whole, based on a range of methods. Because it takes a little over three weeks on average for a person who catches Covid-19 to show symptoms, become sick, and either die or recover, there is a time lag in

what our model can tell us about any re-emergence of the epidemic and where in Scotland this might occur.

However modelling of Covid-19 deaths is an important measure of where Scotland lies in its epidemic as a whole. In addition, the modelling groups that feed into the SAGE consensus use a range of other data along with deaths in their estimates of R and the growth rate. These outputs are provided in this research findings. The type of data used in each model to estimate R is highlighted in Figure 2.

We use the Scottish Contact Survey (SCS) to inform a modelling technique based on the number of contacts between people. Over time, a greater proportion of the population will be vaccinated. This is likely to impact contact patterns and will become a greater part of the analysis going forwards.

The logistical model utilises results from the epidemiological modelling, principally the number of new infections. The results are split down by age group, and the model is used to give a projection of the number of people that will go to hospital, and potentially to ICU. This will continue to be based on both what we know about how different age groups are affected by the disease and the vaccination rate for those groups.

What the modelling tells us about the epidemic as a whole

The various groups which report to the Scientific Pandemic Influenza Group on Modelling (SPI-M) use different sources of data in their models (i.e. deaths, hospital admissions, cases) so their estimates of R are also based on these different methods.

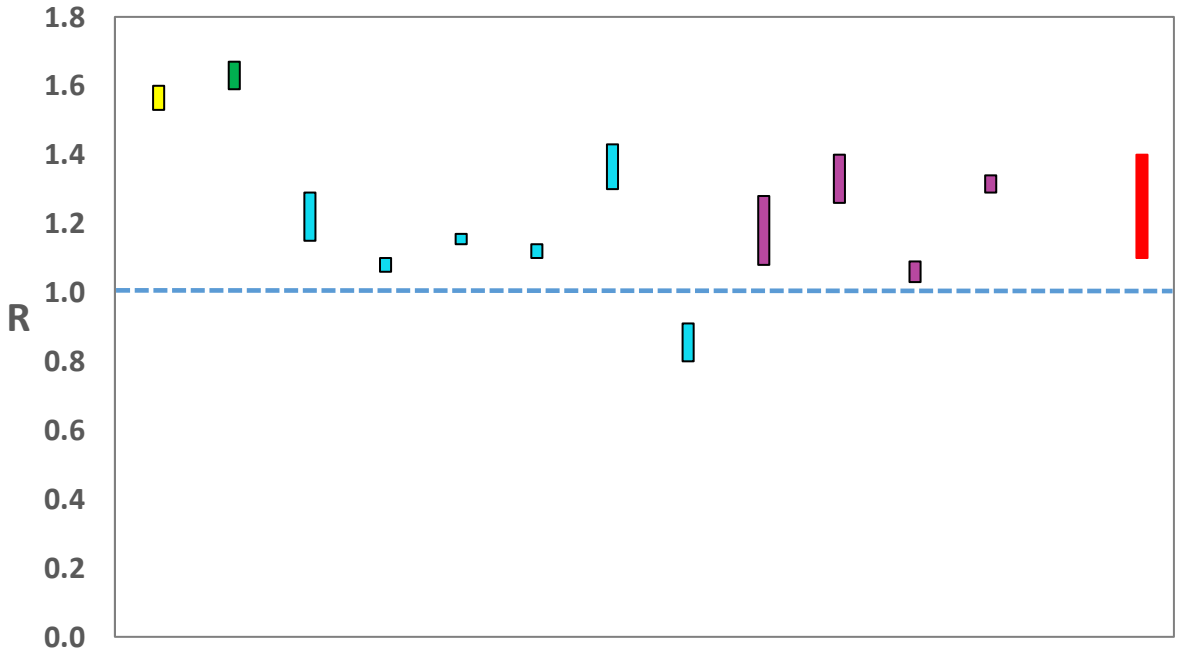
R is an indicator that lags by two to three weeks and therefore does not reflect any behavioural changes that have happened during this time. In particular, the recent decline in the number of new daily cases in Scotland may not yet be fully reflected in the R and growth rate estimates. The decline in new cases suggests it is possible that the current value of R in Scotland could be below 1.

SAGE's consensus view across these methods as of 14th July, using data to 12th July, was that the value of R in Scotland was between 1.1 and 1.4 (see Figure 2)[1].

[1] Particular care should be taken when interpreting this estimate as it is based on low numbers of cases, hospitalisations, or deaths and / or dominated by clustered outbreaks. It should not be treated as robust enough to inform policy decisions alone.

This week the Scottish Government presented two outputs to SPI-M. The first uses confirmed cases as published by Public Health Scotland (PHS). The second uses instead wastewater data to estimate the number of cases. Both outputs are shown in Figures 2 and 3.

Figure 2. Estimates of R_t for Scotland, as of 14th July, including 90% confidence intervals, produced by SAGE[2]. Data to 12th July.

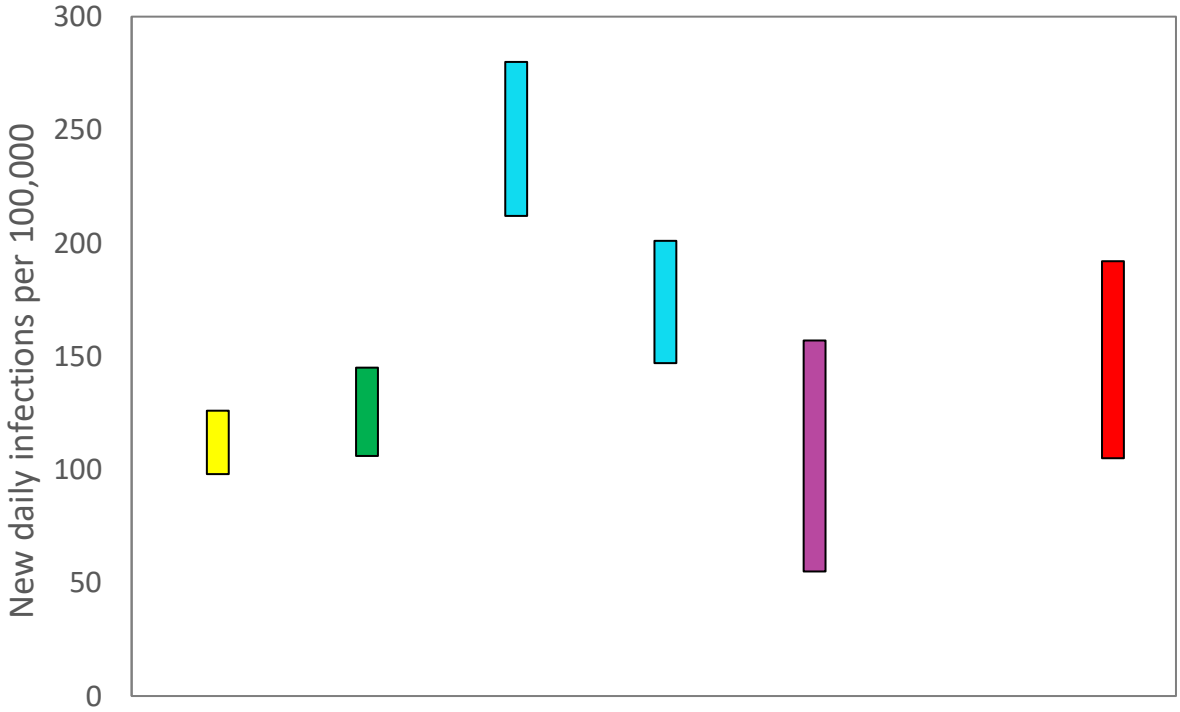


Source: Scientific Advisory Group for Emergencies (SAGE).

The various groups which report to the Scientific Pandemic Influenza Group on Modelling (SPI-M) use different sources of data in their models to produce estimates of incidence (Figure). SPI-M's consensus view across these methods, using data to 12th July, was that the incidence of new daily infections in Scotland was between 105 and 192 new infections per 100,000. This equates to between 5,700 and 10,500 people becoming infected each day in Scotland.

[2] The cyan bars use Covid-19 test data and purple bars use multiple sources of data. The estimates produced by the Scottish Government are the two on the left. (Yellow uses confirmed cases from PHS; green uses wastewater data).The SAGE consensus range is the right-most (red).

Figure 3. Estimates of incidence for Scotland, as of 14th July, including 90% confidence intervals, produced by SPI-M[2]. Data to 12th July.



Source: Scientific Pandemic Influenza Group on Modelling (SPI-M).

The consensus from SAGE for this week is that the growth rate in Scotland is between 2% and 6% per day using data to 12th July. The lower and upper limits have decreased since last week.

What we know about how people's contact patterns have changed

Average contacts have decreased by approximately 18% in the last two weeks (comparing surveys pertaining to 17th June - 23rd June and 1st July - 7th July) with a current level of 3.8 daily contacts as seen in Figure 4[3]. Contacts within the work and other setting (contacts outside of the school, home and work) have decreased compared to two weeks prior by 37% and 13% respectively. Average contacts within the home setting have remained at similar levels over the same period.

[3] PHS reported 2 average contacts per primary case in its publication of 14th July(COVID-19 Statistical Report - 14 July 2021 - COVID-19 statistical report - Publications - Public Health Scotland). Primary contacts only include those who are tested and report to T&P whereas the SCS uses a representative sample of Scottish adult population and collects information on all direct contacts. The PHS figures for the most recent week are provisional and will be updated in next week's publication.

Figure 4: Mean Adult Contacts (truncated at 100) from SCS.

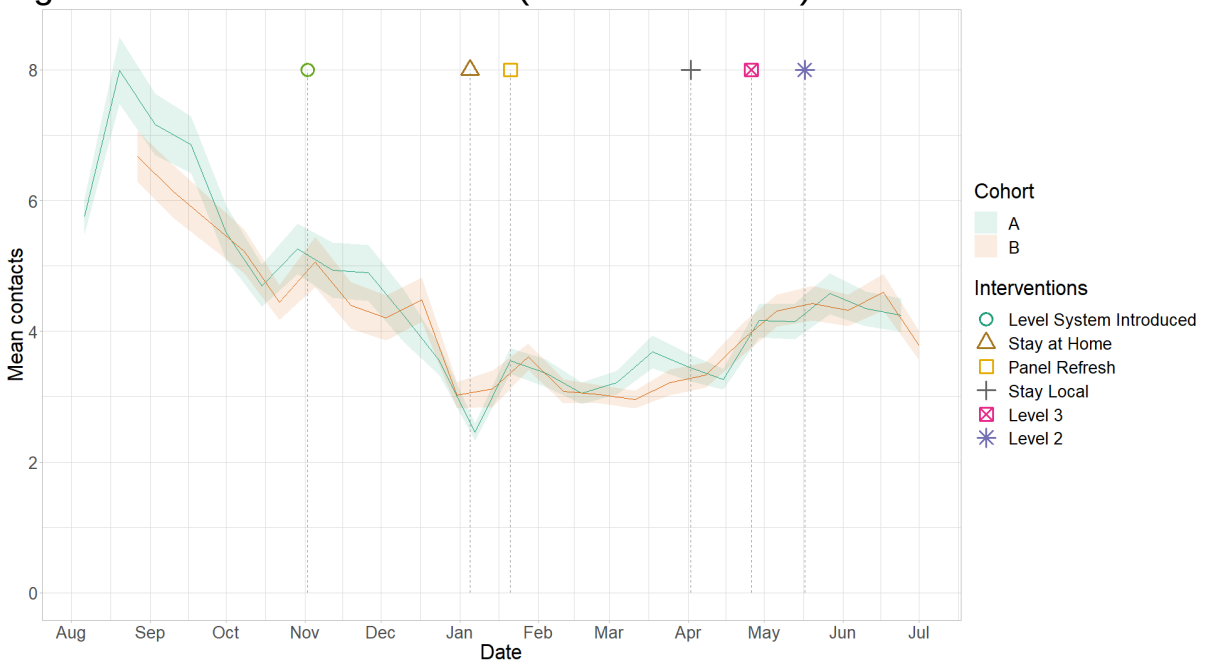


Figure 5 shows how contacts change across age group and setting. Mean contacts across all age groups have shown a reduction in comparison to two weeks prior with those aged between 18-29 reporting the largest decrease of 37%. These decreases are largely driven by reductions in contacts within the other setting for those aged between 18-29 and within the work setting for all remaining age groups.

Figure 5: Average (mean) contacts for each panel per day by setting for adults in Scotland, truncated to 100 contacts per participant (from SCS).

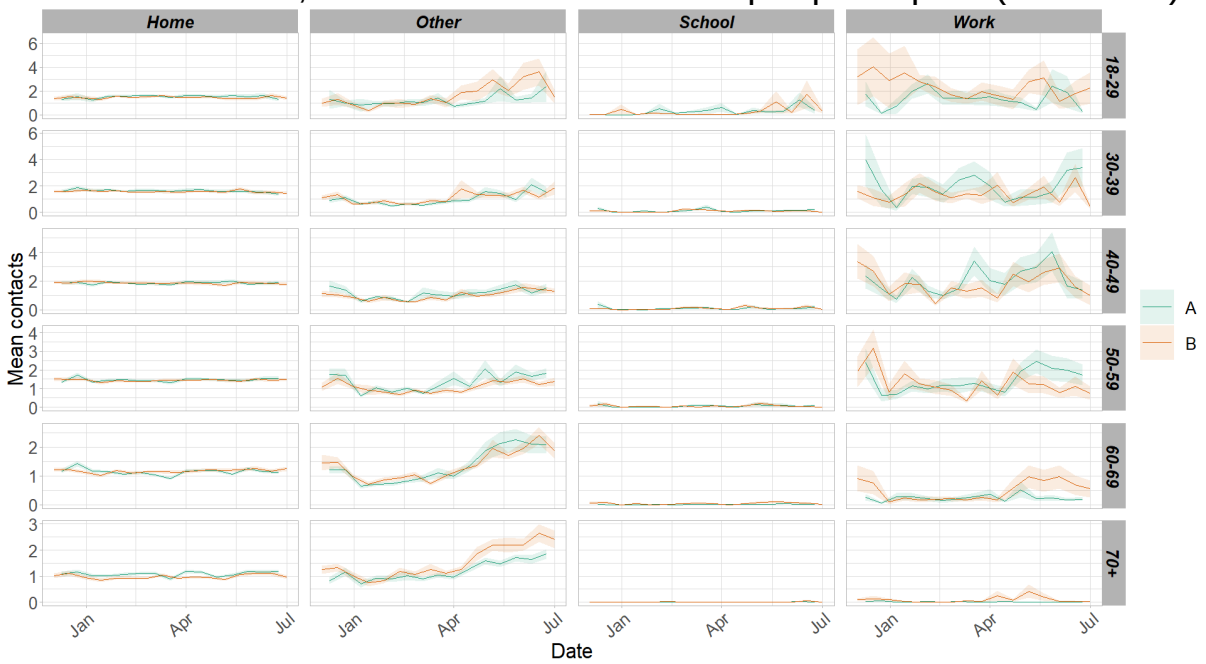
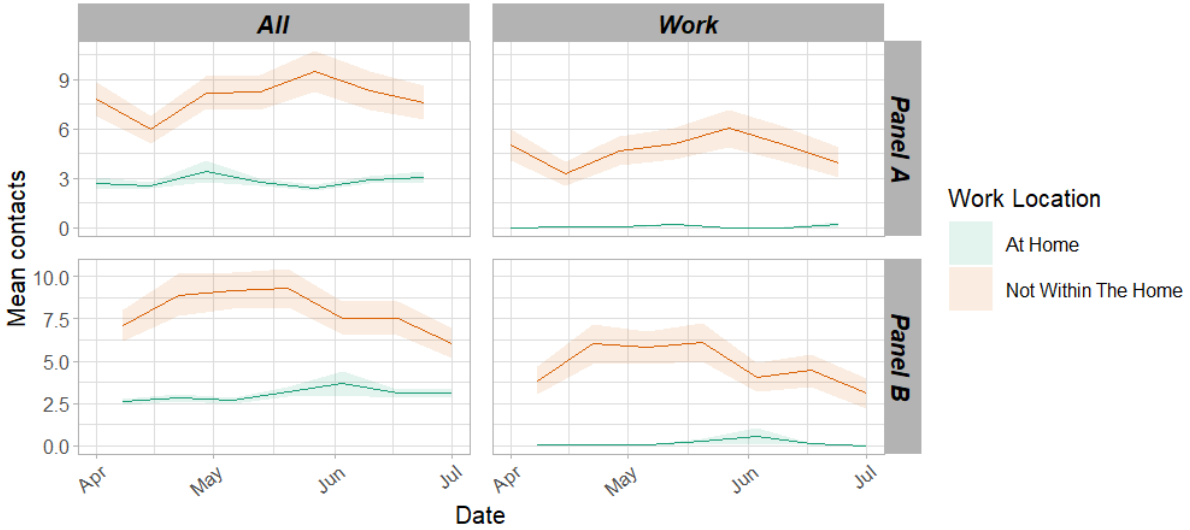


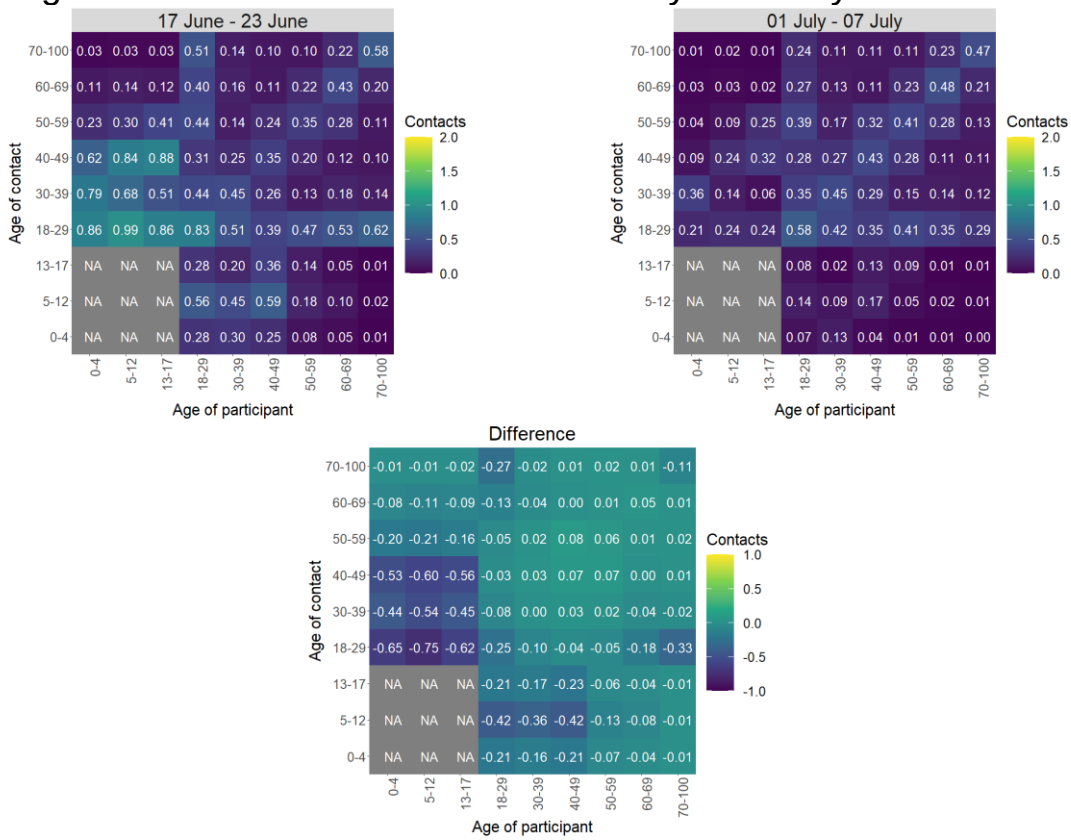
Figure 6 shows the difference in contacts between those who work from home compared to those who have a workplace outside of the home. This shows that those who do not work from home have higher and more variable contacts than those who work from home. This also shows that in the most recent weeks in both panels, there has been a reduction in overall mean contacts for those who do not work from home whereas mean contacts those who do have remained stable.

Figure 6: Overall mean contacts by work location (home or away from home) for each panel for adults in Scotland, truncated to 100 contacts per participant (from SCS).



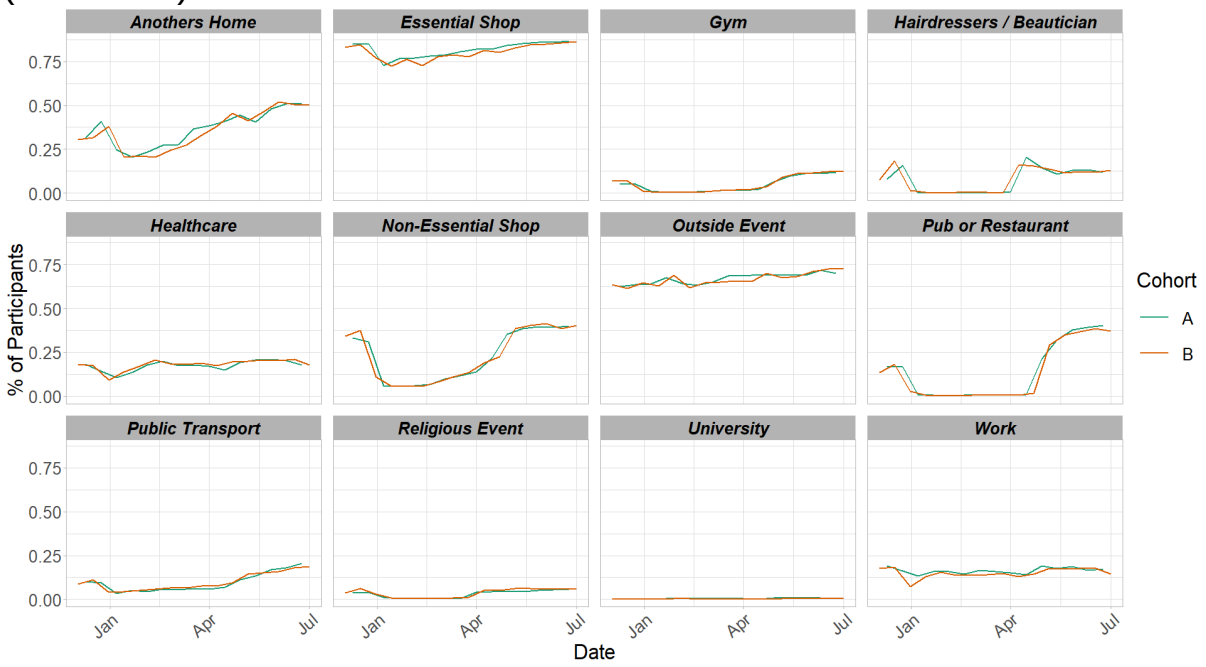
The heatmaps in Figure 7 show the mean overall contacts between age groups for the weeks relating to 17th June - 23rd June and 1st July – 7th July and the difference between these periods. The biggest decrease in interactions is seen between those aged 18-49 with those under 18, decreasing by at least 55%.

Figure 7: Overall mean contacts by age group before for the weeks relating to 17th June - 23rd June and 1st July - 7th July.



As seen in Figure 8, the proportion of participants visiting different locations remains at similar levels across the majority of locations. There has been a reduction in the proportion of participants visiting the workplace, decreasing from 18% to 14% and also a decrease in those visiting a health care facility, decreasing from 21% to 18% in the last two weeks.

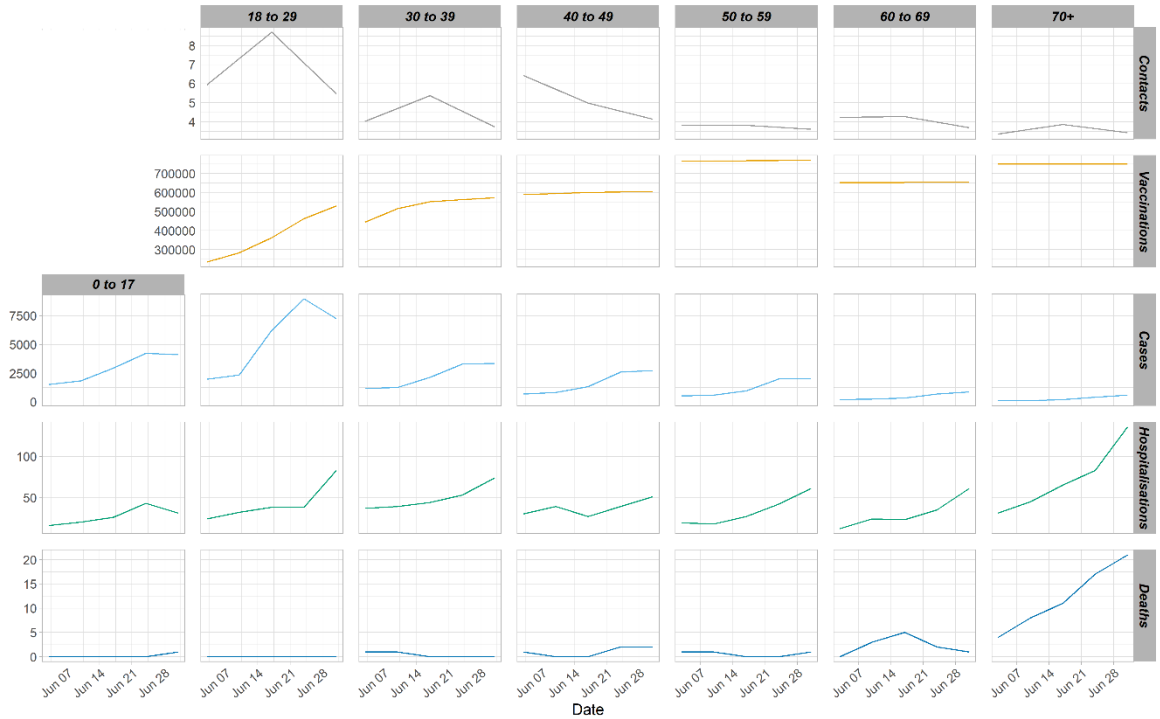
Figure 8: Locations visited by participants at least once for panel A and B (from SCS).



Vaccinations and contacts patterns

From Figure 9, it can be seen that the older age groups have fewer contacts and more vaccinations than the youngest age group, they also have the lowest weekly case number comparatively to the younger age groups. Despite that, they have similar, or higher for the oldest age group, weekly hospitalization levels to that seen with the younger age groups.

Figure 9: Average contacts for Panel B, weekly cases, covid-19 hospital admissions and deaths[4] and cumulative vaccinations by age band[5]

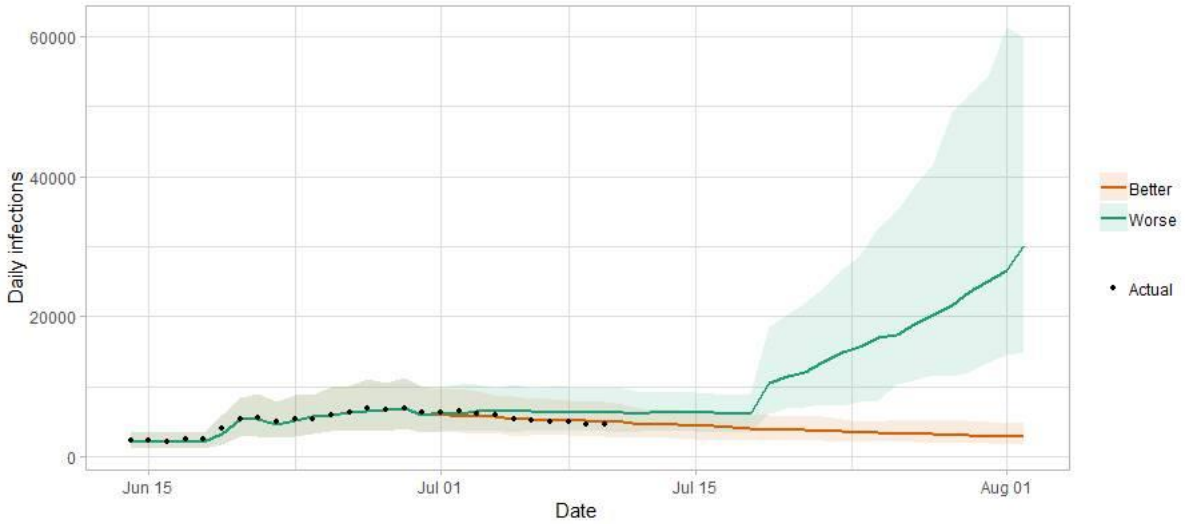


What the modelling tells us about estimated infections as well as Hospital and ICU bed demand

The Scottish Government assesses the impact of Covid-19 on the NHS in the next few weeks in terms of estimated number of infections. Figure 10 shows two projections. 'Worse' assumes that behaviour changes instantaneously after the whole of Scotland moves to Level 0 on 19th July. 'Better' assumes behaviour changes gradually over a period of months.[6]

[4] Deaths, Cases and Hospitalisations from PHS COVID-19 daily cases in Scotland dashboard.
[5] Vaccination and contact data for the 0-17 age cohort is not presented due to the vast majority of this age group not being offered vaccinations and the SCS excluding contacts between children.
[6] Both scenarios are based on current vaccine roll-out plans and efficacy assumptions.

Figure 10. Medium term projections of modelled total new daily infections, adjusting positive tests[7] to account for asymptomatic and undetected infections, from Scottish Government modelling, based on positive test data reported up to 12th July.



There is uncertainty as to whether infections will increase or remain level in coming weeks. This will drive whether hospital beds and intensive care beds also continue to rise.

Figure 11 shows the impact of the projections on the number of people in hospital. The modelling includes all hospital stays, whereas the actuals only include stays up to 28 days duration that are linked to Covid-19. Work is ongoing to show the modelled occupancy for stays up to a 28 day limit.

The increase in cases seen in the last weeks is likely to lead to a continuing increase in hospitalisations and intensive care use, with considerable uncertainty as to future weeks.

[7] The actual positive tests are adjusted to coincide with the estimated day of infection.

Figure 11. Medium term projections of modelled hospital bed demand, from Scottish Government modelling, based on positive test data reported up to 12th July.

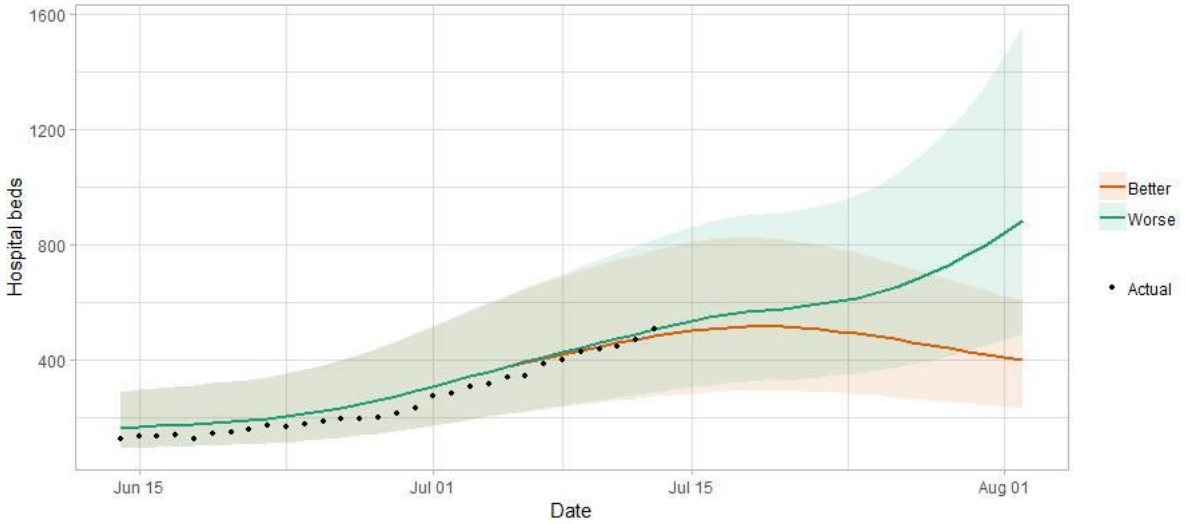
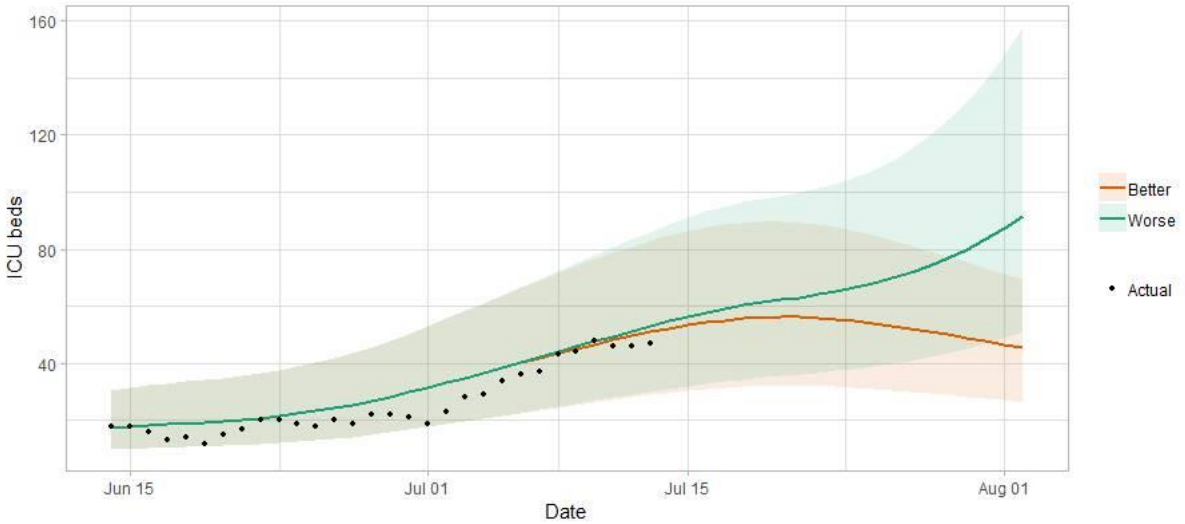


Figure 12 shows the impact of the projection on ICU bed demand.

Figure 12. Medium term projections of modelled ICU bed demand, from Scottish Government modelling[8], based on positive test data reported up to 12th July.



A comparison of the actual data against historical projections is included in the Technical Annex.

[8] Actual data does not include full numbers of CPAP. ICU bed actuals include all ICU patients being treated for Covid-19 including those over 28 days.

What the modelling tells us about projections of hospitalisations and deaths in the medium term

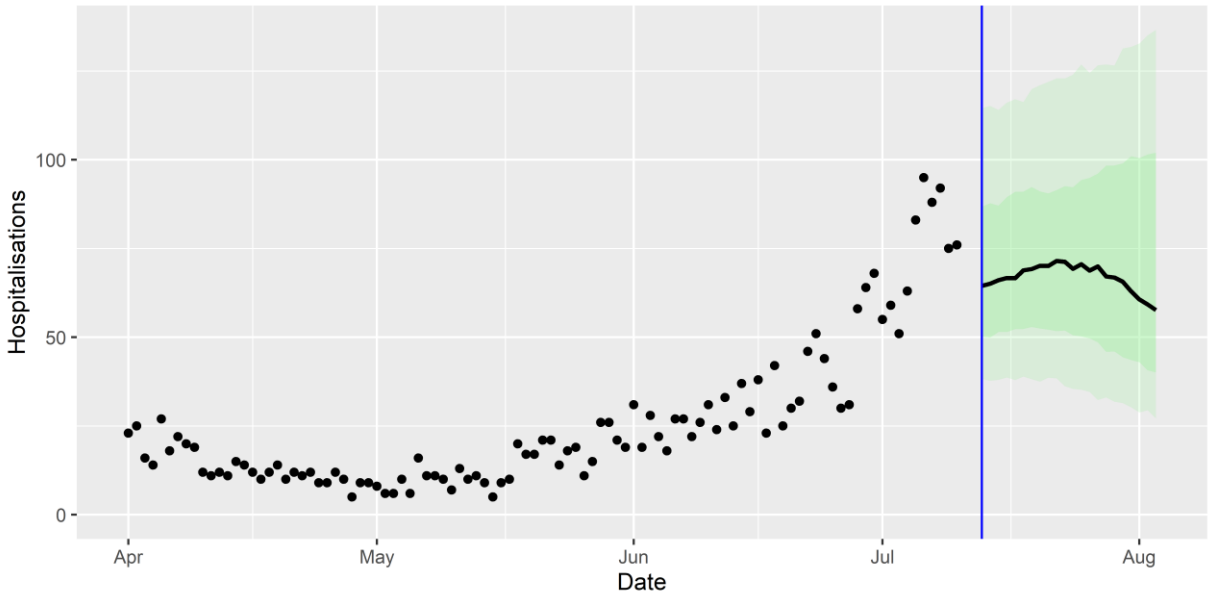
SAGE produces projections of the epidemic[9] (Figure 13), combining estimates from several independent models (including the Scottish Government's logistics modelling, as shown in Figures 10-12). These projections are not forecasts or predictions. They represent a scenario in which the trajectory of the epidemic continues to follow the trends that were seen in the data up to 12th July and do not include the effects of any future policy or behavioural changes.

The delay between infection, developing symptoms, the need for hospital care, and death means they will not fully reflect the impact of behaviour changes in the two to three weeks prior to 12th July. Projecting forwards is difficult when the numbers of cases, admissions and deaths fall to very low levels, which can result in wider credible intervals reflecting greater uncertainty. The interquartile range can be used, with judgement, as the projection from which estimates may be derived until the 3rd August, albeit at lower confidence than the 90% credible interval.

These projections include the potential impact of vaccinations over the next few weeks. Modelling groups have used their expert judgement and evidence from Public Health England, Scottish Universities & Public Health Scotland, and other published efficacy studies when making assumptions about vaccine effectiveness.

[9] Four week projections are provided here: Scientific evidence supporting the government response to coronavirus (COVID-19) - GOV.UK (www.gov.uk)

Figure 13. SAGE medium-term projection of daily hospitalisations in Scotland, including 50% and 90% credible intervals.



We are not projecting the numbers of people expected to die with Covid-19 this week. The number of daily deaths has fallen to very low levels. Projecting forwards is difficult when numbers fall to very low levels, therefore SPI-M-O have decided to pause producing medium term projections for daily deaths in Scotland. SPI-M-O's consensus view is that the number of deaths will remain low over the next few weeks.

What we know about which local authorities are likely to experience high levels of Covid-19 in two weeks' time

We continue to use modelling based on Covid-19 cases and deaths using data to 12th July from several academic groups to give us an indication of whether a local authority is likely to experience high levels of Covid-19 in the future. This has been compiled via SPI-M into a consensus. In this an area is defined as a hotspot if the two week prediction of cases (positive tests) per 100K population is predicted to exceed a threshold, e.g. 500 cases.

Modelled rates of positive tests per 100K using data to 12th July (Figure 14) indicate that, for the week commencing 25th July 2021, there are 26 local authorities with at least a 75% probability of exceeding 100 cases per 100k[10].

[10] The exceptions to this are Argyll & Bute, Dumfries & Galloway, Moray, Na h-Eileanan Siar, Orkney Islands and Shetland Islands.

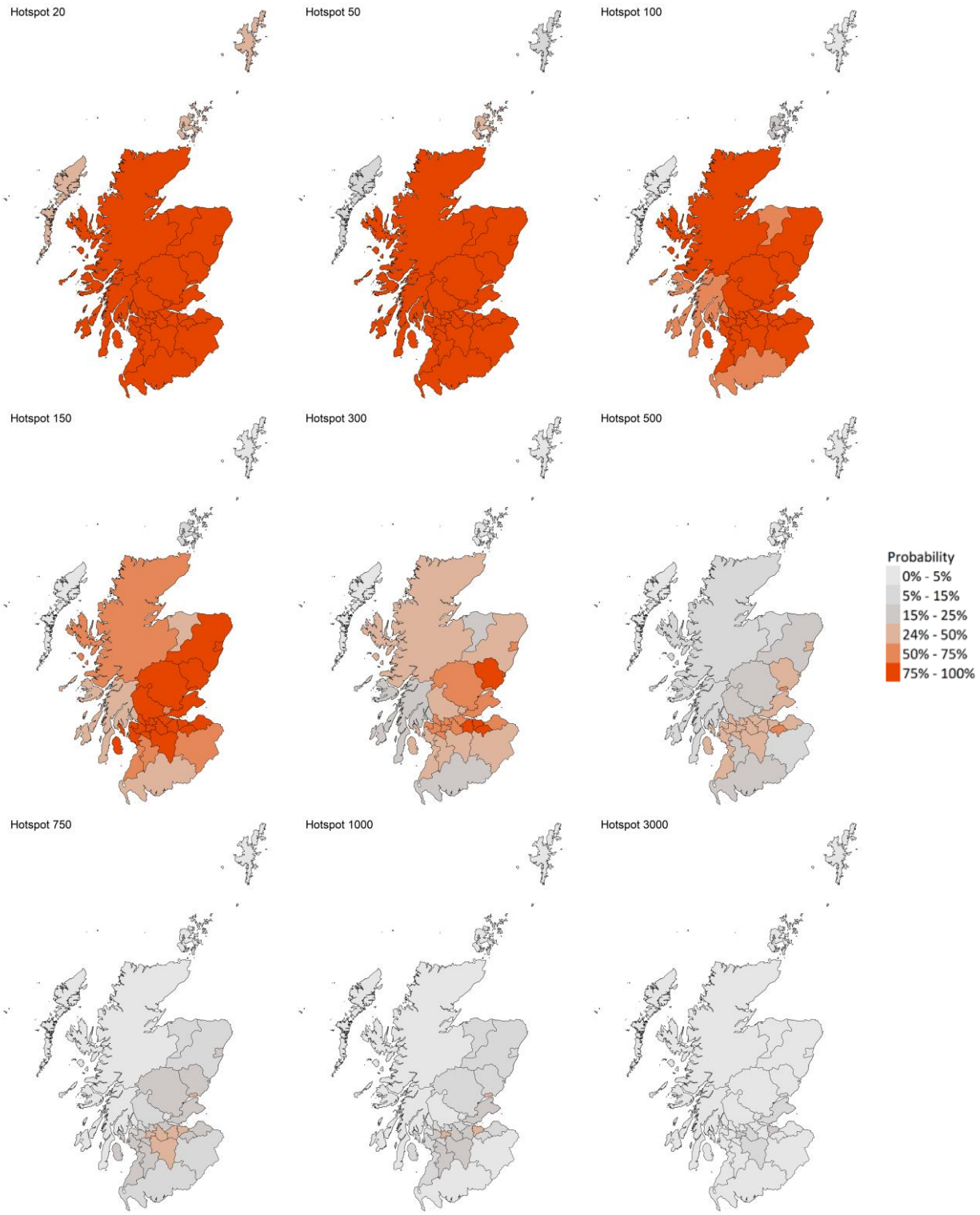
Of these, 4 local authorities (Angus, Edinburgh, Midlothian and West Lothian) have at least a 75% probability of exceeding 300 cases per 100k.

There are no local authorities with at least a 75% probability of exceeding 500 cases per 100k[11].

The local authority level modelling and national level modelling from SPI-M are based on different groups of models and look at different metrics. Furthermore the local level modelling is produced a day later than the national level. As a result, the local authority level and national level modelling do not exactly correspond to each other.

[11] Numbers are included in Table 1 in the Technical Annex.

Figure 14. Probability of local authority areas exceeding thresholds of cases per 100K (25th to 31st July 2021), data to 12th July.



What can analysis of wastewater samples tell us about local outbreaks of Covid-19 infection?

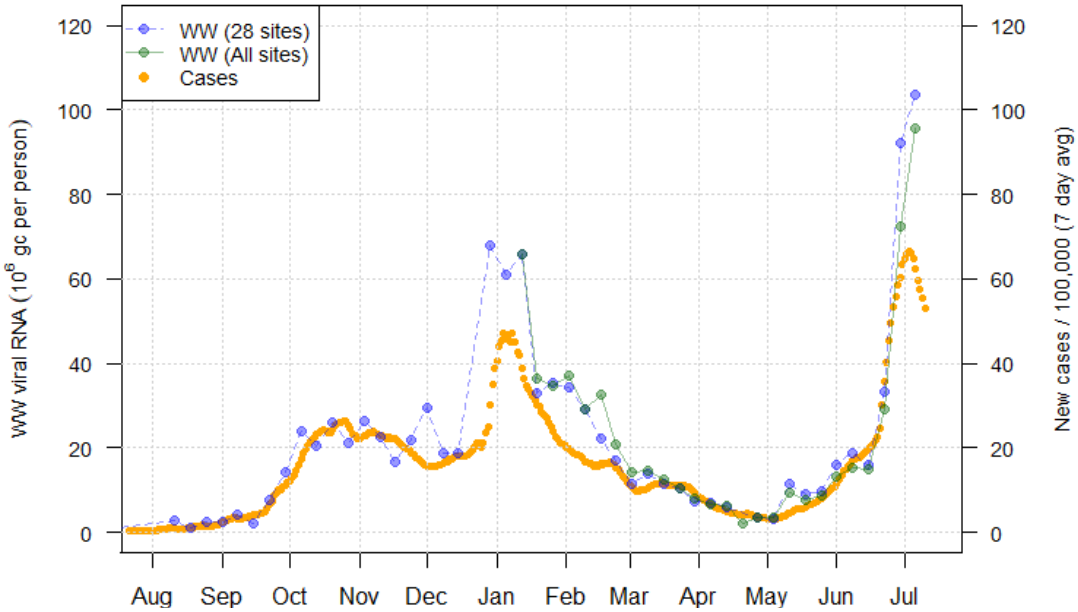
Levels of Covid-19 RNA in wastewater collected at a number of sites around Scotland are adjusted for population and local changes in intake flow rate and compared to daily 7-day average positive case rates derived from Local Authority and Neighbourhood (Intermediate Zone) level aggregate data. See Technical Annex in Issue 34 of these Research Findings for the methodology.

Nationwide, wastewater (WW) Covid-19 RNA levels rose to over 95 million gene copies per person per day (Mgc/p/d), the highest levels observed so far in this pandemic. Increases are seen in a broad range of local authorities, though recent observations in some large sites show a decline over the course of the week.

Note that from this week for approximately the next month, testing methodology for WW RNA is temporarily changed due to organisational issues. Volumes of samples tested are reduced, while some samples are being tested at other laboratories. It is not expected that these changes will have a great impact on accuracy, though samples with low virus concentrations may fall below detection thresholds.

Figure 15 shows the national aggregate for the original 28 sites (in blue) and, from January 2021, the aggregate for the full set of sampled sites (in green), with a small number of unrealistically large outliers excluded. Unlike recent weeks where WW Covid-19 changed in line with case rates, WW Covid-19 significantly exceeded levels suggested by case rates, attaining overall average levels in excess of 95 Mgc/p/d. This is approximately 50% higher than the peak attained at the start of the year. Over half of sites sampled in the last week gave WW Covid-19 levels in excess of 50 Mgc/p/d. None of the sites sampled gave WW Covid-19 test results that fall under detection limit, even with the increase in the latter.

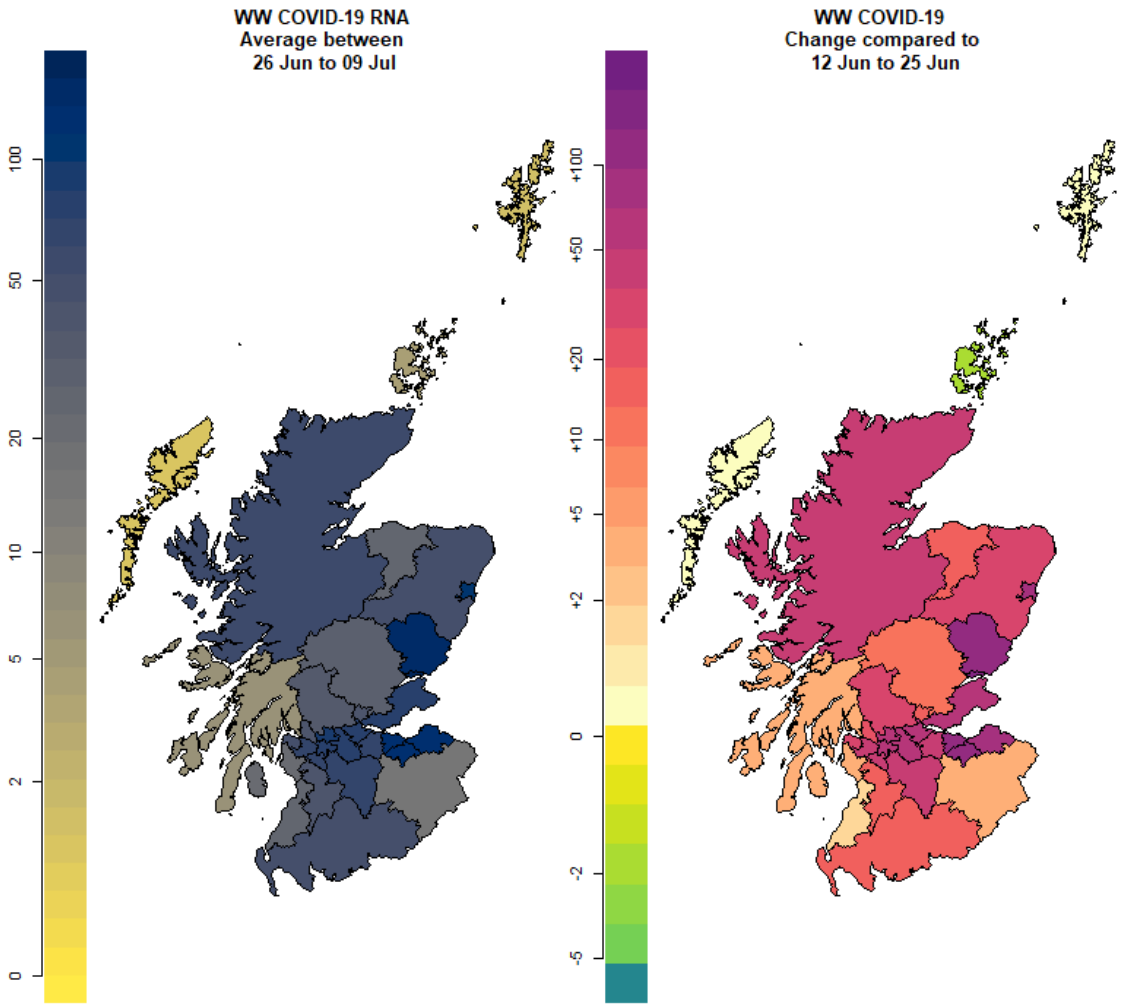
Figure 15. National average trends in wastewater Covid-19 and daily case rates (7 day moving average)[12].



The widespread nature of rises in WW Covid-19 levels is shown in Figure 16, which uses colours to map (i) the local authority average viral RNA levels (in Mgc/p/d) over the two-week period from 26th June to 9th July, and (ii) the change in viral RNA levels compared to the previous two-week period 12th June to 25th June. The highest increases are again seen in and around the major cities.

[12] Anomalously high values, one in Seafield (Edinburgh) in mid-February (See Issue 40), one in Dunblane in mid-June, and two in Daldowie in January, are removed.

Figure 16. Map showing wastewater Covid-19 levels (million gene copies/person/day) for each local authority for 26th June to 9th July and changes relative to 12th June to 25th June.



Of particular note are samples from the Hatton wastewater treatment works (Figure 17), which covers Dundee, and Seafield (Figure 18), which covers Edinburgh.

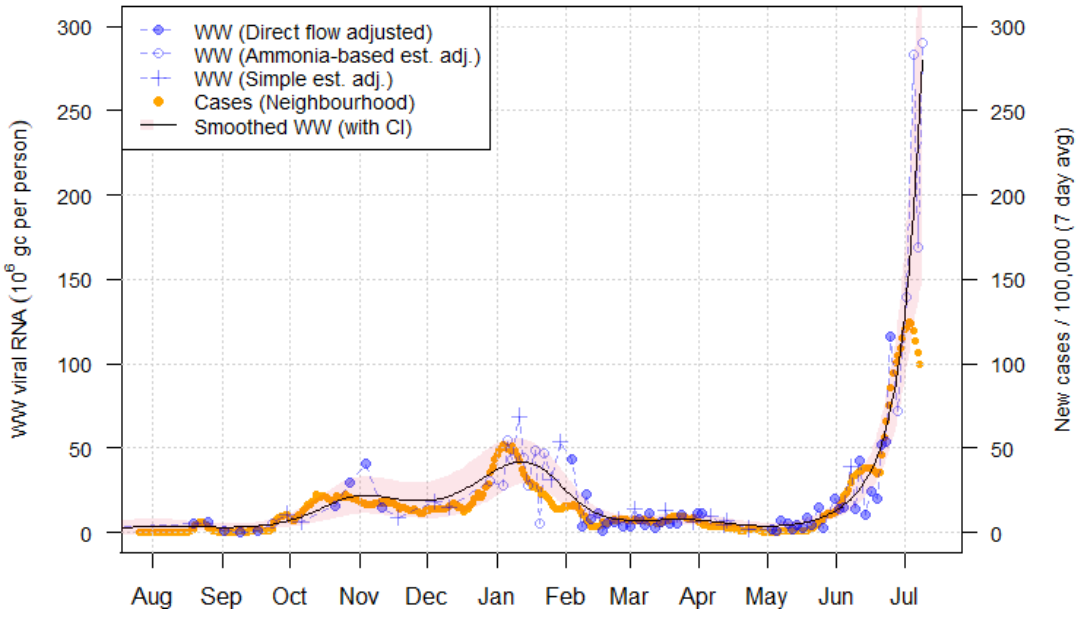
At Hatton, WW Covid-19 levels in the last week rose to extremely high levels, substantially higher than in January, and with multiple measurements in the range of 150-300 Mgc/p/d. While this displays a large amount of variability, this shows a clear departure from case trends and represents the highest levels recorded in a major site.

In Seafield, levels rose to almost 250 Mgc/p/d with a sample taken on 2nd July. However, three subsequent samples were tested and showed a decline in levels from that peak, with the two most recent samples giving

an estimate of around 60 Mgc/p/d. This approximates the pattern in cases, albeit in a more exaggerated manner.

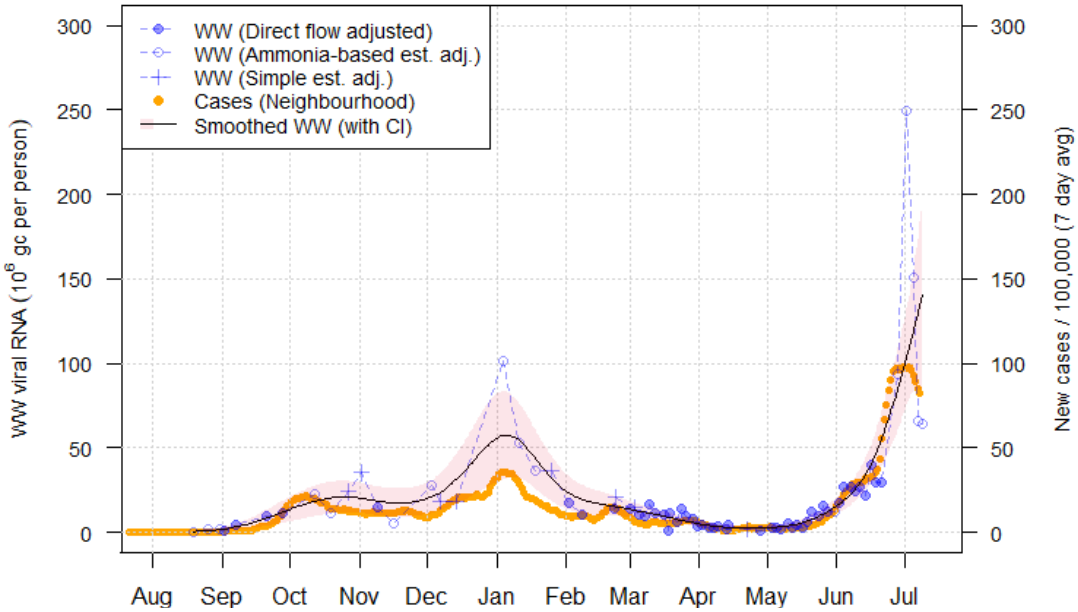
Some other sites, including Nigg (covering Aberdeen) and Dalmuir (covering parts of Glasgow), show a similar pattern of a large increase in one sample followed by a reduced second sample. Taken together, however, this still represents a week to week increase in average WW Covid-19 levels. This sort of rapid (intra-week) change in levels is difficult to capture in aggregated statistics for weekly or fortnightly intervals. It is too early to tell if these reductions in WW Covid-19 levels will be maintained.

Figure 17. Wastewater Covid-19 and daily case rate (7 day moving average) for Hatton (covered pop: 194k) in Dundee[13].



[13] The black line and red shaded area provide a smoothed curve and confidence interval estimated from a generalised additive model based on a Tweedie distribution.

Figure 18. Wastewater Covid-19 and daily case rate (7 day moving average) for Seafield (covered pop: 606k) in Edinburgh.



What next?

The modelled estimates of the numbers of new cases and infectious people will continue to be provided as measures of the epidemic as a whole, along with measures of the current point in the epidemic such as R_t and the growth rate. Further information can be found at https://www.gov.scot/coronavirus-covid-19.

We may report on exceedance in future weeks when the background levels of Covid-19 reduces so that it can be useful in identifying outbreaks.

Technical Annex

Epidemiology is the study of how diseases spread within populations. One way we do this is using our best understanding of the way the infection is passed on and how it affects people who catch it to create mathematical simulations. Because people who catch Covid-19 have a relatively long period in which they can pass it on to others before they begin to have symptoms, and the majority of people infected with the virus will experience mild symptoms, this “epidemiological modelling” provides insights into the epidemic that cannot easily be measured through testing e.g. of those with symptoms, as it estimates the total number of new daily infections and infectious people, including those who are asymptomatic or have mild symptoms.

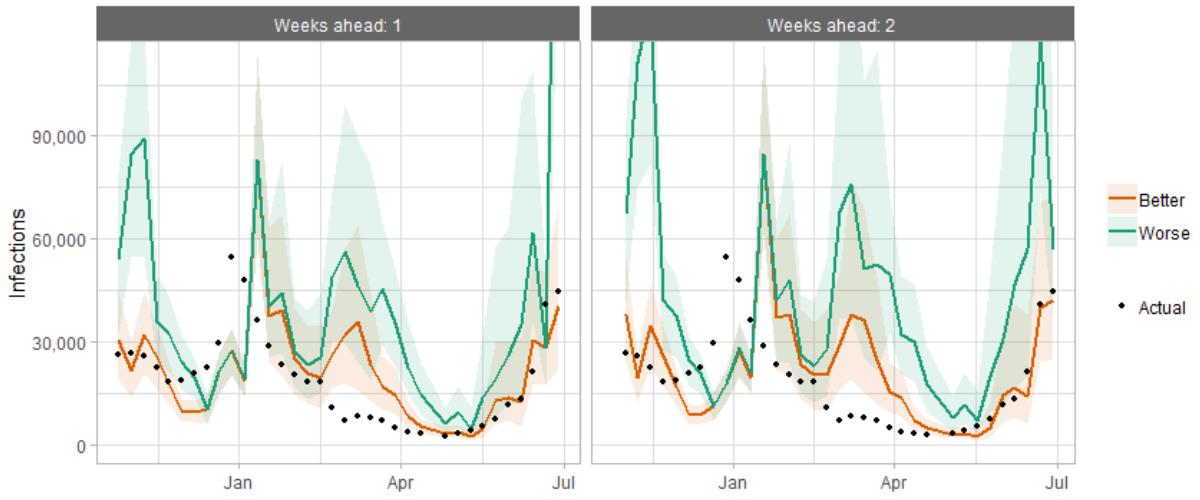
Modelling also allows us to make short-term forecasts of what may happen with a degree of uncertainty. These can be used in health care and other planning. The modelling in this research findings is undertaken using different types of data which going forward aims to both model the progress of the epidemic in Scotland and provide early indications of where any changes are taking place.

The delivery of the vaccination programme will offer protection against severe disease and death. The modelling includes assumptions about compliance with restrictions and vaccine take-up. Work is still ongoing to understand how many vaccinated people might still spread the virus if infected. As Covid-19 is a new disease there remain uncertainties associated with vaccine effectiveness. Furthermore, there is a risk that new variants emerge for which immunisation is less effective.

How the modelling compares to the real data as it emerges

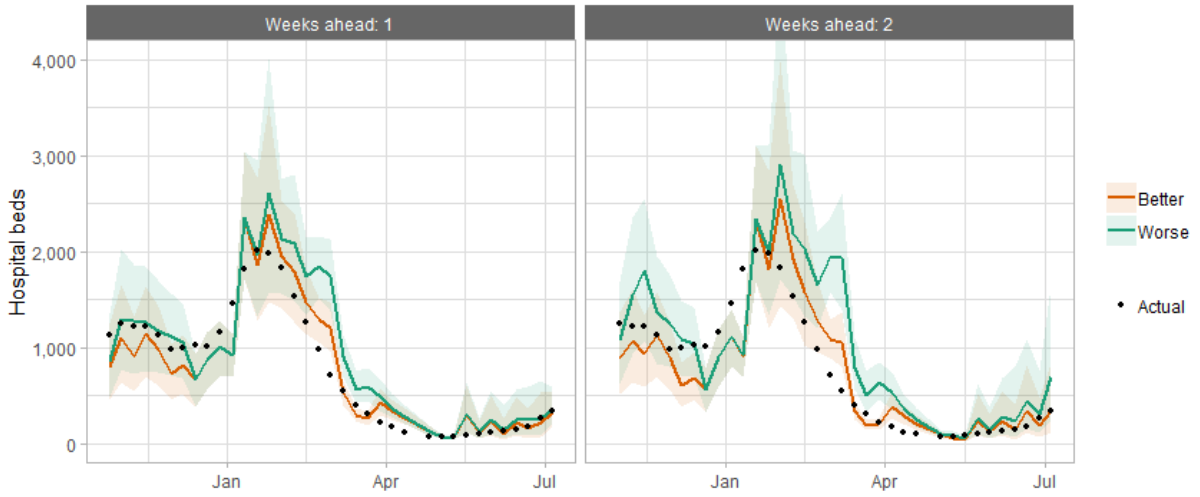
The following charts show the history of our modelling projections in comparison to estimates of the actual data. The infections projections were largely accurate during October to mid-December and from mid-January onward. During mid-December to mid-January, the projections underestimated the number of infections, due to the unforeseen effects of the new variant.

Figure 19. Infections projections versus actuals, for historical projections published between one and two weeks before the actual data came in.



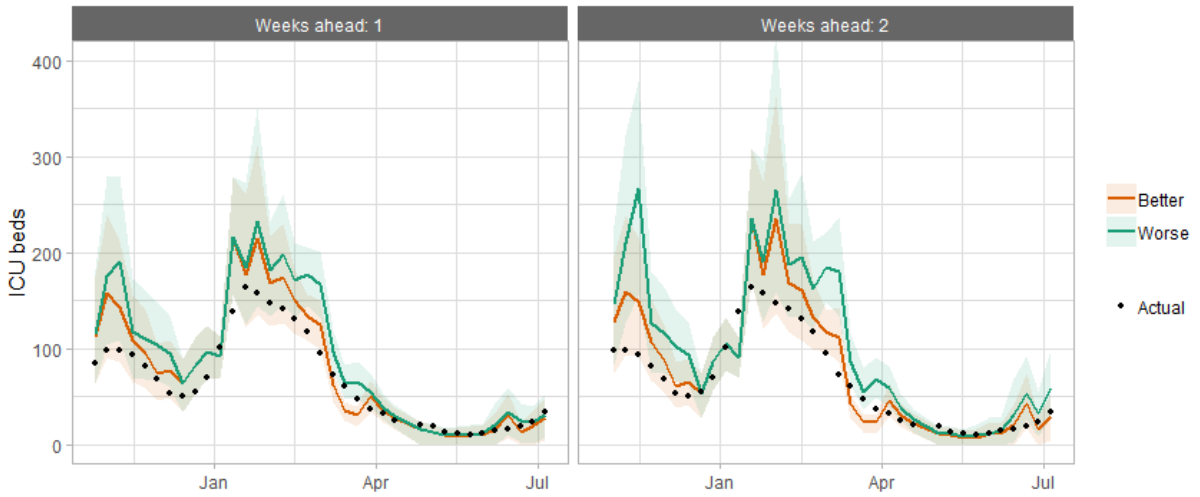
Hospital bed projections have generally been more precise than infections estimates due to being partially based on already known information about numbers of current infections, and number of people already in hospital. The projections are for number of people in hospital due to Covid-19, which is slightly different to the actuals, which are number of people in hospital within 28 days of a positive Covid-19 test.

Figure 20. Hospital bed projections versus actuals, for historical projections published between one and two weeks before the actual data came in.



As with hospital beds, ICU bed projections have generally been more precise than infections. The projections are for number of people in ICU due to Covid-19. The actuals are number of people in ICU within 28 days of a positive Covid-19 test up to 20 January, after which they include people in ICU over the 28 day limit.

Figure 21. ICU bed projections versus actuals, for historical projections published between one and two weeks before the actual data came in.



How outliers are identified in the wastewater data

On occasion, samples of wastewater (WW) produce extremely high measurements of viral RNA concentration that are unlikely to be representative of actual Covid-19 prevalence and revert to low levels subsequently – even in samples taken very soon afterwards. These account for approximately 2% of samples.

These spikes usually remain unexplained. Possible explanations could include an imperfect sampling process, incidents of dumping of virus contaminated waste, or lab contamination. Sometimes, though, there can be a reasonable explanation for the spike, such as an outbreak centred on a hospital or care home, or an influx of holiday-makers.

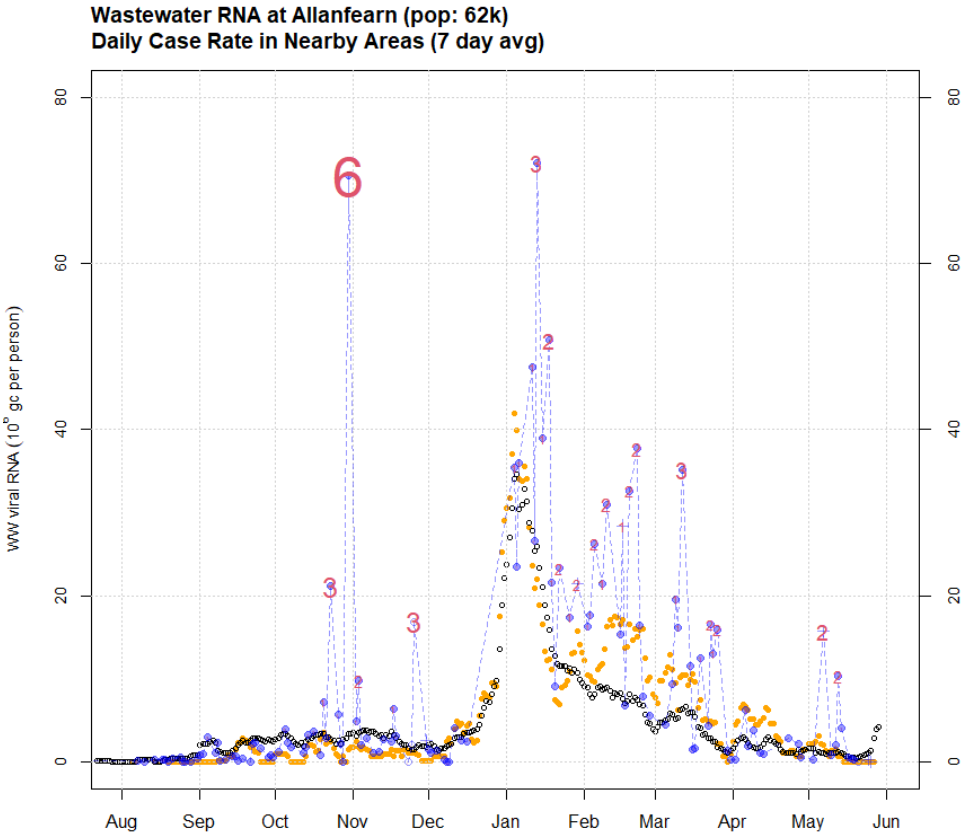
Identification of such spikes improve interpretability of data visualisations, show clearer underlying trends in aggregate levels, avoid spurious alerts, and improve the reliability of measures of uncertainty. It is especially desirable to be able to detect anomalies immediately after the WW RNA value is recorded, since this is when decisions may need to be made, and new samples might be obtained to recheck Covid-19 levels.

Biomathematics and Statistics Scotland (BioSS) has designed an automatic procedure for detecting these spikes, based on modelling their degree of divergence from case trends and prior WW RNA trends. After first normalising WW RNA values with respect to flow, the outlier removal methodology has these steps:

1. For each WW observation, a measure of its effectiveness in predicting subsequent Covid-19 increases is calculated, based on its ratio with local case rates in the week immediately after.
2. The observation's ratio with prior case rates is calculated, as well a measure of how much the rate of change in WW RNA levels compares to previous changes in RNA at the same site.
3. The value in step 1 is modelled as a function of the two calculated values in step 2, using a generalised additive model with appropriately chosen logarithmic transformations.
4. For each newly observed WW measurement, the same covariates as in step 2 can be calculated, and the model we fitted may be used to forecast the new measurement's predictive effectiveness, calculating a propensity score for that value to be an outlier between 0 and 10. When a decision is required, a threshold then may be imposed on this propensity using a preliminary analysis with manually identified spikes.

An example of the output from the algorithm is show below in Figure 22.

Figure 22: Wastewater and case trends at the Allanfearn wastewater treatment works, with calculated outlier propensity scores superimposed on the graph.



Comparing to manually chosen outliers, a threshold of 4 picks up about 70% of manually detected spikes and misclassifies around 0.7% of non-anomalous values. Note that this threshold choice is quite conservative, choosing to avoid classifying borderline cases as outliers. Applying this threshold in the example above means only the late October spike is identified as an outlier.

Use of outlier identification

For aggregate values like national or local authority means, anomalous values are removed to produce more reliable results, though sometimes this may leave aggregates entirely missing major cities in an area. We are considering further how to improve the management of these cases.

However, it is generally believed that a positive WW value, even an erroneously large one, nevertheless indicates the presence of Covid-19 in a region. This means that outliers should not be removed when it comes to presence/absence analyses.

The outlier detection methodology is currently implemented in graphical visualisations in the weekly WW national reporting, for the tables of local authority averages, and in interval-based summaries of Covid-19 levels for local authorities (Table 2).

How is wastewater data used in our modelling?

The Scottish Government has historically used either deaths or cases, as published by Public Health Scotland (PHS), to inform its model to estimate current R values, incidence figures and growth rates.

In recent months, these research findings have explained how an estimate of cases can be made by examining the levels of Covid-19 RNA in wastewater, collected throughout Scotland and adjusted for population and local changes in intake flow rate.

We have developed our modelling such that it is possible to calculate the main nowcast outputs by using this wastewater data, instead of the case data from PHS.

The Scottish WW data is population weighted averages for normalised Wastewater Covid levels. The units are provided in 1 million gene copies per person per day, which roughly matches with cases per 100,000 per day. This is converted into daily cases at a national level. The model makes an allowance for the proportion of infections which are positively

identified as cases (using a comparison with the ONS Covid Infection Survey[14]), and then uses a Bayesian method to estimate the key variables throughout the pandemic.

We are currently only using the wastewater data for Scottish cases, but are working with colleagues in the other UK nations to use their wastewater data in a similar way.

[14] Coronavirus (COVID-19) Infection Survey, UK Statistical bulletins - Office for National Statistics

Table 1. Probability of local authority areas exceeding thresholds of cases per 100K (25th to 31st July 2021), data to 12th July.

	Probability of exceeding (cases per 100k)								
Local Authority (LA)	20	50	100	150	300	500	750	1000	2000
Aberdeen City	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	0-5%
Aberdeenshire	75-100%	75-100%	75-100%	75-100%	25-50%	15-25%	5-15%	5-15%	0-5%
Angus	75-100%	75-100%	75-100%	75-100%	75-100%	25-50%	15-25%	5-15%	0-5%
Argyll and Bute	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	0-5%	0-5%	0-5%
City of Edinburgh	75-100%	75-100%	75-100%	75-100%	75-100%	25-50%	25-50%	25-50%	15-25%
Clackmannanshire	75-100%	75-100%	75-100%	50-75%	25-50%	5-15%	0-5%	0-5%	0-5%
Dumfries & Galloway	75-100%	75-100%	50-75%	25-50%	15-25%	15-25%	5-15%	0-5%	0-5%
Dundee City	75-100%	75-100%	75-100%	75-100%	50-75%	50-75%	25-50%	25-50%	15-25%
East Ayrshire	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	15-25%	15-25%	0-5%
East Dunbartonshire	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	0-5%
East Lothian	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	0-5%
East Renfrewshire	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	0-5%
Falkirk	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	0-5%
Fife	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	15-25%	5-15%
Glasgow City	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	25-50%	25-50%	15-25%
Highland	75-100%	75-100%	75-100%	50-75%	25-50%	5-15%	0-5%	0-5%	0-5%
Inverclyde	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	5-15%	0-5%	0-5%
Midlothian	75-100%	75-100%	75-100%	75-100%	75-100%	50-75%	15-25%	5-15%	0-5%
Moray	75-100%	75-100%	50-75%	25-50%	15-25%	5-15%	5-15%	5-15%	0-5%
Na h-Eileanan Siar	25-50%	5-15%	0-5%	0-5%	0-5%	0-5%	0-5%	0-5%	0-5%
North Ayrshire	75-100%	75-100%	75-100%	75-100%	25-50%	25-50%	15-25%	5-15%	0-5%
North Lanarkshire	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	25-50%	15-25%	5-15%
Orkney Islands	25-50%	25-50%	15-25%	5-15%	0-5%	0-5%	0-5%	0-5%	0-5%
Perth and Kinross	75-100%	75-100%	75-100%	75-100%	50-75%	15-25%	15-25%	5-15%	0-5%
Renfrewshire	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	15-25%	15-25%	5-15%
Scottish Borders	75-100%	75-100%	75-100%	50-75%	25-50%	5-15%	5-15%	0-5%	0-5%
Shetland Islands	25-50%	5-15%	0-5%	0-5%	0-5%	0-5%	0-5%	0-5%	0-5%
South Ayrshire	75-100%	75-100%	75-100%	50-75%	25-50%	25-50%	15-25%	5-15%	0-5%
South Lanarkshire	75-100%	75-100%	75-100%	75-100%	25-50%	25-50%	25-50%	15-25%	15-25%
Stirling	75-100%	75-100%	75-100%	75-100%	25-50%	15-25%	5-15%	0-5%	0-5%
West Dunbartonshire	75-100%	75-100%	75-100%	75-100%	50-75%	25-50%	5-15%	5-15%	0-5%
West Lothian	75-100%	75-100%	75-100%	75-100%	75-100%	25-50%	25-50%	15-25%	5-15%

What levels of Covid-19 are indicated by wastewater (WW) data?

Table 2 provides population weighted daily averages for normalised WW Covid-19 levels in the weeks beginning the 26th June and 3rd July, with no estimate for error. This is given in Million gene copies per person, which approximately corresponds to new cases per 100,000 per day. Coverage is given as percentage of LA inhabitants covered by a wastewater Covid-19 sampling site delivering data during this period[15].

Table 2. Average daily cases per 100k as given by WW data

Local authority (LA)	Average daily WW case estimate, with outliers included		Average daily WW case estimate, with outliers removed		Coverage[16]
	w/b 26th June	w/b 3rd July	w/b 26th June	w/b 3rd July	
Aberdeen City	87.0	136.0	87.0	136.0	80%
Aberdeenshire	32.0	62.0	32.0	57.0	52%
Angus	85.0	201.0	85.0	201.0	56%
Argyll and Bute	0.0	10.0	0.0	10.0	18%
City of Edinburgh	172.0	94.0	172.0	94.0	96%
Clackmannanshire	33.0	46.0	33.0	46.0	92%
Dumfries & Galloway	25.0	67.0	25.0	28.0	32%
Dundee City	106.0	248.0	106.0	248.0	100%
East Ayrshire	30.0	57.0	30.0	54.0	69%
East Dunbartonshire	83.0	114.0	83.0	114.0	99%
East Lothian	154.0	99.0	154.0	99.0	65%
East Renfrewshire	62.0	73.0	62.0	73.0	95%
Falkirk	67.0	81.0	67.0	81.0	69%
Fife	73.0	86.0	73.0	86.0	80%
Glasgow City	70.0	97.0	70.0	97.0	98%
Highland	32.0	79.0	32.0	78.0	33%
Inverclyde	40.0	60.0	40.0	60.0	92%
Midlothian	161.0	108.0	161.0	108.0	88%
Moray	21.0	32.0	7.0	32.0	70%
Na h-Eileanan Siar	0.0	3.0	0.0	3.0	21%
North Ayrshire	23.0	22.0	23.0	22.0	93%
North Lanarkshire	37.0	126.0	37.0	126.0	95%
Orkney Islands	4.0	6.0	4.0	6.0	34%
Perth and Kinross	32.0	35.0	32.0	35.0	45%
Renfrewshire	44.0	89.0	44.0	89.0	57%
Scottish Borders	12.0	21.0	10.0	21.0	38%
Shetland Islands	0.0	0.0	0.0	0.0	29%
South Ayrshire	23.0	27.0	23.0	27.0	82%
South Lanarkshire	58.0	70.0	58.0	65.0	84%
Stirling	28.0	44.0	28.0	44.0	63%
West Dunbartonshire	11.0	76.0	11.0	76.0	98%
West Lothian	50.0	86.0	46.0	87.0	85%

[15] Advancements in detection and interpretation practices allow us to identify when outlying results are anomalous rather than indicators of spikes in Covid-19 levels. Table 2 provides population weighted daily averages for normalised WW Covid-19 levels both with and without the outliers removed. See the section in the Technical Annex for further details.

[16] Coverage as at the week beginning 3rd July 2021.

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