Coronavirus (COVID-19): Analysis

Coronavirus (COVID-19): modelling the epidemic in Scotland (Issue No. 52)

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 13 May 2021. The estimates in this document help the Scottish Government, the health service and the wider public sector plan and put in 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 0.9 and 1.2, with the growth rate increasing to between -3% and 2% and modelled estimates of infections now plateauing or increasing over the next four weeks. Furthermore, positive test data over the last week is showing an increase in Covid-19 cases, and this is also being reflected in the wastewater data. Exceedance modelling indicates that there are nine local authority areas at higher risk of increasing transmission.

All of the measures modelled for this week, as described above, indicate that we are seeing a deteriorating position in Scotland, with considerable uncertainty as to what this means for future weeks.

Key Points

- The reproduction rate R in Scotland is currently estimated as being between 0.9 and 1.2. This is an increase in the range since last week.
- The number of new daily infections for Scotland is estimated as being between 4 and 10, per 100,000 people. This has increased since last week.

- The growth rate for Scotland is currently estimated as being between -3% and 2%. This is an increase in the top of the range since last week.
- Average contacts have increased by 12% in the last two weeks (comparing surveys pertaining to 22nd – 28th April and 6th - 12th May) with a current level of 4.3 daily contacts.
- The biggest increase in contacts is seen within leisure settings (contacts outside of the school, home and work), rising by 26%. Contacts within work and school have also increased by 14% and 22% respectively.
- All individuals with the exception of those aged between 40 and 59 increased their contacts in the last two weeks. The biggest increase is seen by those aged between 18-29, increasing by 50%, largely driven by work contacts.
- The biggest increase in interactions between age groups is seen between those aged 18-29 with each other, increasing by 170%.
- The biggest change in the proportion of participants visiting different locations is seen in those visiting a pub or restaurant. This has increased from less than 2% to 29% in the last two weeks, followed by visiting a non-essential shop, increasing from 22% to 39%, coinciding with the easing of restrictions on 26th April.
- Hospital bed and ICU occupancy are projected to plateau or rise over the next few weeks, as a result of relaxations of non-pharmaceutical interventions.
- There were nine local authority areas that exceeded what would be expected at this stage in the epidemic. Between 13th and 19th May, Midlothian, Stirling, Glasgow City, Clackmannanshire, East Dunbartonshire, East Renfrewshire, Na h-Eileanan Siar, Borders and Edinburgh were areas at higher risk of increasing transmission.
- Modelled rates per 100K indicate that for the week commencing 30 May 2021, the only local authority with at least a 75% probability of exceeding 50 cases is Glasgow City.
- The overall level of wastewater Covid-19 has increased notably this week, reaching around two and a half times last week's levels and exceeding the rate of increase in cases. This is particularly driven by new outbreaks in the Glasgow area.
- Alloa in Clackmannanshire and Lerwick in the Shetland Islands both show increases in virus levels that are not yet reflected by the case levels. Additional sites where wastewater shows a rise in Covid-19, albeit to a lesser extent, are Hatton around Dundee, Inverclyde, Allanfearn in the Highlands, and some sites in the Falkirk area.

Overview of Scottish Government Modelling

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.

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 1.

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 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.

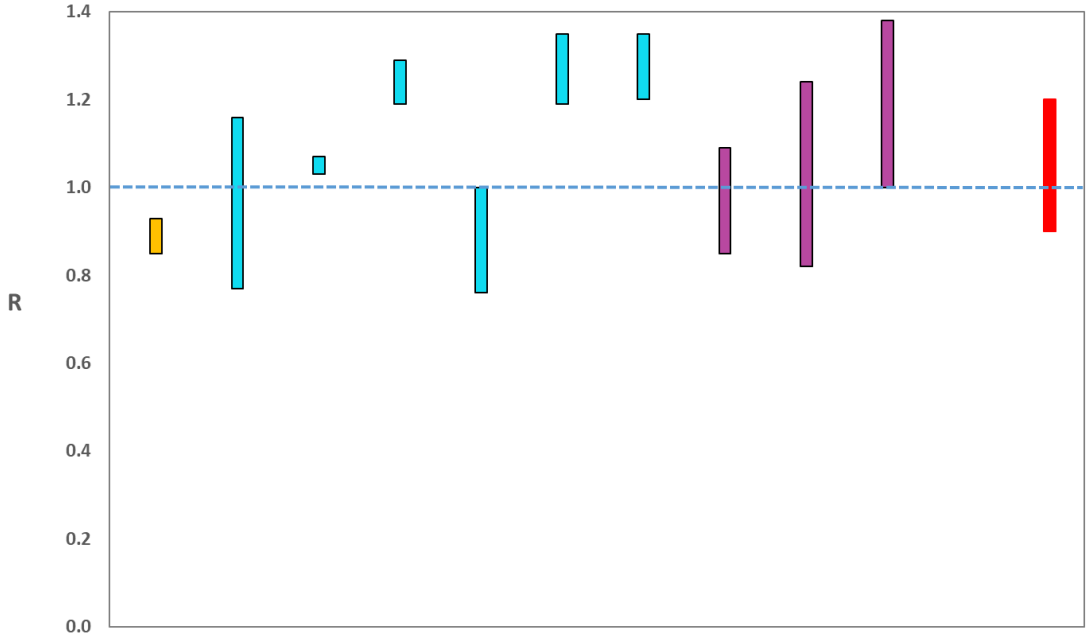
The logistical model utilises results from the epidemiological modelling, principally the number of new infections. The results are split down by age group, and the model is used to give a projection of the number of people that will go to hospital, and potentially to ICU. This will continue to be based on both what we know about how different age groups are effected 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. SAGE's consensus view across these methods, as of 19th May, was that the value of R in Scotland was between 0.9 and 1.2 (see Figure 1). This has increased from the range of 0.8 to 1.0 last week[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. They should not be treated as robust enough to inform policy decisions alone.

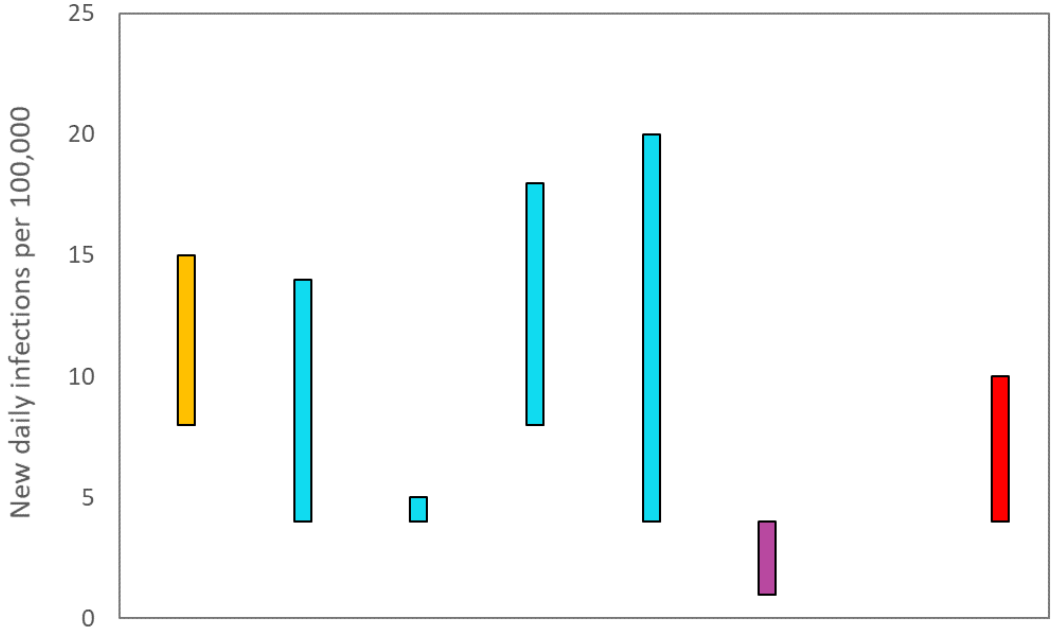
Figure 1. Estimates of R_t for Scotland, as of 19th May, including 90% confidence intervals, produced by SAGE. The cyan bars use Covid-19 test data and purple bars use multiple sources of data. The estimate produced by the Scottish Government (based on deaths) is the left-most (yellow), while the SAGE consensus range is the right-most (red).



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 2). SPI-M's consensus view across these methods, as of 19th May, was that the incidence of new daily infections in Scotland was between 4 and 10 new infections per 100,000. This is an increase since last week. This equates to between 200 and 500 people becoming infected each day in Scotland.

Figure 2. Estimates of incidence for Scotland, as of 19th May, including 90% confidence intervals, produced by SPI-M. The cyan bars use Covid-19 test data and purple bars use multiple sources of data. The estimate produced by the Scottish Government is the first on the left (yellow), while the SAGE consensus range is the right-most (red).



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 -3% and 2% per day. This is an increase in the top of the range from 12th May.

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

Average contacts have increased by approximately 12% in the last two weeks (comparing surveys pertaining to 22nd – 28th April and 6th - 12th May) with a current level of 4.3 daily contacts as seen in Figure 3. The biggest increase in contacts is seen within the leisure settings (contacts outside of the school, home and work), rising by 26%. Contacts within work and school have also increased by 14% and 22% respectively. In contrast contacts within the home setting have decreased slightly (5%) over the same period.

Figure 3: Mean Adult Contacts (truncated at 100) from SCS.

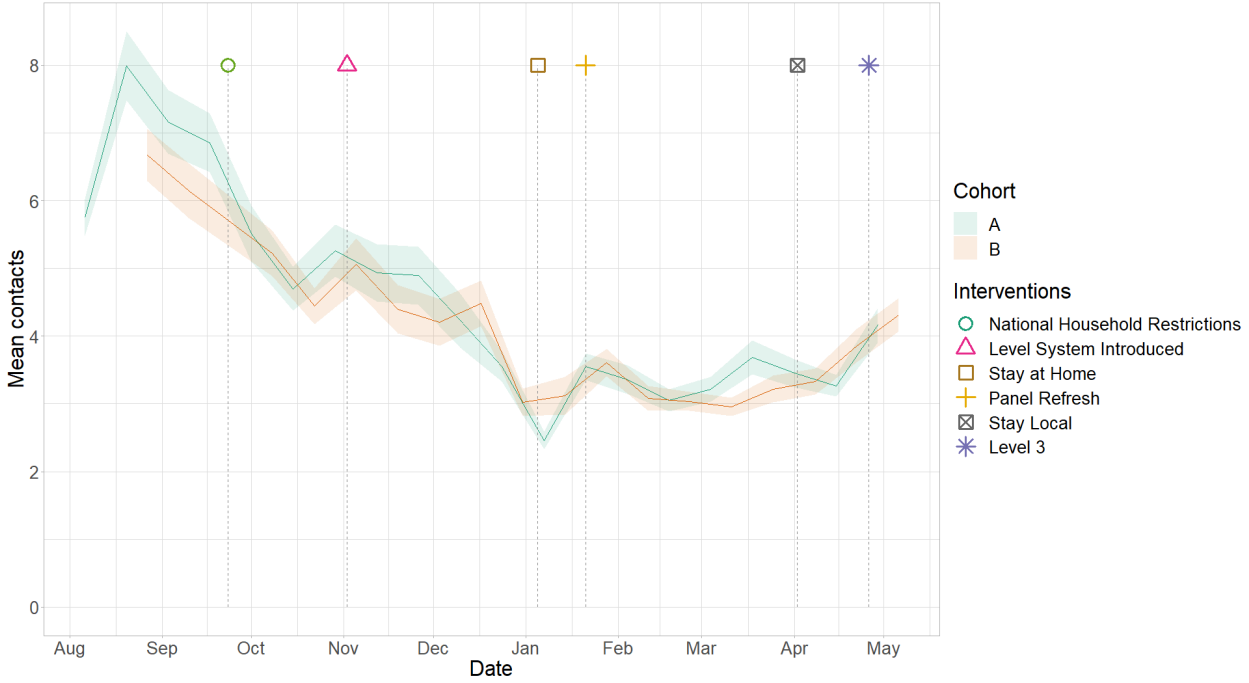
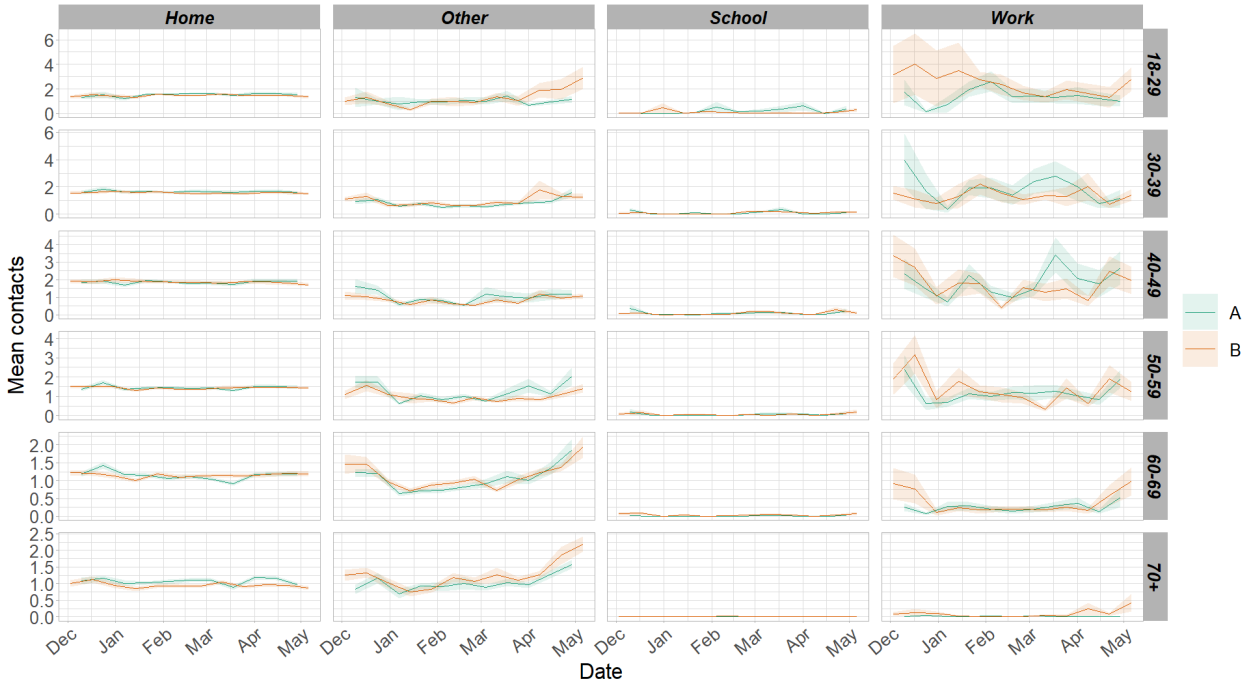


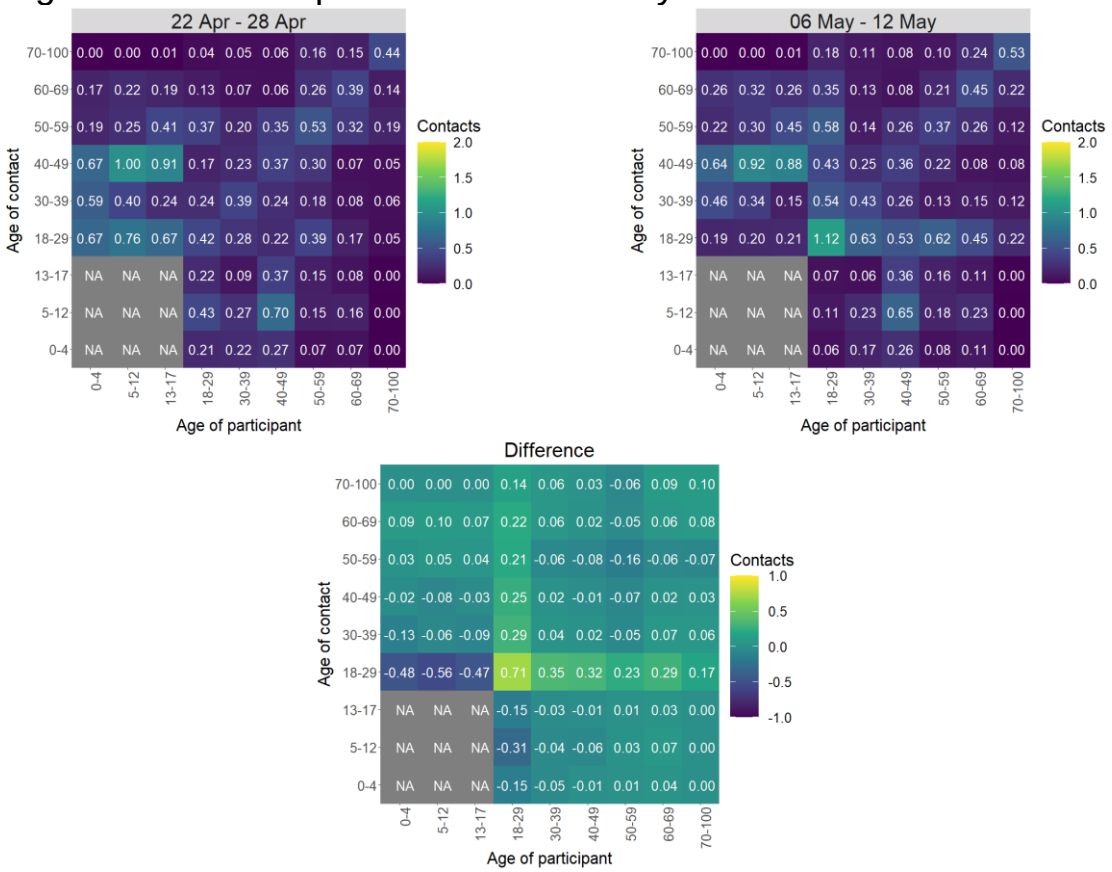
Figure 4 shows how contacts change across age group and setting. All individuals with the exception of those aged between 40 and 59 increased their contacts in the last two weeks. The biggest increase is seen by those aged between 18-29, increasing by 50%, largely driven by work contacts. All age groups have decreased their contacts within the home, with those aged between 18-29 showing the biggest decrease in this setting (10%).

Figure 4: Average (mean) contacts for each panel per day by setting for adults in Scotland, truncated to 100 contacts per participant (from SCS).



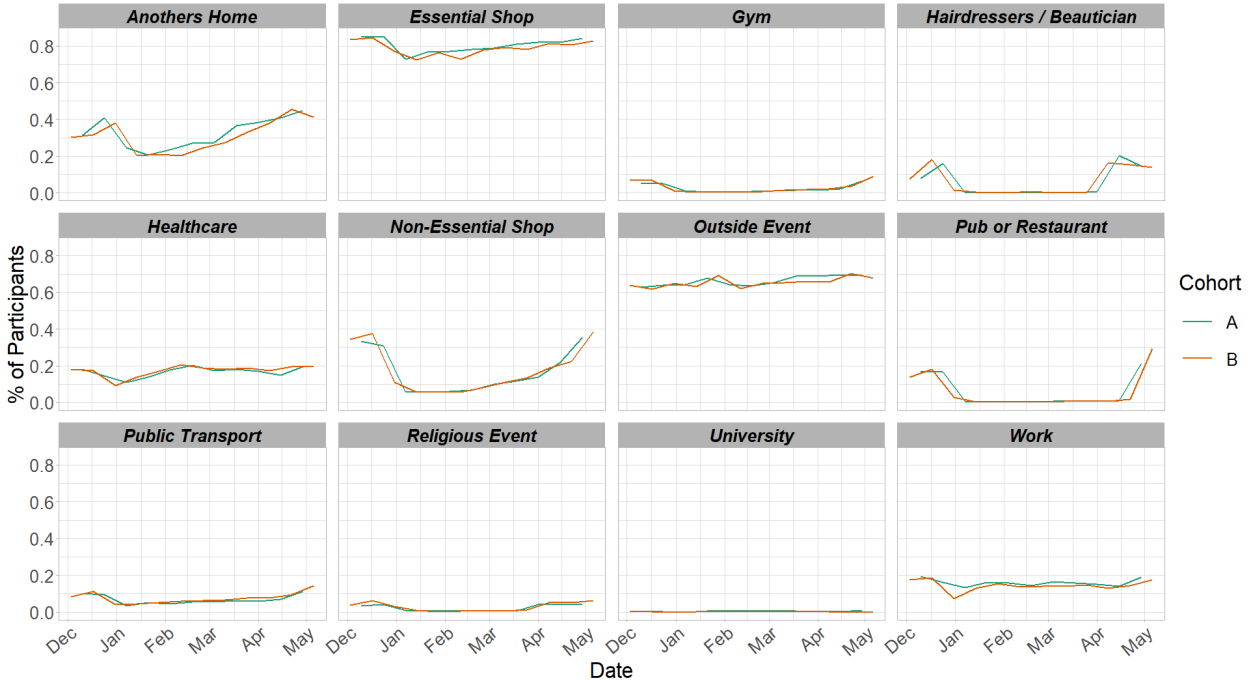
The heatmaps in Figure 5 show the mean overall contacts between age groups for the weeks relating to 22nd – 28th April and 6th - 12th May, and the difference between these periods. The biggest increase is seen between those aged 18-29 with each other, increasing by 170%. This age group has also increased interactions with all age groups 30 and over but decreased their interactions with those under 18.

Figure 5: Overall mean contacts by age group before for the weeks relating to 22nd – 28th April and 6th - 12th May



The biggest change in the proportion of participants visiting different locations is seen in those visiting a pub or restaurant. This has increased from less than 2% to 29% in the last two weeks, followed by visiting a non-essential shop, increasing from 22% to 39%, coinciding with the easing of restrictions on 26th April. The proportion of individuals visiting another's home has shown a slight decrease for the first time since the middle of January, at a current level of 41%.

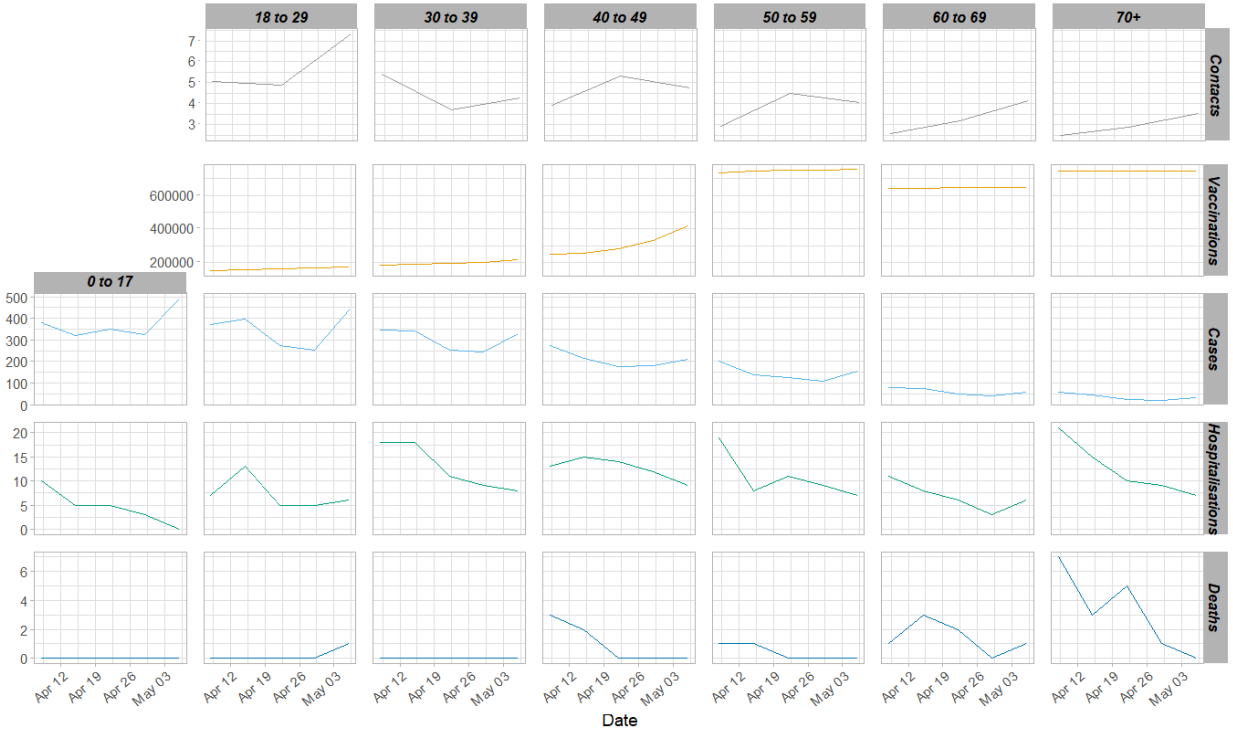
Figure 6: Locations visited by participants at least once for panel A and B (from SCS).



Vaccinations and contacts patterns

From Figure 7, it can be seen that even when contacts have increased for all age groups, cases and deaths have decreased. This coincides with the increasing number of vaccinations supplied to the population.

Figure 7: Average contacts for Panel B, daily cases, covid-19 hospital admissions and deaths[2] and cumulative vaccinations by age band[3]



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. For more on how we do this see page 4 of Issue 1 of the Research Findings[4]. Figure 8 shows two projections[5], where the better projection does not account for a new variant and the worse projection does[6]. The projections also take into account the recent increase in infections observed in the last week.

[2] Deaths, Cases and Hospitalisations from PHS COVID-19 daily cases in Scotland dashboard. Covid-19 hospital admissions data is shown up to 9th May 2021.
[3] 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.
[4] Coronavirus (COVID-19): modelling the epidemic - gov.scot (www.gov.scot)
[5] Four week projections are included here.
[6] Both scenarios are based on current vaccine roll-out plans and efficacy assumptions.

Figure 8. Medium term projections of modelled total new infections, adjusting positive tests[7] to account for asymptomatic and undetected infections, from Scottish Government modelling, positive test data up to 15 May.

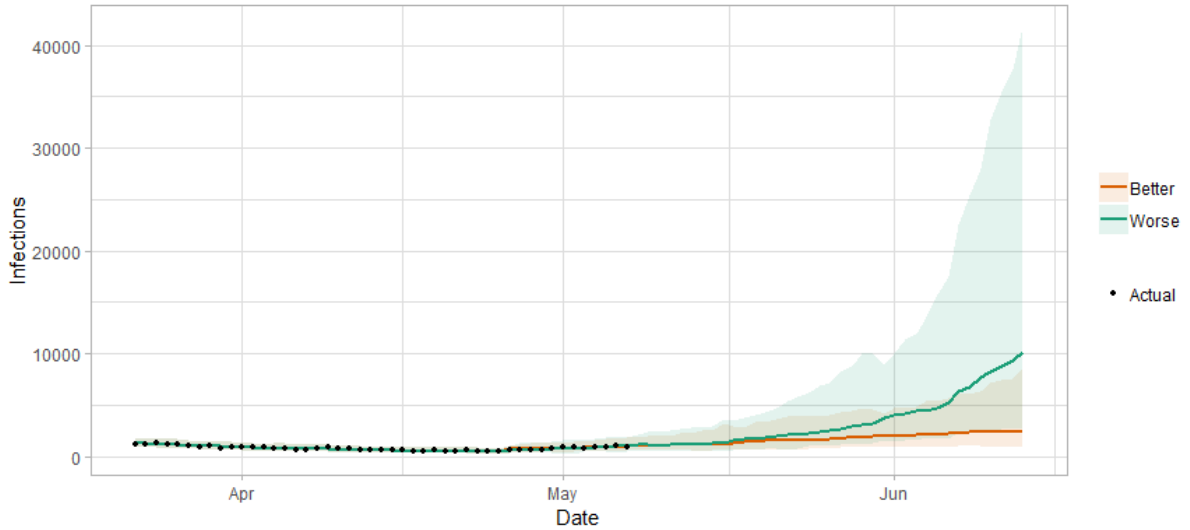
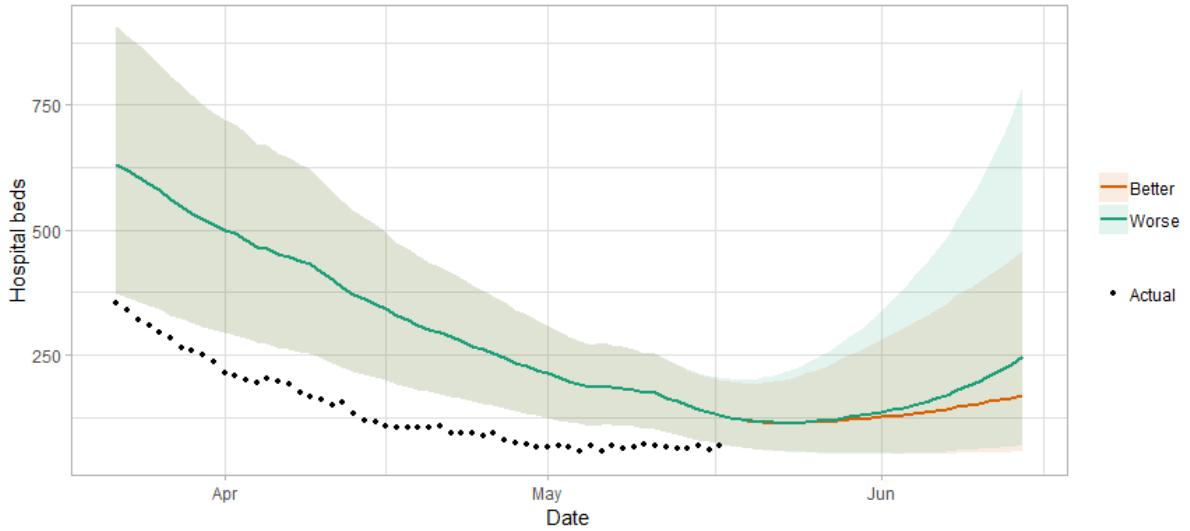


Figure 9 shows the impact of the projections on the number of people in hospital. The modelling includes all hospital stays, whereas the actuals only include stays up to 28 days duration which are linked to Covid-19. Work is ongoing to show the modelled occupancy for stays up to a 28 day limit.

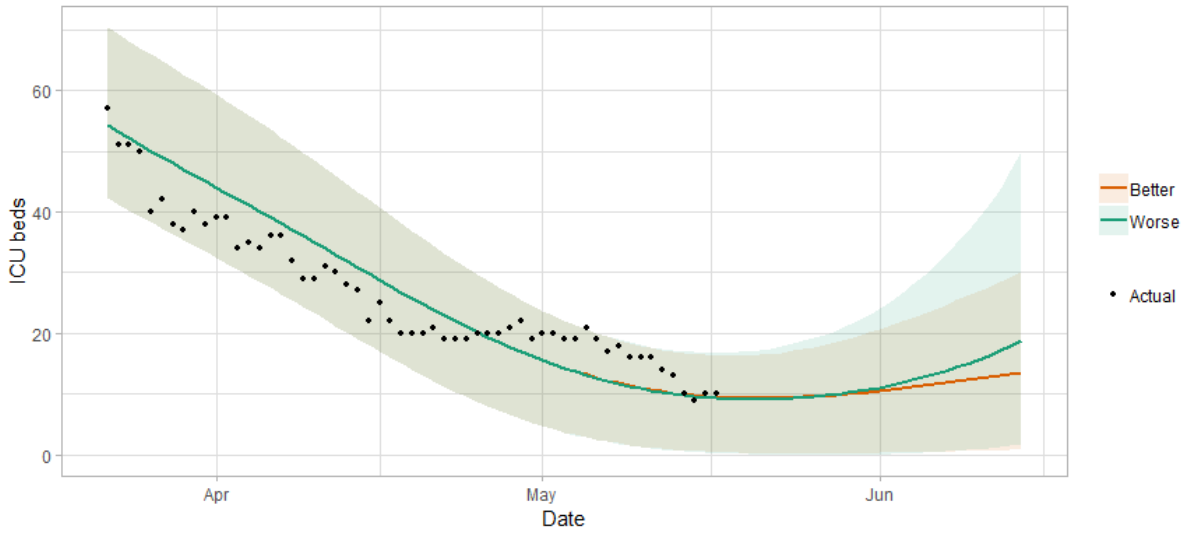
Figure 9. Medium term projections of modelled hospital bed demand, from Scottish Government modelling.



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

Figure 10 shows the impact of the projection on ICU bed demand.

Figure 10. Medium term projections of modelled ICU bed demand, from Scottish Government modelling[8].



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

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

SAGE produces projections of the epidemic[9] (Figure 11), combining estimates from several independent models (including the Scottish Government's logistics modelling, as shown in Figures 8-10). 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 17 May.

Modelling groups have used data from contact surveys, previous findings[10] and their own expert judgement to incorporate the impact of recent relaxations on transmission. **The projections do not include the effects of any other future policy or behavioural changes.**

[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.

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

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/963359/S1072_SPI-M-O_Statement_on_relaxation_of_NPI_scenarios__schools_.pdf

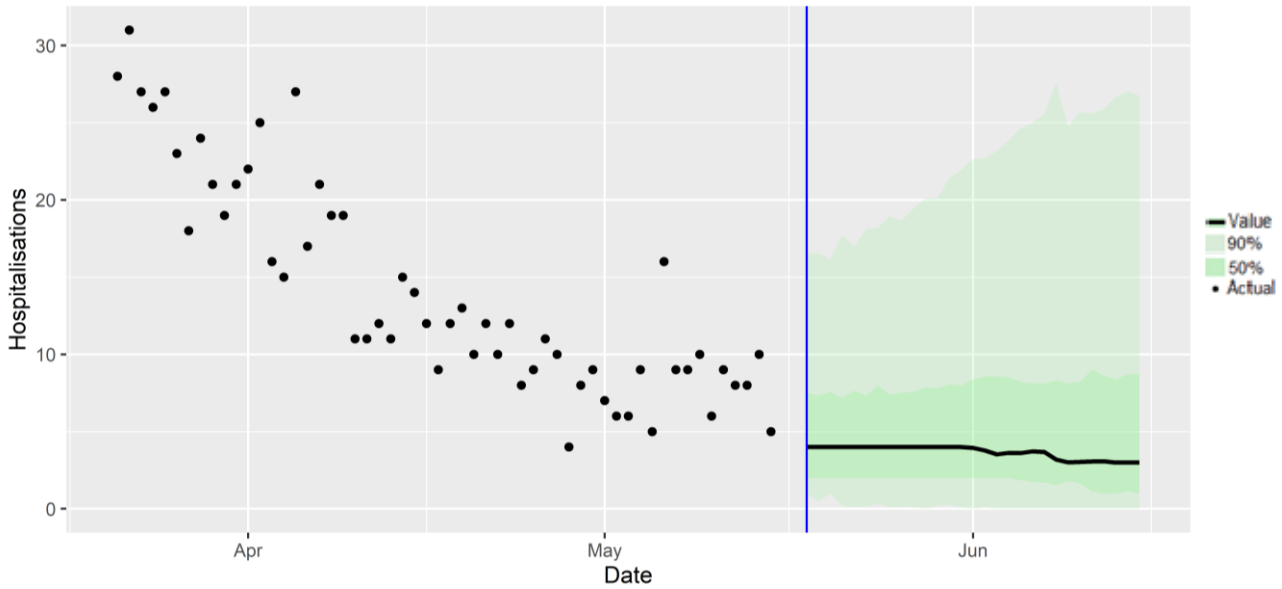
The delay between infection, developing symptoms, the need for hospital care, and death means they will not fully reflect the impact of behaviour changes in the two to three weeks prior to 17 May. Projecting forwards is difficult when the numbers of cases, admissions and deaths fall to very low levels, 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 for the next four weeks, albeit at lower confidence than the 90% credible interval.

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

Beyond two weeks, the projections become more uncertain with greater variability between individual models. This reflects the large differences that can result from fitting models to different data streams, and the influence of small deviations in estimated growth rates and current incidence.

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 over recent weeks. 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 very low over the next four weeks.

Figure 11. SAGE medium-term projection of daily hospitalisations in Scotland, including 50% and 90% credible intervals.



What the modelling tells us about whether Covid-19 infections exceeded what would be expected at this stage in the epidemic

Exceedance indicates whether the number of confirmed infections (based on testing) in each local authority area exceeds the number that was expected. Numbers of positive tests recorded each day, adjusted for population of each local authority and number of cases seen in preceding weeks, should fall within a certain distribution of values, which will rise and fall depending on the number of cases being seen nationally. Areas where the number of positive test results fall beyond the upper 95th percentile of this distribution may be at risk of seeing increased local transmission of Covid-19 and heightened vigilance may be required. This happens when the cumulative exceedance is higher than 6.0. See the Technical Annex in issue 47 for more information.

Figures 12 and 13 show exceedance for local authority areas. Recent cumulative exceedance highlights Midlothian (exceedance = 6.79), Stirling (6.66), Glasgow City (6.17), Clackmannanshire (5.53), East Dunbartonshire (5.05), East Renfrewshire (4.86), Na h-Eileanan Siar (4.75), Borders (4.00) and Edinburgh (3.29) as areas at higher risk of increasing transmission.

Figure 12. Map of cumulative weekly exceedance to 19th May, for Scottish Local Authorities.

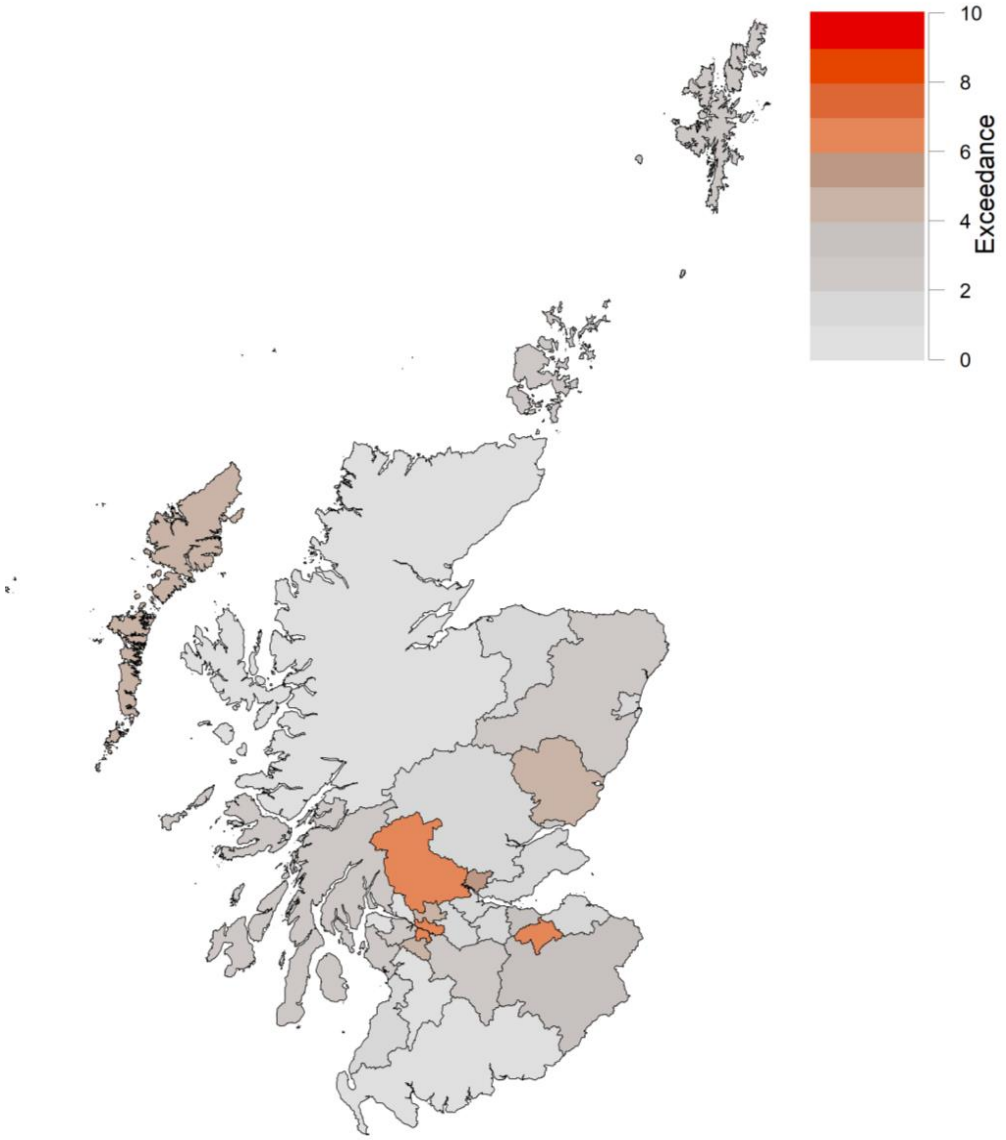
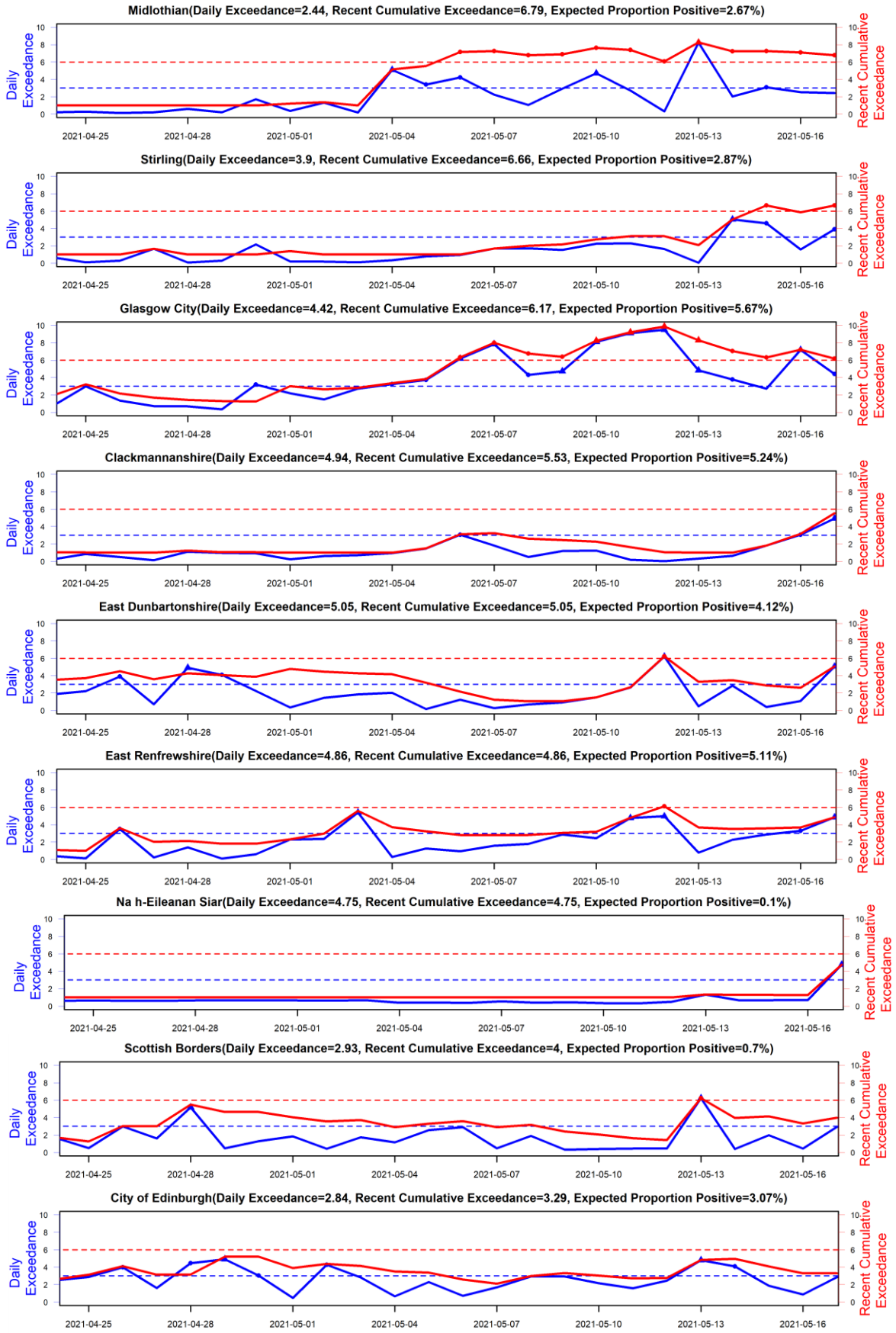


Figure 13. Graphs of daily and cumulative exceedance for the local authorities deemed as higher risk over the period 13th to 19th May.



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

We are using modelling based on Covid-19 cases and deaths 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 per 100K (Figure 14) indicate that for the week commencing 30 May 2021, Glasgow City was the only local authority with at least a 75% probability of exceeding 50 cases.

Figure 14. Probability of local authority areas having more than 50, 100, 300 or 500 cases per 100K (30 May – 5 June 2021).

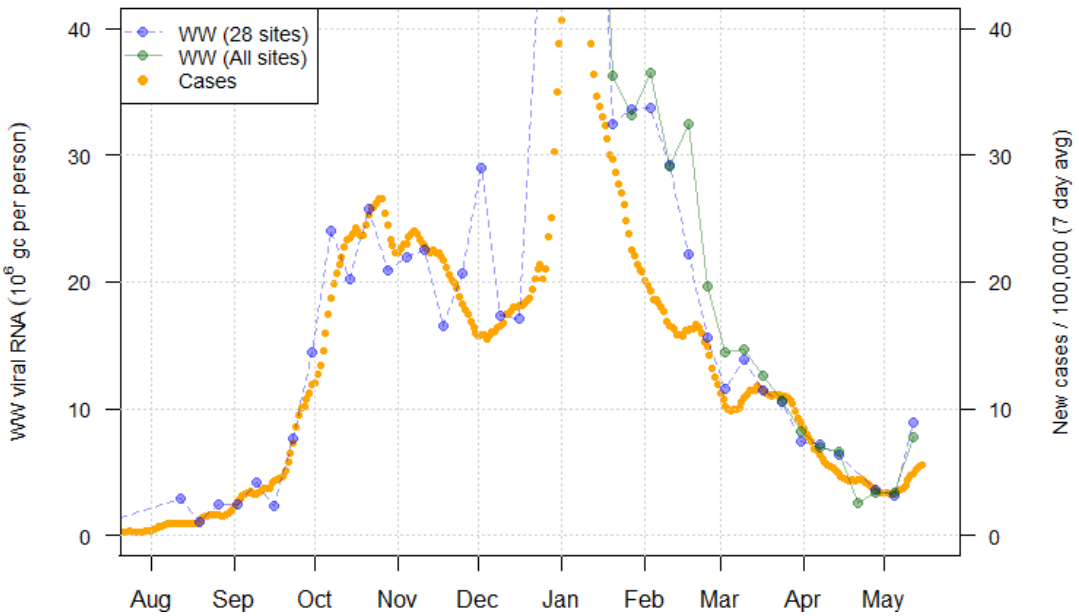
What can analysis of wastewater samples tell us about local outbreaks of Covid-19 infection?

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 levels increased notably this week, exceeding the rate of increase in cases. This is particularly driven by new outbreaks in the Glasgow area as can be seen in the data for sites like Shieldhall, though some other locations also show an increase.

Figure 15 shows the national aggregate for the original 28 sites with long-term records (in blue) and, from January 2021, the aggregate for the full set of up to 106 currently sampled sites (in green). This data shows a clear increase in wastewater Covid-19 levels, reaching around two and a half times last week's levels at 7.75 million gene copies per person per day (Mgc/p/d) averaged across all sites, exceeding levels seen in April.

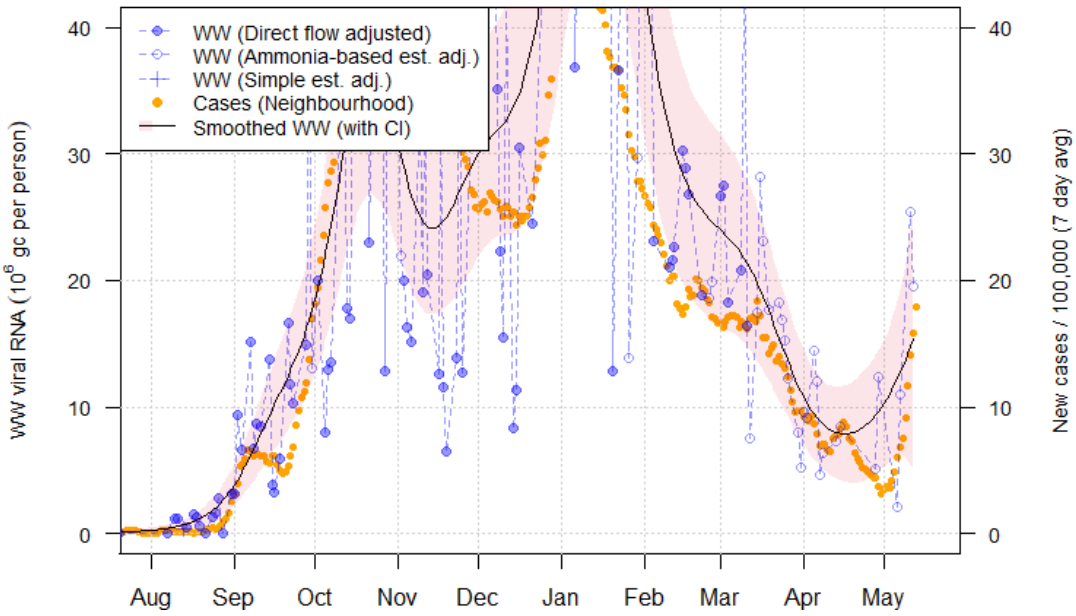
Figure 15. National average trends in wastewater Covid-19 and daily case rates (7 day moving average). An anomalously high value in Seafield (Edinburgh) in mid-February is removed.



The bulk of the rise originates from the Glasgow area. Shieldhall, a large site in this area, shows a particularly clear and large rise in recent levels

of both WW Covid-19 and case rates (Figure 16). Dalmuir, also in the Glasgow area, showed a similar rise, and together these sites overlap several local authorities (Glasgow City, North and South Lanarkshire, East and West Dunbartonshire, Renfrewshire, and East Renfrewshire).

Figure 16. Wastewater Covid-19 and daily case rate (7 day moving average) for Shieldhall in Glasgow City (pop: 377k) The black line and red shaded area provide a smoothed curve and confidence interval.



In contrast, the pattern is less clear in the Edinburgh area, where the large site at Seafield covering the City of Edinburgh and Midlothian showed no rise in WW Covid-19 levels, with similarly no increase in cases in associated neighbourhoods. However, in the Midlothian local authority there was an increase in cases, and the Penicuik wastewater site within Midlothian, remarked upon in report issue 51, continues to show high levels of the virus. However, the levels are somewhat lower in the most recent measurement than was reported on last week.

In other locations wastewater Covid-19 measurements suggest increases in virus levels that are not yet seen in the case levels. Examples include Alloa in Clackmannanshire (Figure 17) and Lerwick in the Shetland Islands (Figure 18). Both show continued elevated levels of WW Covid-19, despite no substantial rise in cases. In particular, case rates in Lerwick continue to be below the level of censoring, while consecutive WW Covid-19 measurements show a low but positive level. Additional sites where wastewater shows a rise in Covid-19 – albeit less clearly – include Hatton around Dundee, Inverclyde, Allanfearn in the Highlands, and some sites in the Falkirk area.

Figure 17. Wastewater Covid-19 and daily case rate (7 day moving average) for Alloa in Clackmannanshire (pop: 35k)

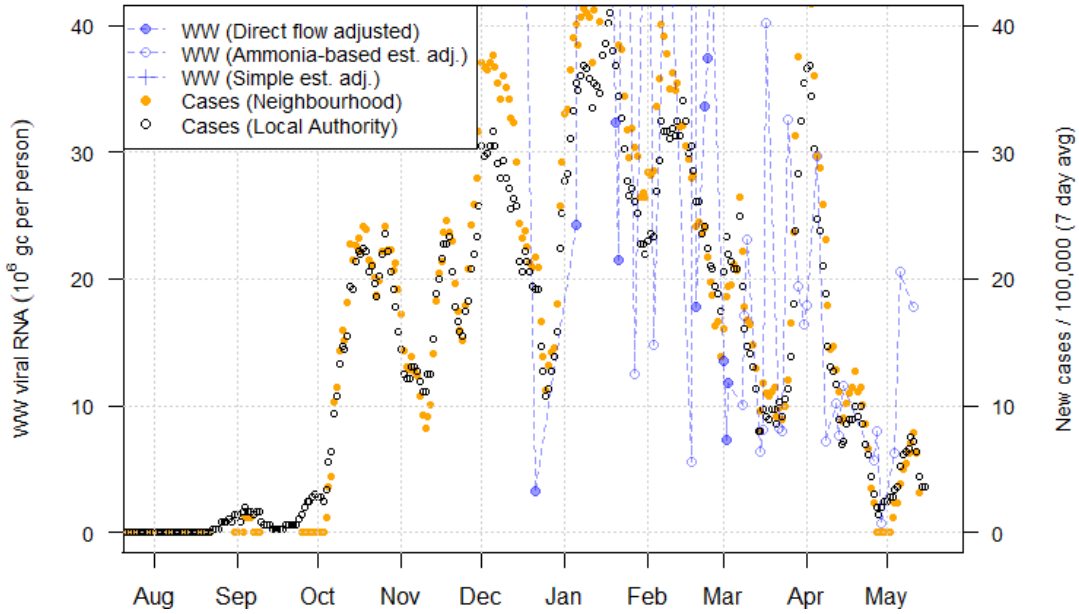
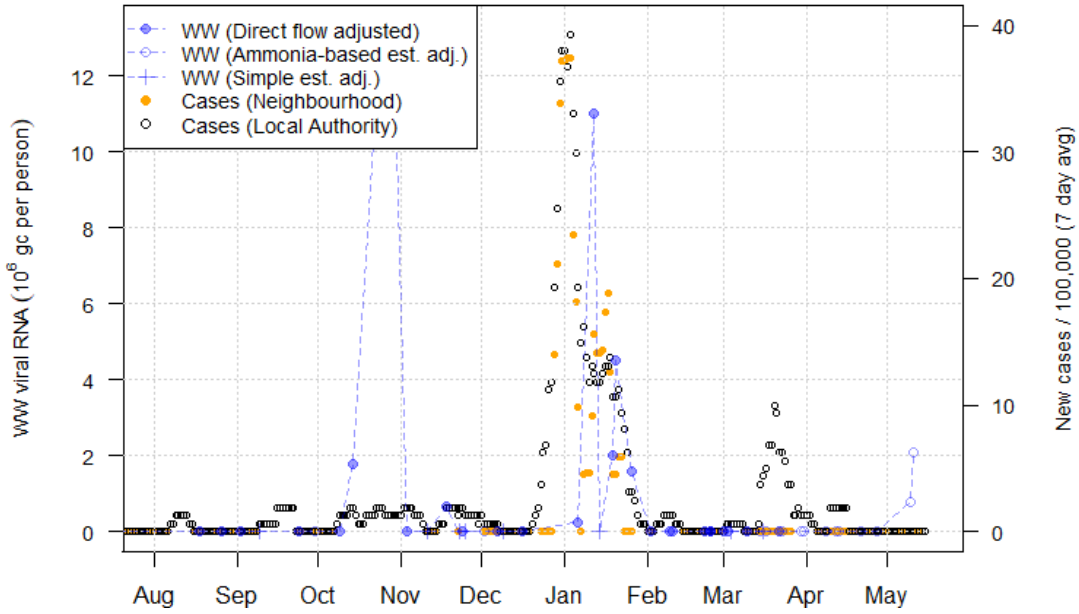
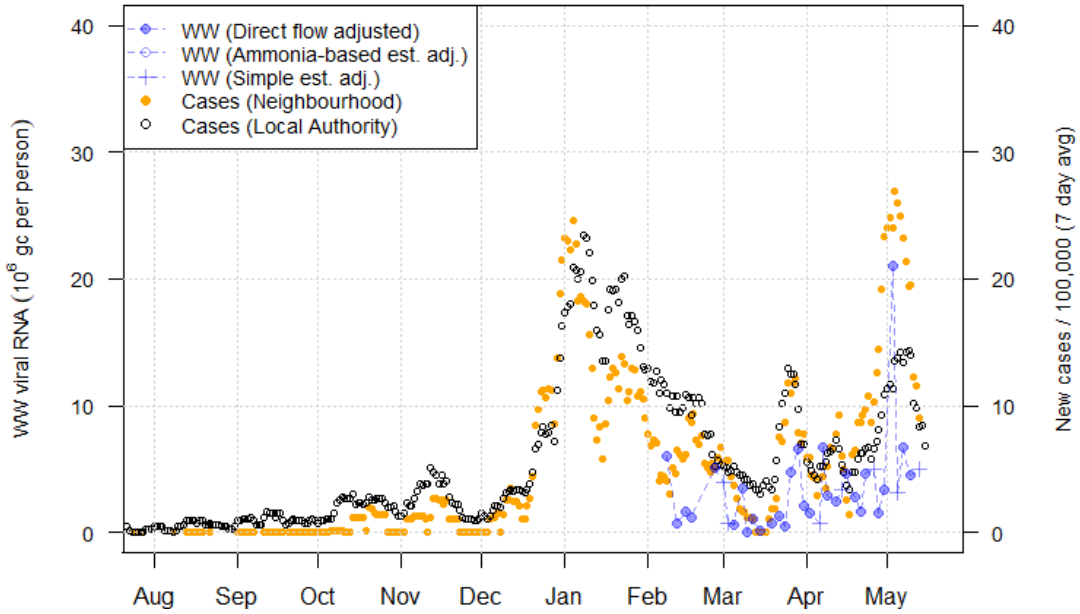


Figure 18. Wastewater Covid-19 and daily case rate (7 day moving average) for Lerwick in Shetland Islands (pop: 8k)



A more positive picture can be seen at Lossiemouth in Moray (Figure 19), where WW Covid-19 levels have declined to around 5 Mgc/p/d from the peak of over 20 Mgc/p/d, together with a decrease in case numbers of a similar magnitude.

Figure 19. Wastewater Covid-19 and daily case rate (7 day moving average) for Lossiemouth in Moray (pop: 38k)



What next?

The Scottish Government continues to work with a number of academic modelling groups to develop other estimates of the epidemic in Scotland.

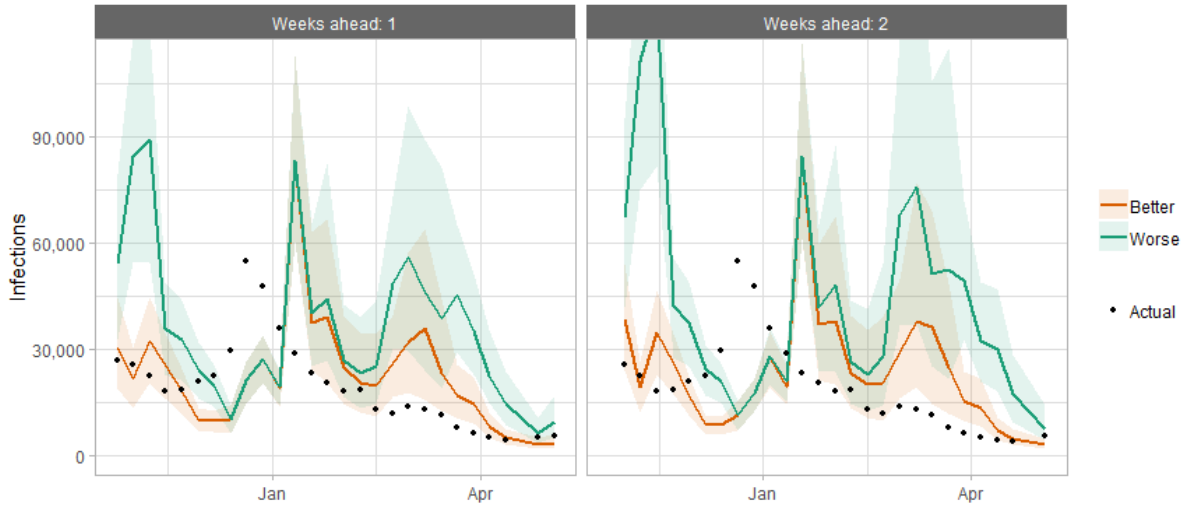
The modelled estimates of the numbers of new cases and infectious people will continue to be provided as measures of the epidemic as a whole, along with measures of the current point in the epidemic such as R_t and the growth rate. Further information can be found at https://www.gov.scot/coronavirus-covid-19.

Technical Annex

How the modelling compares to the real data as it emerges

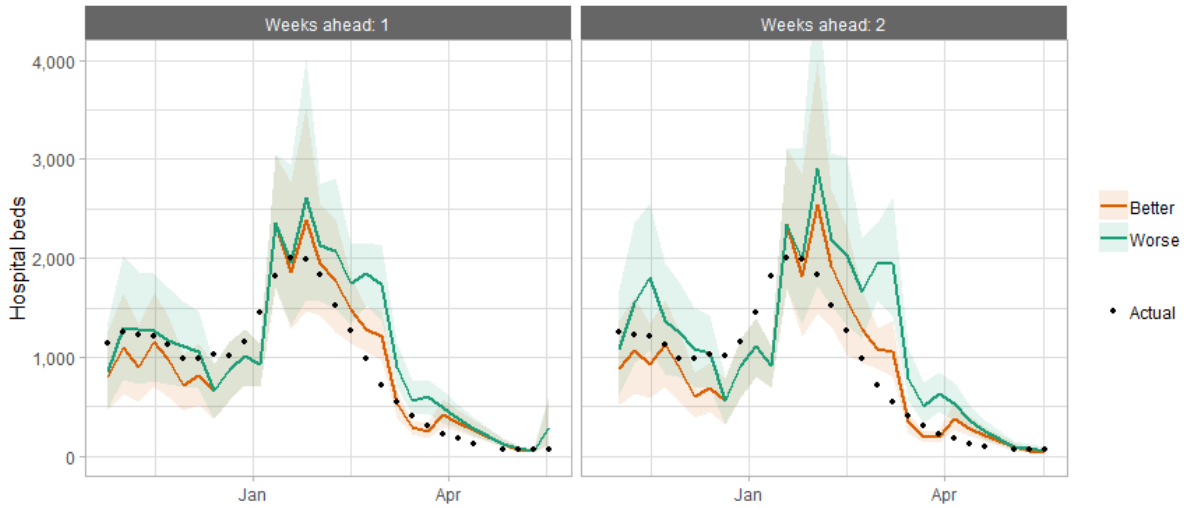
The following charts show the history of our modelling projections in comparison to estimates of the actual data. The infections projections were largely accurate during October to mid-December and from mid-January onward. During mid-December to mid-January, the projections underestimated the number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

Figure 20. Infections projections versus actuals, for historical projections published between one and three 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 21. Hospital bed projections versus actuals, for historical projections published between one and three 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 22. ICU bed projections versus actuals, for historical projections published between one and three weeks before the actual data came in.

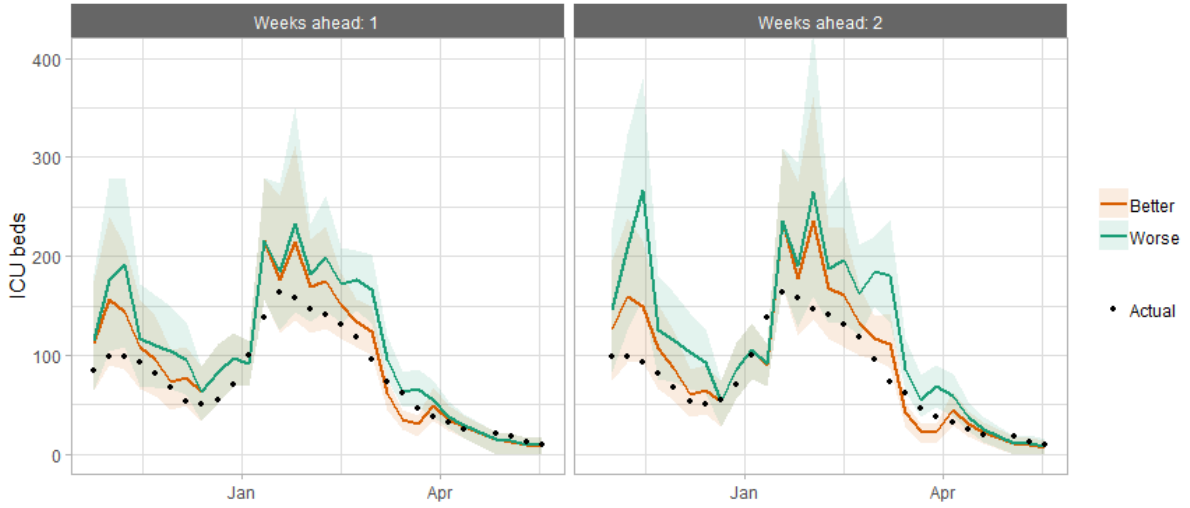


Table 1. Probability of local authority areas having more than 50, 100, 300 or 500 cases per 100K (30 May to 5 June 2021).

LA	P (Cases > 500)	P (Cases > 300)	P (Cases > 100)	P (Cases > 50)
Aberdeen City	0-5%	0-5%	0-5%	15-25%
Aberdeenshire	0-5%	0-5%	0-5%	5-15%
Angus	0-5%	0-5%	0-5%	0-5%
Argyll and Bute	0-5%	0-5%	0-5%	0-5%
City of Edinburgh	0-5%	0-5%	15-25%	25-50%
Clackmannanshire	0-5%	0-5%	0-5%	5-15%
Dumfries & Galloway	0-5%	0-5%	0-5%	5-15%
Dundee City	0-5%	0-5%	0-5%	0-5%
East Ayrshire	0-5%	0-5%	0-5%	5-15%
East Dunbartonshire	0-5%	0-5%	0-5%	25-50%
East Lothian	0-5%	0-5%	0-5%	0-5%
East Renfrewshire	0-5%	0-5%	25-50%	50-75%
Falkirk	0-5%	0-5%	5-15%	15-25%
Fife	0-5%	0-5%	15-25%	25-50%
Glasgow City	25-50%	25-50%	50-75%	75-100%
Highland	0-5%	0-5%	0-5%	5-15%
Inverclyde	0-5%	0-5%	0-5%	5-15%
Midlothian	5-15%	5-15%	15-25%	25-50%
Moray	0-5%	0-5%	15-25%	50-75%
Na h-Eileanan Siar	0-5%	0-5%	0-5%	0-5%
North Ayrshire	0-5%	0-5%	0-5%	5-15%
North Lanarkshire	5-15%	5-15%	15-25%	25-50%
Orkney Islands	0-5%	0-5%	0-5%	0-5%
Perth and Kinross	0-5%	0-5%	0-5%	5-15%
Renfrewshire	0-5%	0-5%	0-5%	5-15%
Scottish Borders	0-5%	0-5%	0-5%	0-5%
Shetland Islands	0-5%	0-5%	0-5%	0-5%
South Ayrshire	0-5%	0-5%	0-5%	5-15%
South Lanarkshire	0-5%	0-5%	15-25%	25-50%
Stirling	0-5%	0-5%	0-5%	5-15%
West Dunbartonshire	0-5%	0-5%	0-5%	5-15%
West Lothian	0-5%	0-5%	0-5%	5-15%

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

Table 2 provides population weighted daily averages for normalised WW Covid-19 levels in the week covering 9th – 15th May with no estimate for error. These units equate to cases per 100,000 per day.

Table 2. Average daily cases per 100k as given by WW data, 9th – 15th May

Local Authority	Average daily WW Case Estimate per 100k	Local Authority WW Coverage
Aberdeen City	2.31	80%
Aberdeenshire	2.89	47%
Angus	3.80	43%
Argyll and Bute	1.28	18%
City of Edinburgh	3.06	97%
Clackmannanshire	13.97	92%
Dumfries and Galloway	0.48	30%
Dundee City	3.80	100%
East Ayrshire	3.82	72%
East Dunbartonshire	19.81	99%
East Lothian	2.62	65%
East Renfrewshire	21.03	95%
Falkirk	5.31	69%
Fife	6.16	84%
Glasgow City	19.65	98%
Highland	3.00	36%
Inverclyde	9.12	92%
Midlothian	3.35	88%
Moray	3.55	55%
Na h-Eileanan Siar	0.00	21%
North Ayrshire	2.61	93%
North Lanarkshire	6.48	86%
Orkney Islands	0.28	34%
Perth and Kinross	2.88	45%
Renfrewshire	6.81	57%
Scottish Borders	1.28	56%
Shetland Islands	1.43	29%
South Ayrshire	3.66	82%
South Lanarkshire	8.87	79%
Stirling	0.81	10%
West Dunbartonshire	9.83	98%
West Lothian	2.66	85%

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The views expressed in this report are those of the researcher and do not necessarily represent those of the Scottish Government or Scottish Ministers.

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