GSE Government Science & Engineering

GORS Government Operational Research Service

Scottish Government
Riaghaltas na h-Alba
gov.scot

Coronavirus (COVID-19): Analysis

Coronavirus (COVID-19): modelling the epidemic in Scotland (Issue No. 45)

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 25 March 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.

Key Points

- The reproduction rate R in Scotland is currently estimated as being between 0.8 and 1.0.
- The number of new daily infections for Scotland is estimated as being between 13 and 31, per 100,000 people.
- The growth rate for Scotland is currently estimated as being between -4% and -1%.
- Average contacts have increased by approximately 15% in the last two weeks, at a current level of 3.7 daily contacts.
- Contacts within the work, school and other settings outside of school and home have all shown an increase in the last two weeks, with school contacts increasing by 50% and work and other contacts increasing by 33% and 23% respectively.
- Those aged under 70 have shown an increase in contacts in the most recent survey, largely driven by contacts in the work and school setting.
- Since the start of the phased school return, the biggest increase in interactions has been for those aged 30-49 with individuals under 18, with interactions doubling as a minimum.

- The proportion of participants that have visited another's home has risen from 28% to 37% in the last two weeks.
- There is no significant difference in contacts between the vaccinated and unvaccinated within either the 60-64 or 55-59 age groups.
- Although there are increases in contacts for those aged between 50 and 70, there is a continued decline in positive Covid-19 cases and deaths for those aged over 45.
- Hospital bed and ICU occupancy are projected to fall over the next few weeks, but these both may plateau or increase as a result of schools reopening and other relaxations of non-pharmaceutical interventions.
- Modelled rates per 100K indicate that for the week commencing 11 April 2021, 7 local authorities have at least a 75% probability of exceeding 50 cases, 1 of those have at least a 75% probability of exceeding 100 cases and none of those have at least a 75% probability of exceeding 300 cases. In last week's issue of these Research Findings, 8 local authorities had a 75% or higher probability of exceeding 50 cases per 100K.
- The overall level of wastewater Covid this week is similar to the last three weeks, consistent with the continued levelling off in the rate of new cases. As before, this pattern was driven by the largest catchments, which sustained moderate levels of Covid-19 wastewater. In contrast, many small, more isolated catchments have very low levels.

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 deaths is an important measure of where Scotland lies in its epidemic as a whole. In addition, the modelling groups which 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 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.

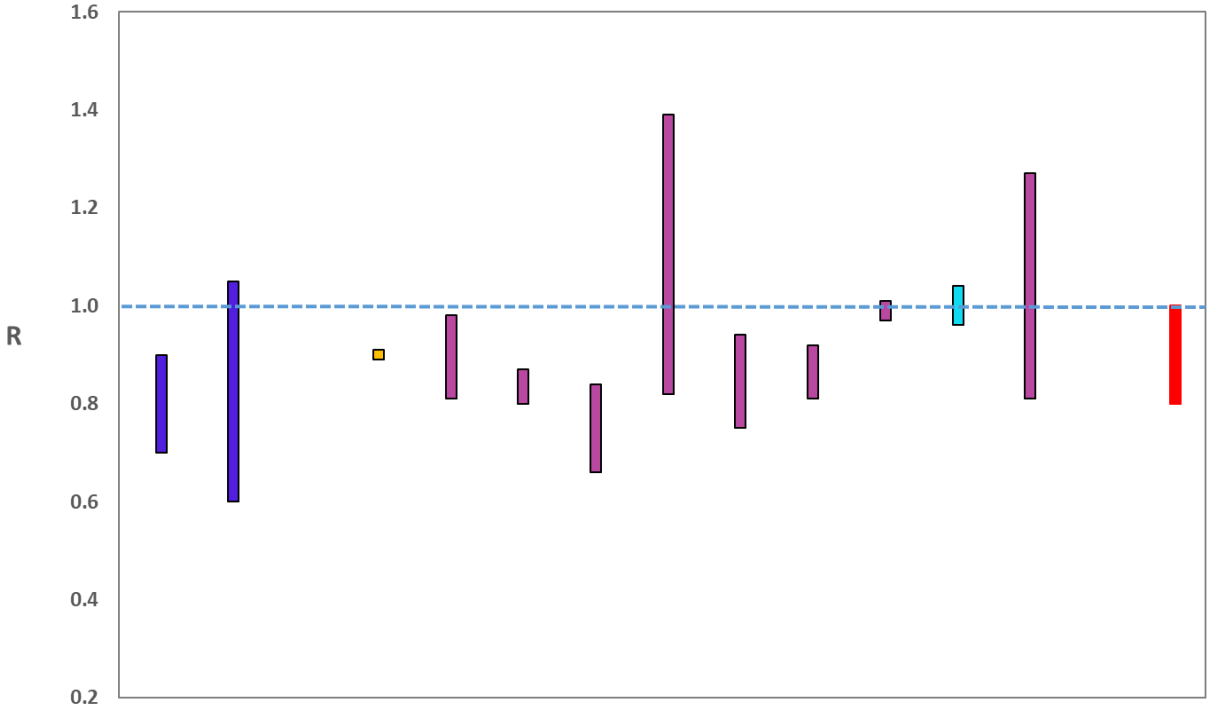
The logistical model utilises results from the epidemiological modelling, principally the number of new infections. The results are split down by age group, and the model is used to give a projection of the number of people that will go to hospital, and potentially to ICU. This will continue to be based 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 31 March, was that the value of R in Scotland was between 0.8 and 1.0 (see Figure 1). This is unchanged from the estimate of R as of 24 March.

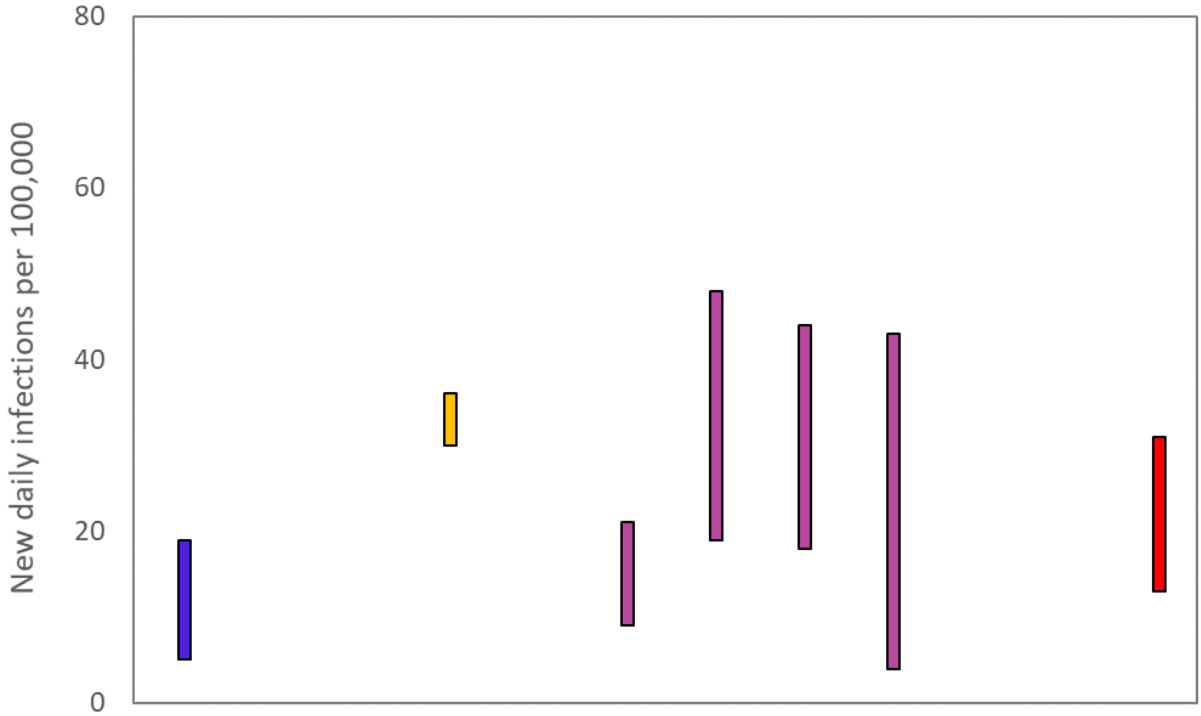
Figure 1. Estimates of R_t for Scotland, as of 31 March, including 90% confidence intervals, produced by SAGE. The blue bars are death-based models, purple use multiple sources of data and cyan uses Covid-19 test results. The estimate produced by the Scottish Government is the third from left (yellow), 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). The Scottish Government results this week have been computed using a platform called Epidemia (see Technical Annex in issue 37) which expands the Bayesian semi-mechanistic model which the Scottish Government runs. SPI-M's consensus view across these methods, as of 31 March, was that the incidence of new daily infections in Scotland was between 13 and 31 new infections per 100,000. This equates to between 700 and 1,700 people becoming infected each day in Scotland.

Figure 2. Estimates of incidence for Scotland, as of 31 March, including 90% confidence intervals, produced by SPI-M. The blue bar is a death-based model and the purple bars represent models which use multiple sources of data. The estimate produced by the Scottish Government (a semi-mechanistic model) is the second from 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 -4 and -1% per day. This is unchanged from the estimate of the growth rate as of 24 March.

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

The average number of contacts has increased by approximately 15% in the last two weeks, with a current level of 3.7 daily contacts as seen in Figure 3. Contacts within the work, school and any other settings outside of work and the home have all shown an increase in the last two weeks, with school contacts increasing by 50% and work and other contacts increasing by 33% and 23% respectively. Contacts within the home decreased over the same period, which coincides with the relaxation in rules around outdoor social mixing.

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

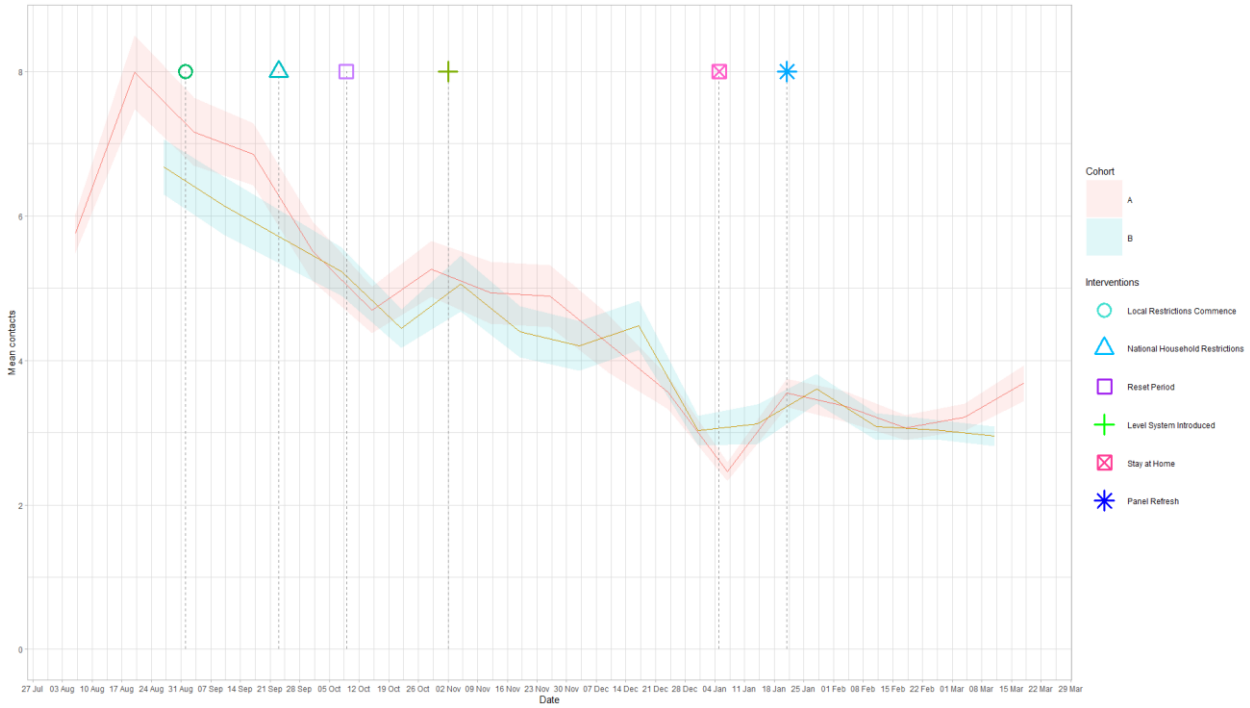
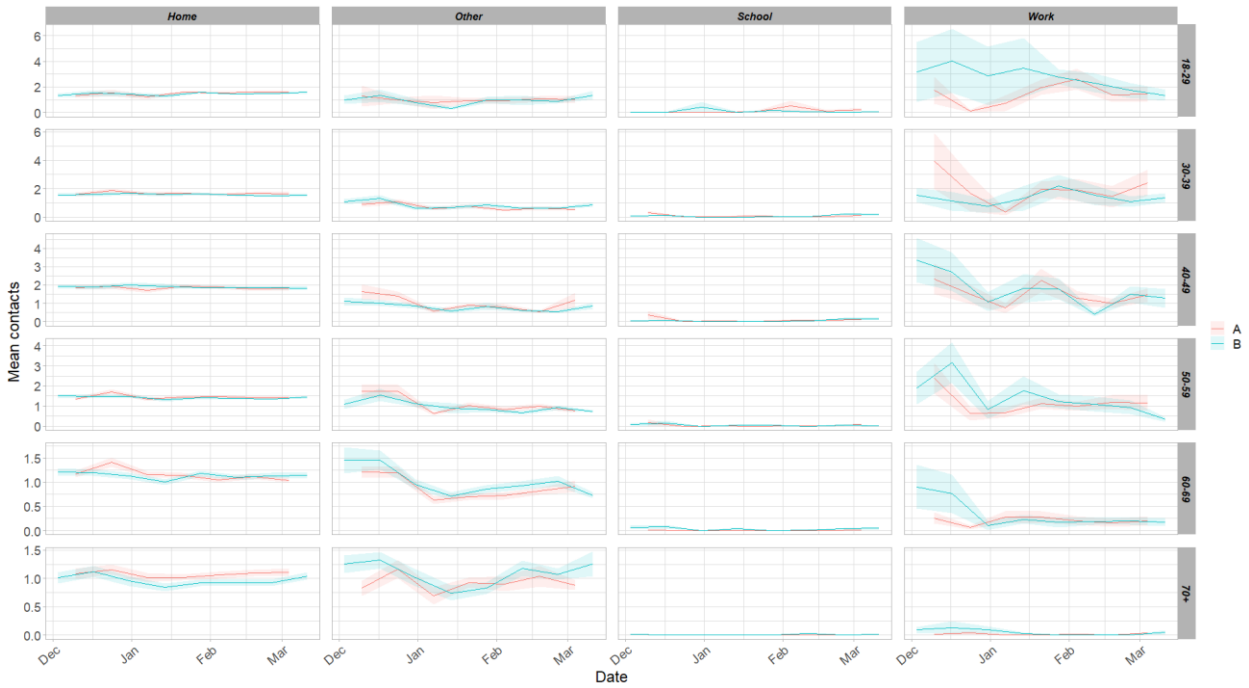


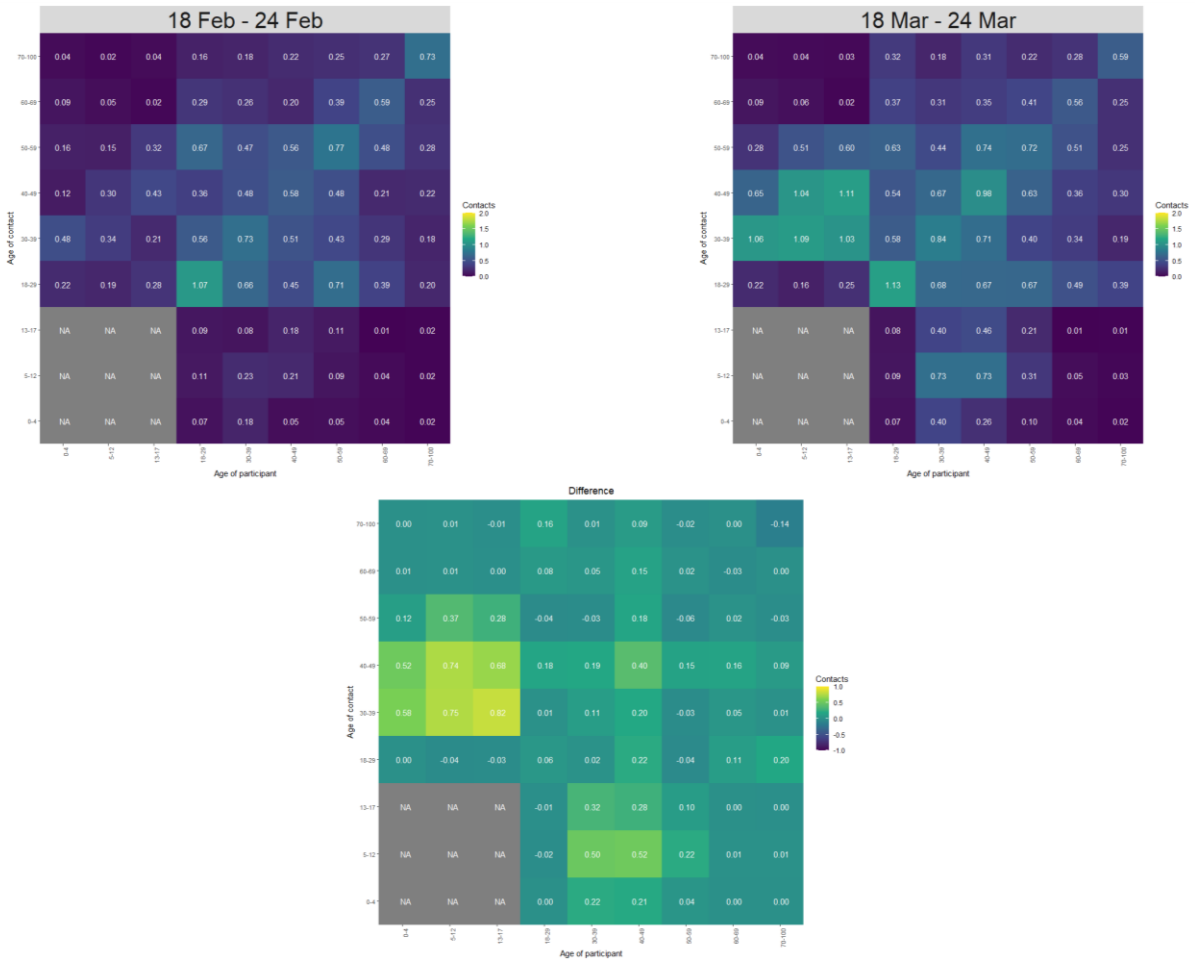
Figure 4 shows how contacts change across age group and setting. Those aged under 70 have shown an increase in contacts in the most recent survey, largely driven by contacts in the work and school setting. Those aged 40-49 have had the biggest increase in average contacts, now reporting 71% higher daily contacts in comparison to the overall adult average.

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



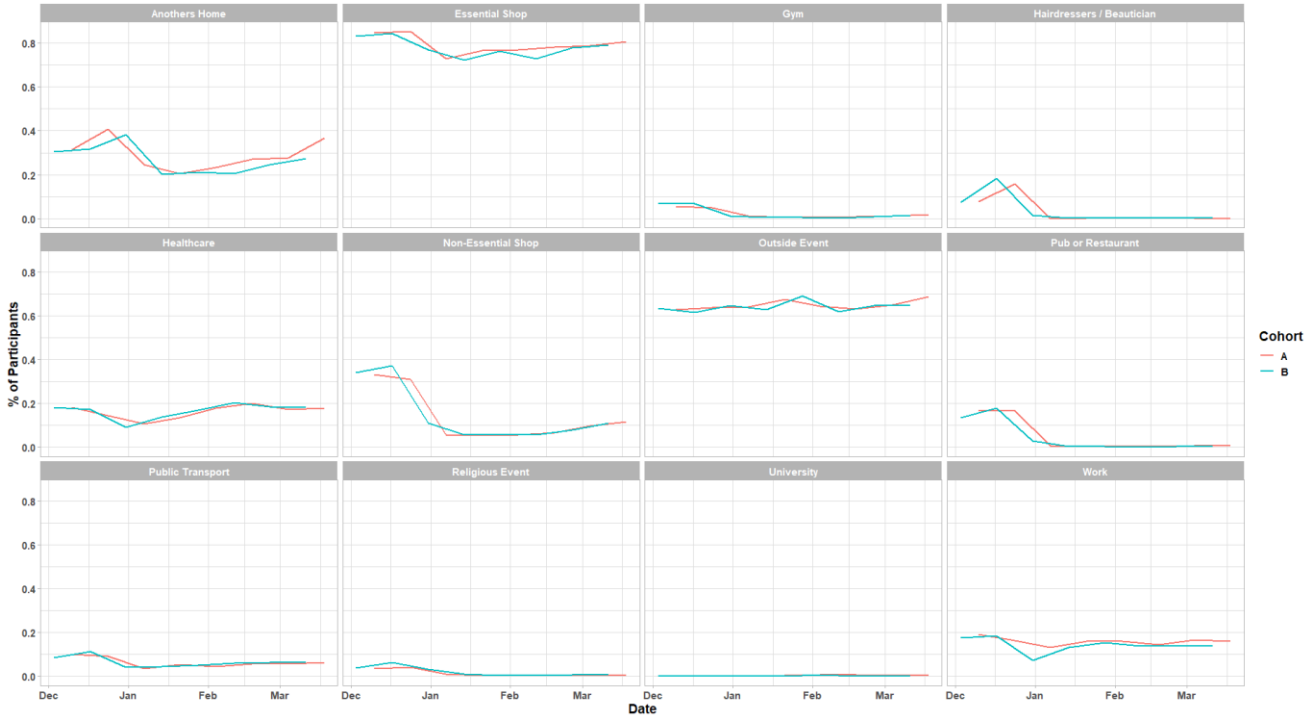
The heatmaps in Figure 5 show the average overall contacts between age groups for the weeks relating to the phased school return, 18th – 24th February (primary 1-3 returning on 22nd February), the 18th – 24th March (remaining primary school children return to school full-time with all secondary pupils returning on a part-time basis from 15th March) and the difference between these periods. Since the start of the phased school return, the biggest increase in interactions has been for those aged 30-49 with individuals under 18, with interactions doubling as a minimum. Those aged between 40-49 have also increased their interactions with every other age group over this period.

Figure 5. Overall mean contacts by age group for the weeks relating to 18th - 24th February and 18th – 24th March.



As shown in Figure 6, the biggest change in behaviour in the last two weeks has been the increase in the proportion of people that have visited other people's homes. This has risen from 28% to 37%, although as mentioned above, the average number of contacts within this setting has decreased.

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

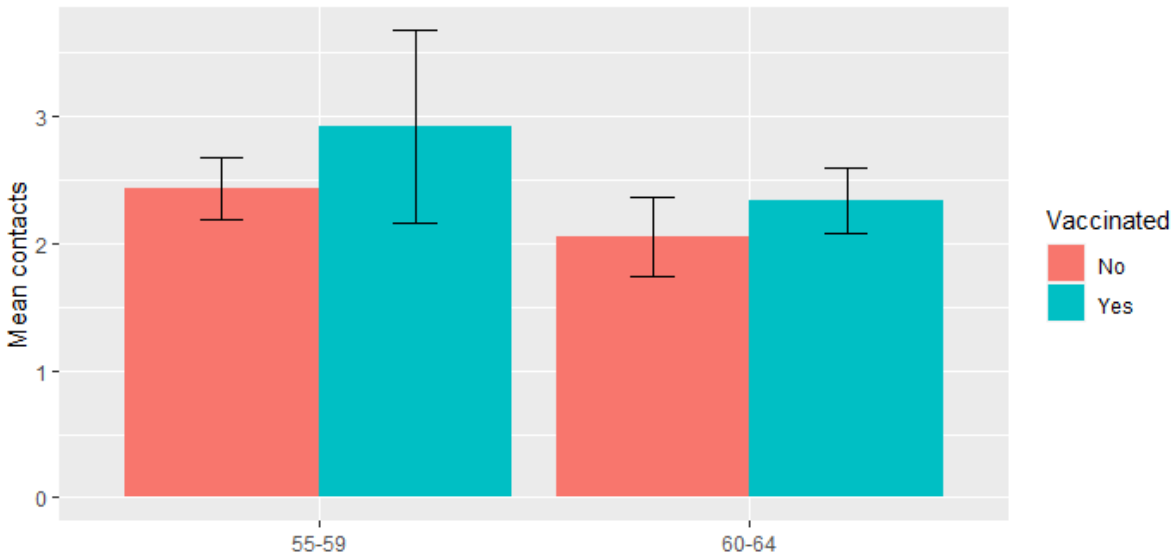


Vaccinations and contacts patterns

The vaccinations programme commenced in Scotland in December 2020. This section looks at the contact patterns of those who have been vaccinated against those who have not.

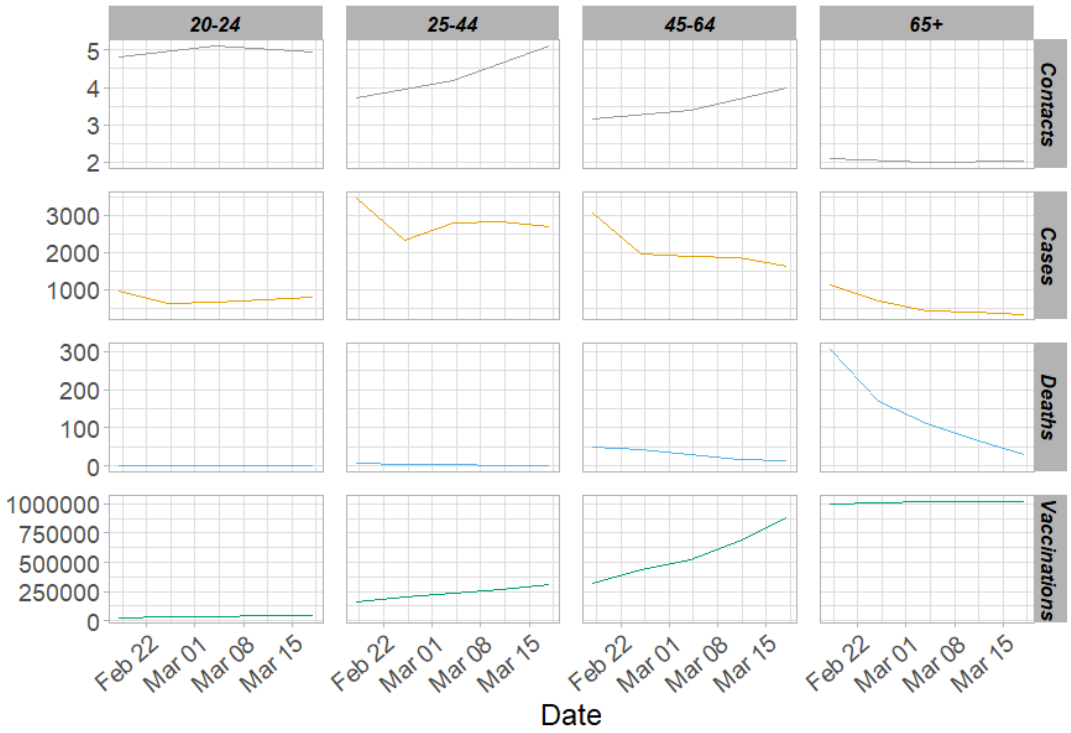
Currently, the age group invited for vaccinations are those aged between 55-59. Figure 7 shows no significant difference in contacts between the vaccinated and unvaccinated within either the 60-64 or 55-59 age groups (once healthcare professionals, who were vaccinated earlier as a priority group, were removed).

Figure 7. Mean contacts for the vaccinated and unvaccinated within the 60-64 age group.



From Figure 8, it can be seen that where contacts have remained consistent or even increased for the older age groups, cases and deaths have decreased. This coincides with the increasing number of vaccinations supplied to the population. Although there are increases in contacts for those aged between 50 and 70, there is a continued decline in positive Covid-19 cases and deaths for those aged over 45.

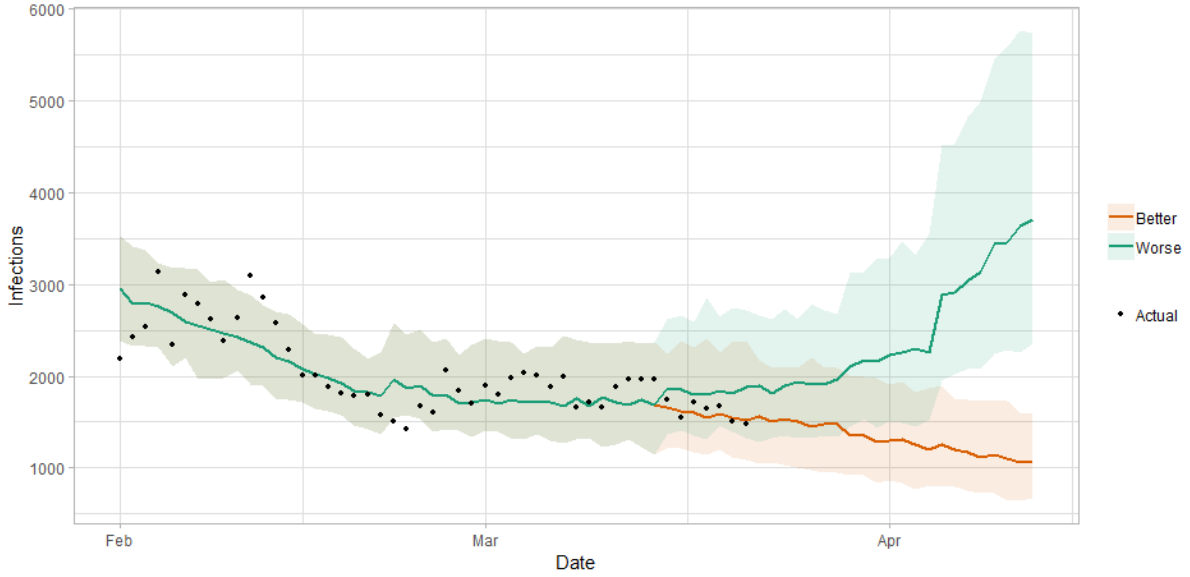
Figure 8. Average contacts, daily cases, deaths and cumulative vaccinations by age band.



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

The Scottish Government assesses the impact of Covid 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[1]. Figure 9 shows two projections[2] which take account of compliance and behaviour (better and worse[3]).

Figure 9. Medium term projections of modelled total new infections, adjusting positive tests[4] to account for asymptomatic and undetected infections, from Scottish Government modelling, positive test data up to 27 March.



[1] Coronavirus (COVID-19): modelling the epidemic - gov.scot (www.gov.scot)
[2] Two week projections are included here, extending to the Easter weekend.
[3] Both scenarios are based on current vaccine roll-out plans and efficacy assumptions. The difference between the two projections reflects uncertainty about behaviour and compliance as interventions are relaxed.
[4] The actual positive tests are adjusted to coincide with the estimated day of infection.

Figure 10 shows the impact of the projections on the number of people in hospital.

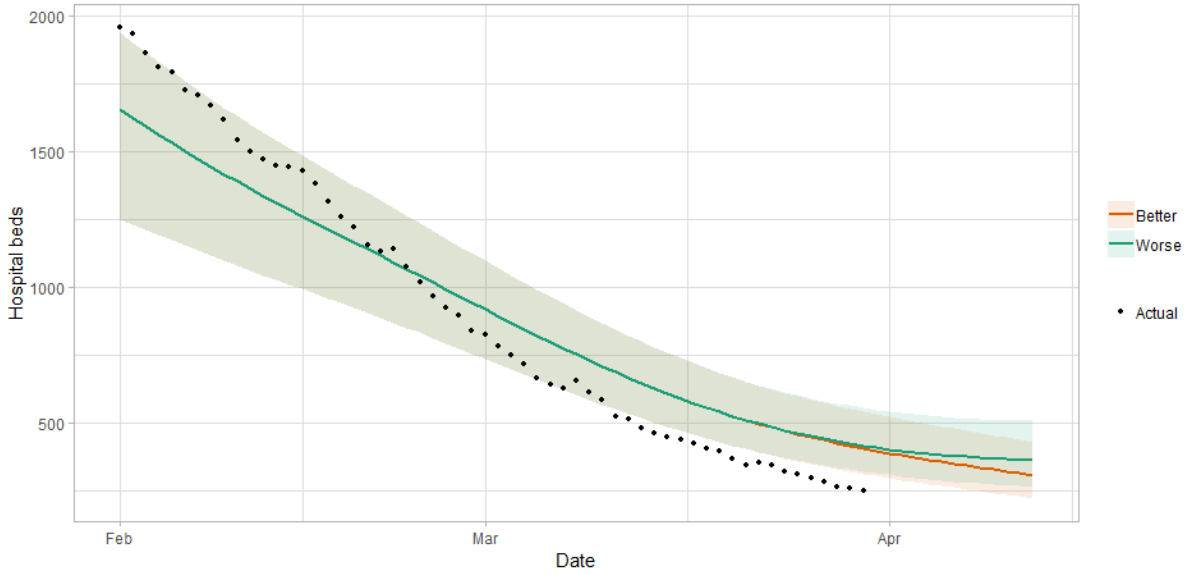
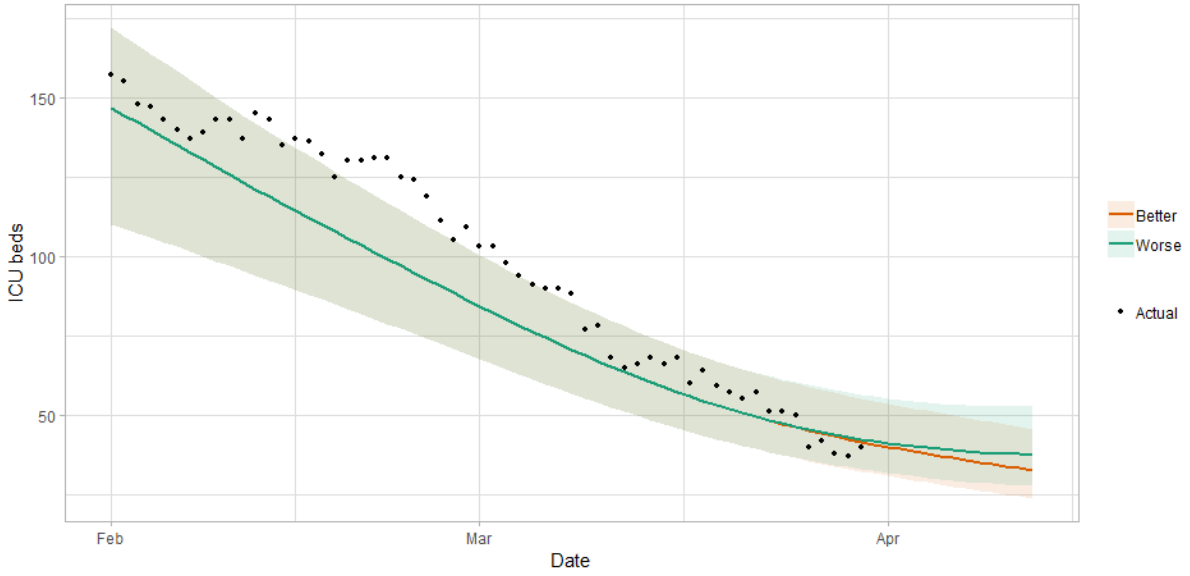


Figure 10. Medium term projections of modelled hospital bed demand[5], from Scottish Government modelling.

Figure 11 shows the impact of the projection on ICU bed demand.

Figure 11. Medium term projections of modelled ICU bed demand, from Scottish Government modelling[6].



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

[5] Hospital bed actuals only include hospital stays up to 28 days duration linked to Covid-19.
[6] 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[7] (Figures 12 and 13), combining estimates from several independent models (including the Scottish Government's logistics modelling, as shown in figures 9, 10 and 11). 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 29 March.

Modelling groups have used data from contact surveys, previous findings[8] and their own expert judgement to incorporate the impact of re-opening schools. **The projections do not include the effects of any other 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 29 March. Projecting forwards is difficult when the numbers of cases, admissions and deaths fall to very low levels.

These projections include the potential impact of vaccinations over the next two weeks. Modelling groups have used their expert judgement and evidence from the JCVI, Public Health England, Scottish universities and Public Health Scotland as well as other published sources when making assumptions about vaccine effectiveness[9].

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.

---

[7] A two week projection is provided here.

[8] 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

[9] Optimising the COVID-19 vaccination programme for maximum short-term impact - GOV.UK (www.gov.uk)

Figure 12. SAGE medium-term projection of daily hospitalisations in Scotland, including 50% and 90% credible intervals.

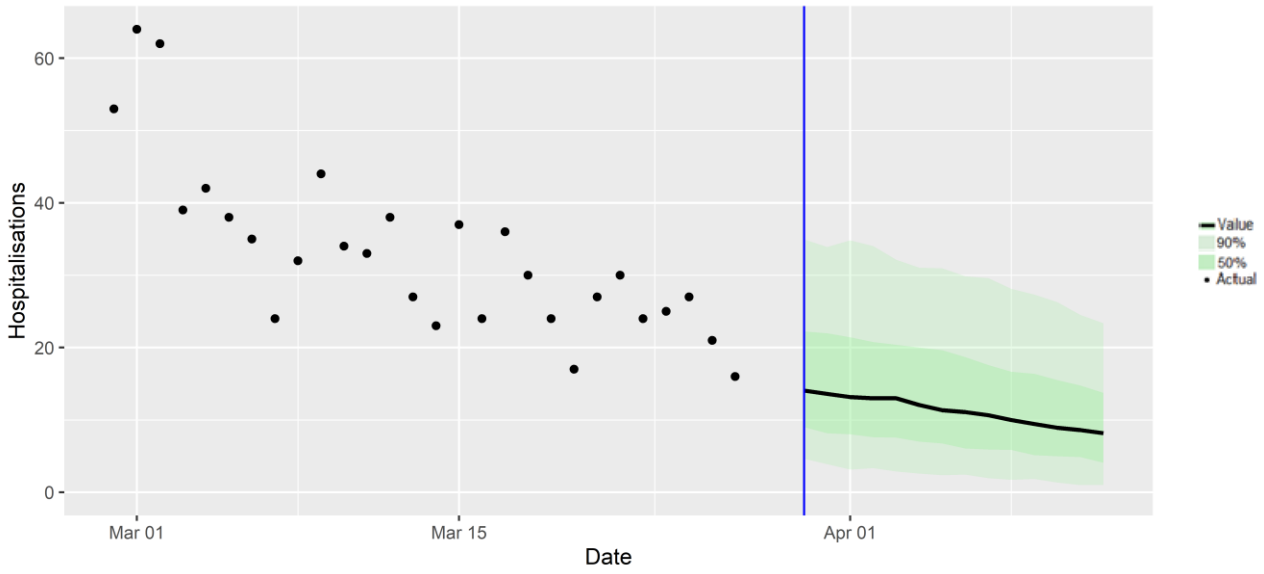
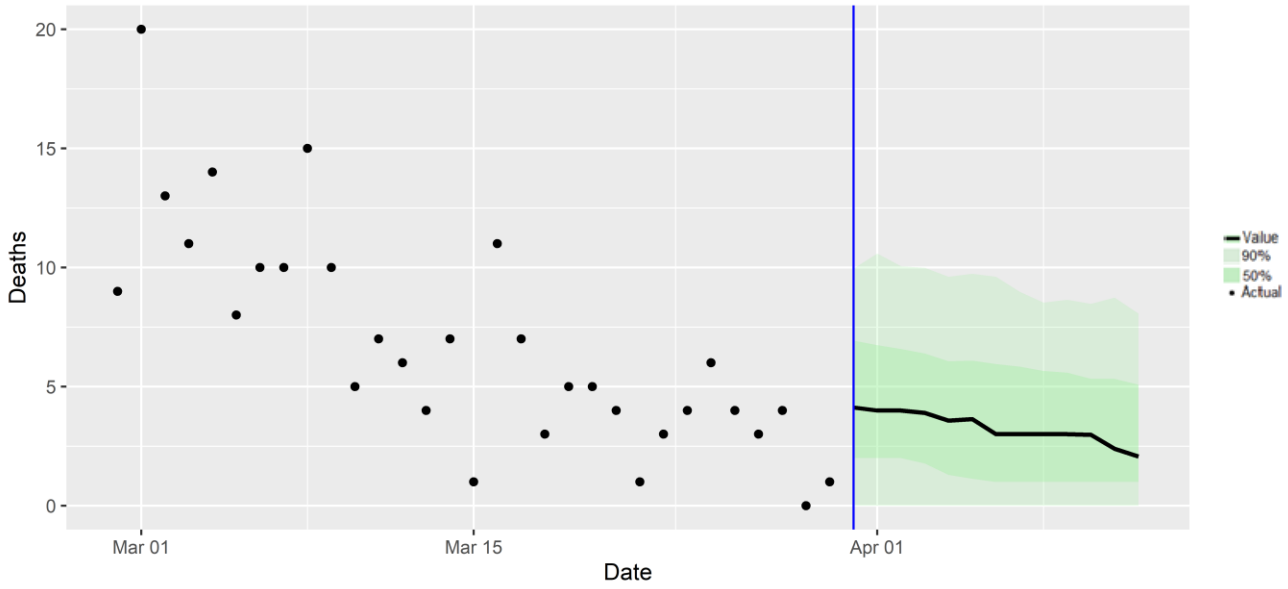


Figure 13. SAGE medium-term projection of daily deaths[10] in Scotland, including 50% and 90% credible intervals.



What we know about which local authorities are likely to experience high levels of Covid

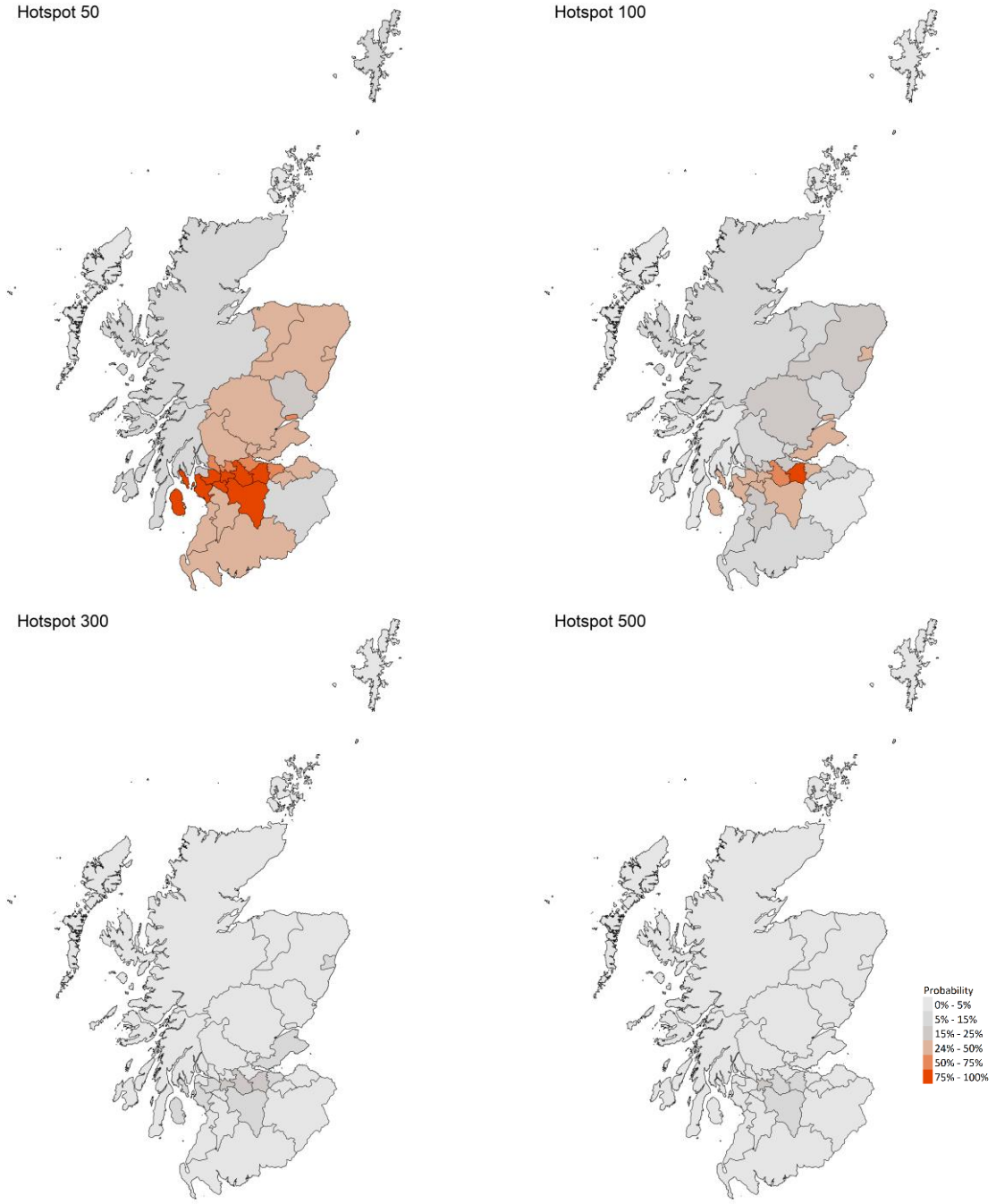
We are using modelling based on Covid cases and deaths from several academic groups to give us an indication of whether a local authority is likely to experience high levels of Covid in the future. This has been compiled via SPI-M into a consensus. In this an area is defined as a

[10] PHS defines a confirmed COVID-19 death as an individual who dies within 28 days of their first positive COVID-19 laboratory report.

hotspot if the two week prediction of cases (positive tests) per 100K population are predicted to exceed a threshold, e.g. 500 cases.

Modelled rates per 100K (Figure 14) indicate that for the week commencing 11 April 2021, 7 local authorities have at least a 75% probability of exceeding 50 cases, 1 of those have at least a 75% probability of exceeding 100 cases and none of those have at least a 75% probability of exceeding 300 cases. In last week's issue of these Research Findings, 8 local authorities had a 75% or higher probability of exceeding 50 cases per 100K.

Figure 14. Probability of local authority areas having more than 50, 100, 300 or 500 cases per 100K (11 – 17 April 2021).



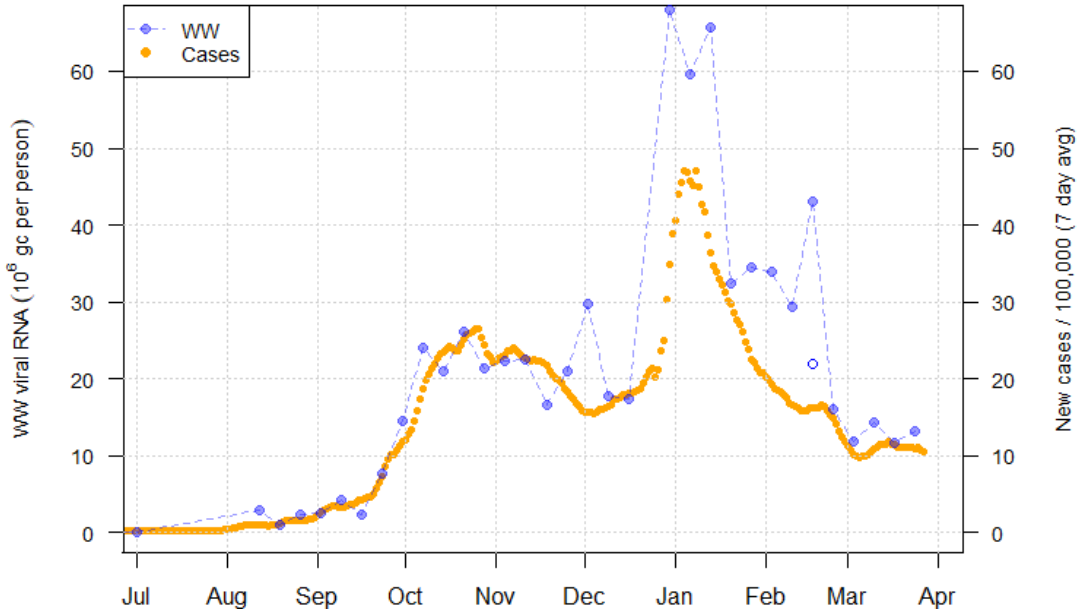
What can analysis of wastewater samples tell us about local outbreaks of Covid-19 infection?

Levels of Covid in wastewater collected at many 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.

The overall level of wastewater Covid this week was similar to the last three weeks, consistent with the continued levelling off in the rate of new cases. As before, this pattern was driven by the largest catchments, which sustained moderate levels while small, more isolated catchments have very low levels.

This can be seen in Figure 15, which gives a national aggregate for the original 28 sites with long-term record. Indeed, of these 28 sites, 12 now have low levels of wastewater Covid, although those sites altogether make up only 4.6% of the total population sampled. Meanwhile, the three largest sites (Seafield, Dalmuir, Shieldhall) have 53% of the sampled population, and moderate levels of wastewater Covid.

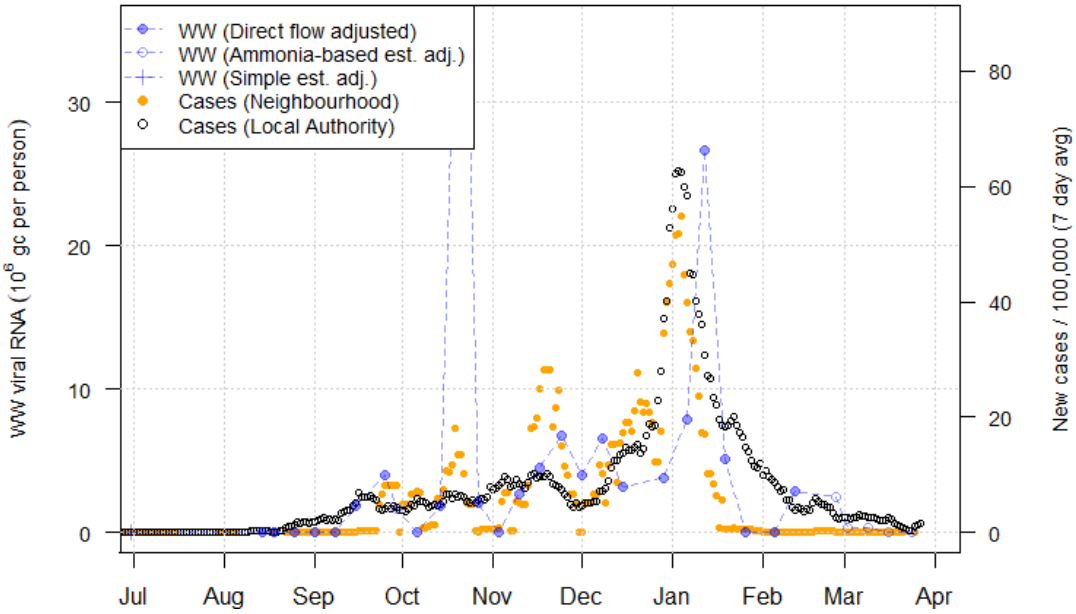
Figure 15. National average trends in wastewater Covid and daily case rates (7 day moving average)[11]



Despite the overall average being static, many smaller sites have shown a large decline in wastewater Covid. One example is Peebles (Figure 16), which is one of the sites now giving negative Covid-19 test results. Other sites are shown in Figure 19.

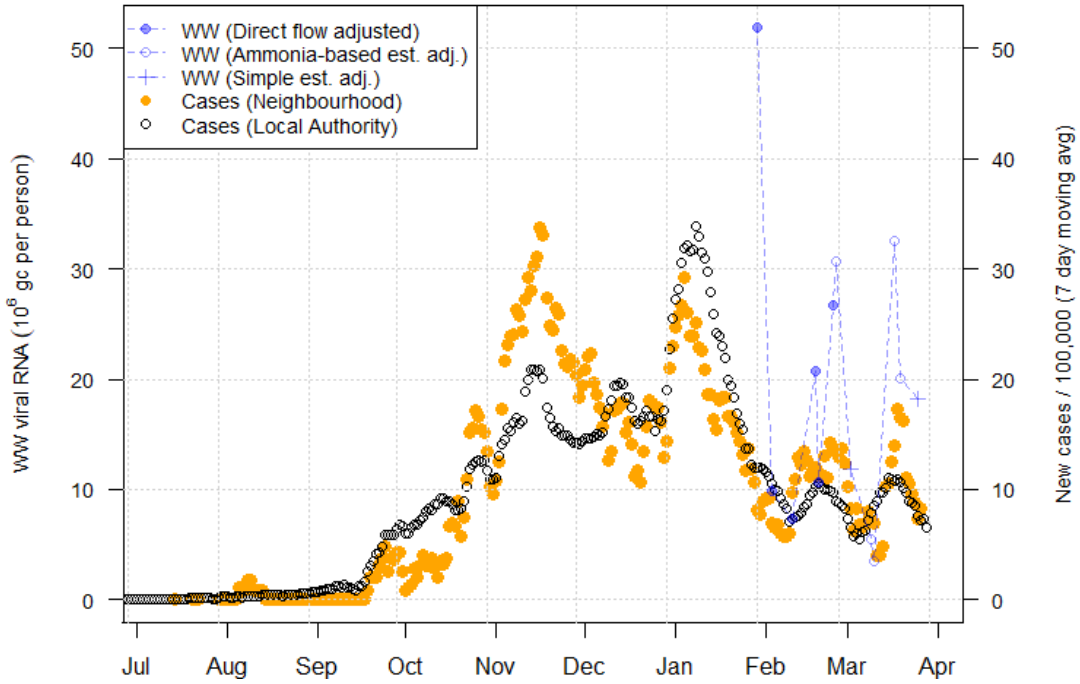
[11] The single unfilled point in mid-February denotes the average for that single week with an anomalously high reading at Seafield removed. See Issue 40 of the Research Findings for details.

Figure 16. Wastewater Covid and daily case rate (7 day moving average) for Peebles in Scottish Borders (pop: 8k)



In addition to the original 28 sites, which have been sampled for many months, further sites are now being tested in support of the Community Testing Programme. In total, there are 96 sites currently being sampled. One example is Kirkcaldy, where wastewater COVID corresponds well to case data with the exception of an anomalous spike in levels recorded at the first measurement. (Figure 17). A difficulty arising with many of these new sites is the relatively small associated population, which makes it difficult to obtain and publish suitable case data covering the catchment area. Kirkcaldy, however, is one of the larger sites. Here, a March increase in wastewater Covid corresponded in an increase in cases, which has since reverted to below 10 cases/100k residents per day.

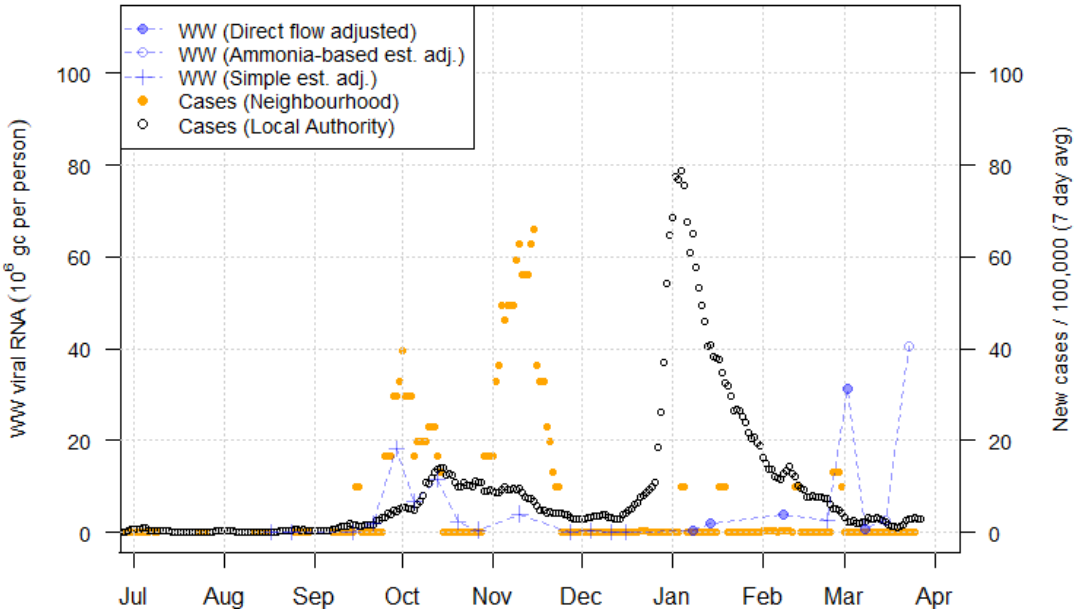
Figure 17. Wastewater Covid and daily case rate (7 day moving average) for Kirkcaldy in Fife (pop: 51k)



Dalbeattie (Figure 18) is one of the 28 original sites but covers a relatively small population. Figure 20 shows that, whilst the wastewater RNA measurements do not seem to be proportionate to new cases as seen at other sites, they have been fairly consistently higher during periods of time when there were cases than when there were none. For example, during October and November, the wastewater measurements were largely positive when there were outbreaks.

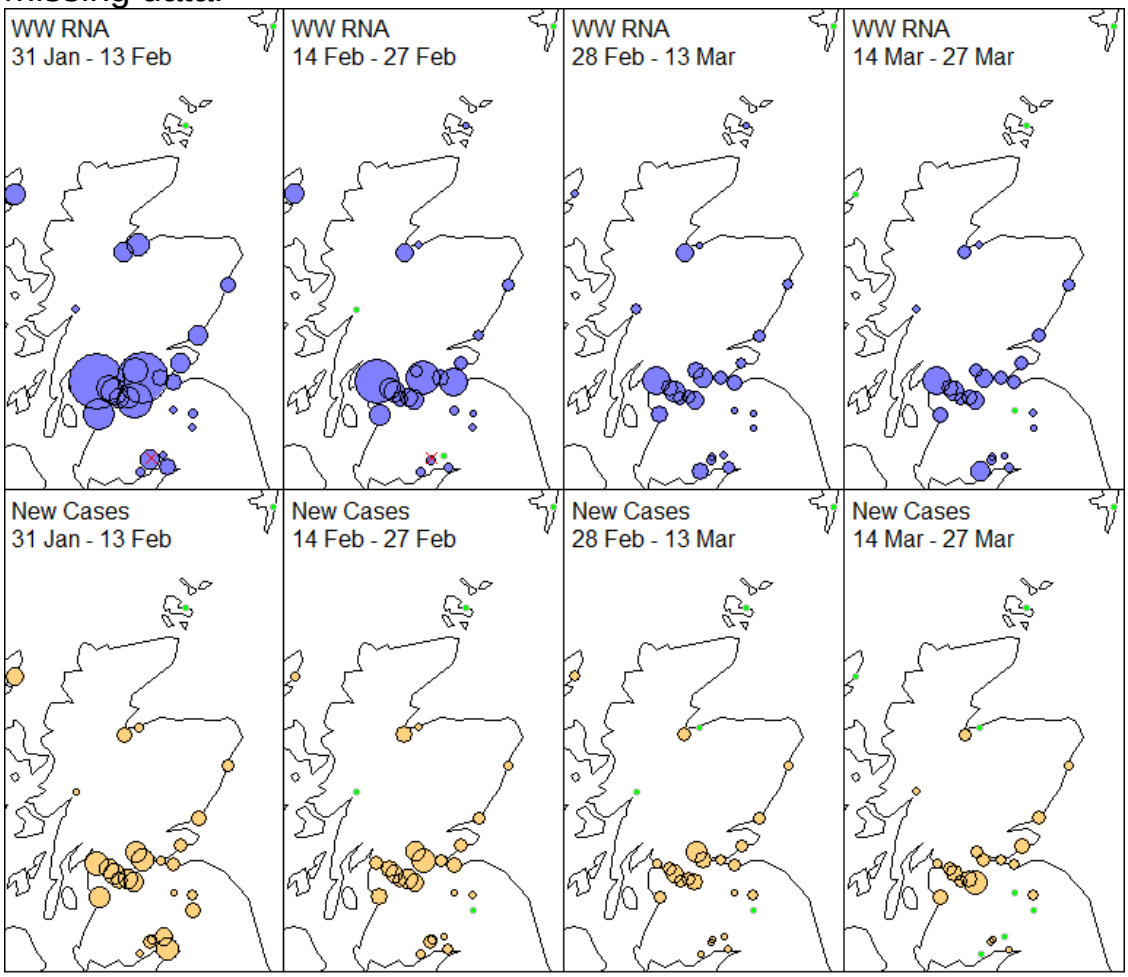
Like the case numbers, they have been intermittently positive from January onwards. However, more recently the wastewater measurements have been clearly positive, whilst corresponding case numbers have been zero or very low.

Figure 18. Wastewater Covid and daily case rate (7 day moving average) for Dalbeattie in Dumfries & Galloway (pop: 4k)



The geographic pattern of Covid across the original 28 sites in shown in Figure 19. The pattern of wastewater Covid and case data have both changed little over the last two periods, and are broadly similar to each other. Using a green colour to indicate levels that are below the minimum for each method (either falling below the detection limit as in the case of wastewater Covid, or below the censoring threshold for case data), we see the continued prevalence of sites with no recently reported new cases (at least, above the threshold for censoring applied to neighbourhood cases) but still positive levels of wastewater Covid. The only sites with negative wastewater Covid are in the Northern and Western Isles, together with Peebles, while case data shows several other sites, especially in the south, having low levels.

Figure 19. Map of mean levels over time for daily wastewater Covid per person (blue) and new cases per person (orange). Green points indicate sites consistently below the limit of detection for wastewater RNA, or the threshold of censoring for case data. Red crosses show sites with missing data.



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**.**

Investigations are ongoing by NERVTAG, SPI-M, SAGE and Scottish Government regarding the impact of the new variant, SARS-CoV-2 VOC 202012/01, which will be reflected here as work is undertaken.

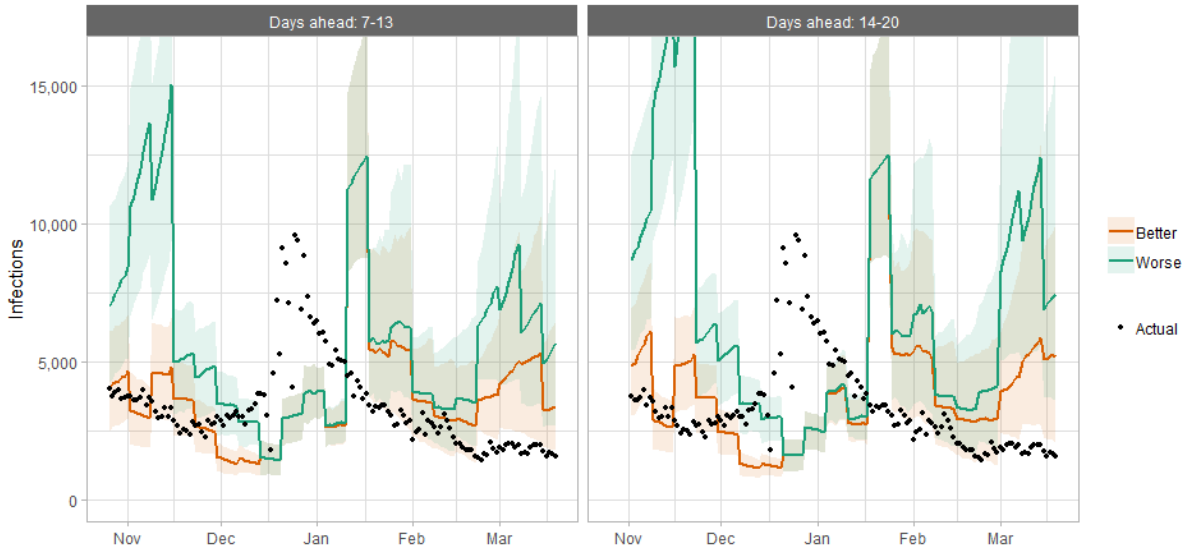
Analysis from the EAVE 2 group, which tells us about the pattern of demographics and clinical risk groups over time for those who are testing positive with Covid, will be provided in future issues.

Technical Annex

How the modelling compares to the real data as it emerges

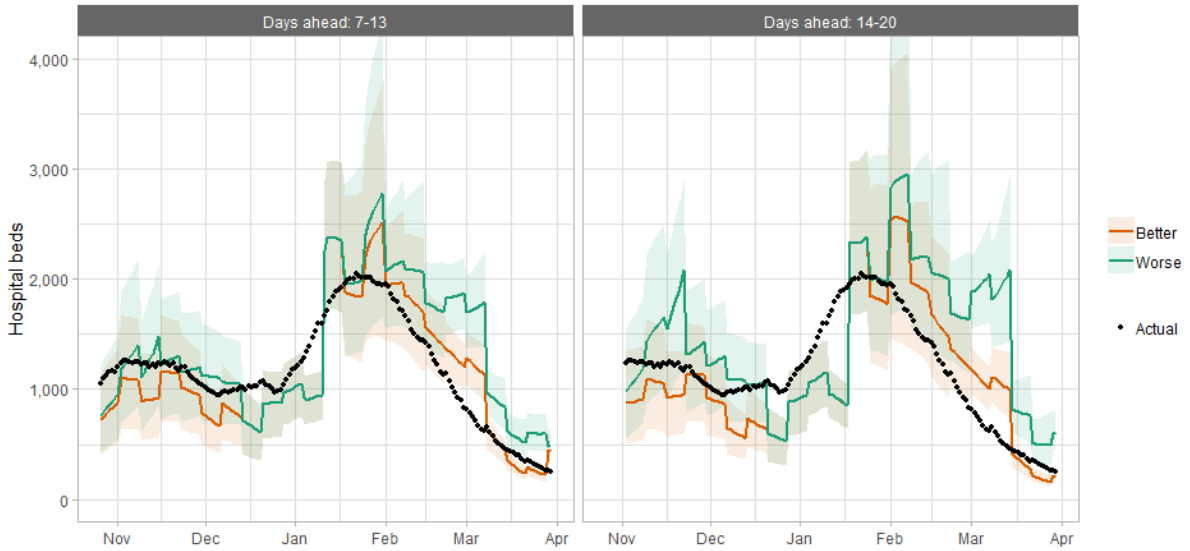
The following charts show the history of our modelling projections in comparison to estimates of the actual data. The infections projections were largely accurate during October to mid-December and from mid-January onward. During mid-December to mid-January, the projections underestimated the number 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, which is slightly different to the actuals, which are number of people in hospital within 28 days of a positive Covid 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. The actuals are number of people in ICU within 28 days of a positive Covid 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.

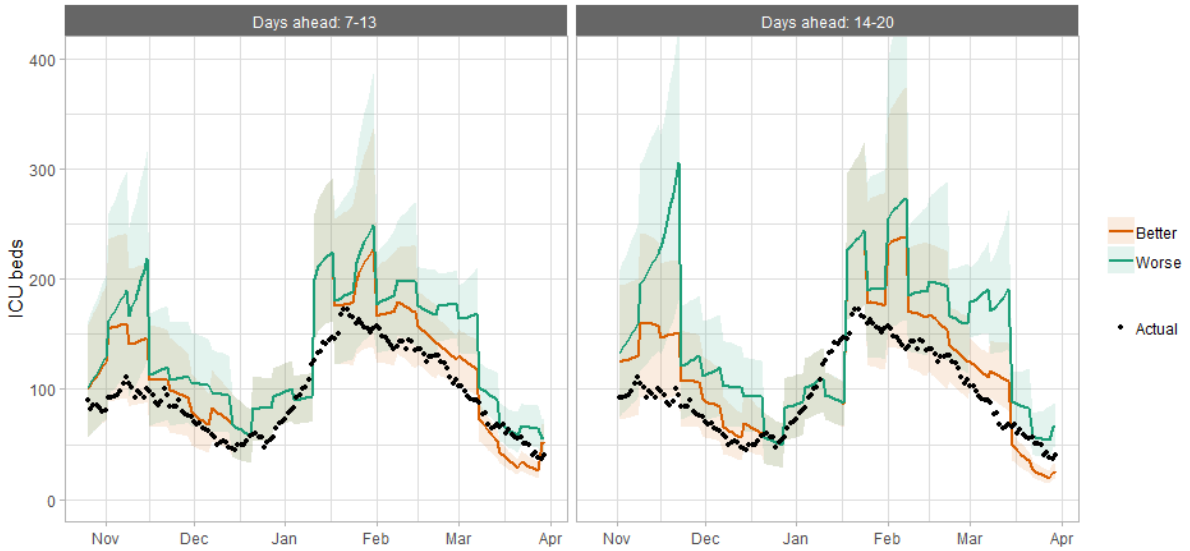


Table 1. Probability of local authority areas having more than 50, 100, 300 or 500 cases per 100K (11 – 17 April 2021).
Data updated on 31 March.

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

This publication will be available in accessible HTML on the gov.scot website

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

This document is also available from our website at www.gov.scot.
ISBN: 978-1-80004-928-4

The Scottish Government
St Andrew's House
Edinburgh
EH1 3DG

Produced for
the Scottish Government
by APS Group Scotland
PPDAS858726 (04/21)
Published by
the Scottish Government,
April 2021

ISBN 978-1-80004-928-4

Web Publication

PPDAS858726 (04/21)