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Coronavirus (COVID-19): Analysis

Coronavirus (COVID-19): modelling the epidemic in Scotland (Issue No. 29)

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 26 November 2020. 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 44 and 82, per 100,000 people.
- The growth rate for Scotland is estimated as being between - 3% and - 1%.
- Average contacts per day are approximately 60% higher than the level at the beginning of the stay-at-home advice, and less than half of the level pre-stay-at-home advice.
- The number of contacts has fallen in the last two weeks (down around 12%). This suggests the Protection Level restrictions are having an effect that may feed through to confirmed cases over the next week.

- Older people generally have fewer reported contacts than younger people, but the difference is largely from work and school contacts, rather than in the home or in other settings. All age groups below 60 report fewer contacts in the home during the last two weeks.
- Modelled rates per 100K indicate that by the week of 13 – 19 December, 16 (down 5 from last week) local authorities have at least a 75% probability of exceeding 50 cases, 4 (down 3) 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 (or 500) cases. This is an improvement compared to last week.

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 the first part of this research findings. The type of data used in each model to estimate R is highlighted in Figure 2.

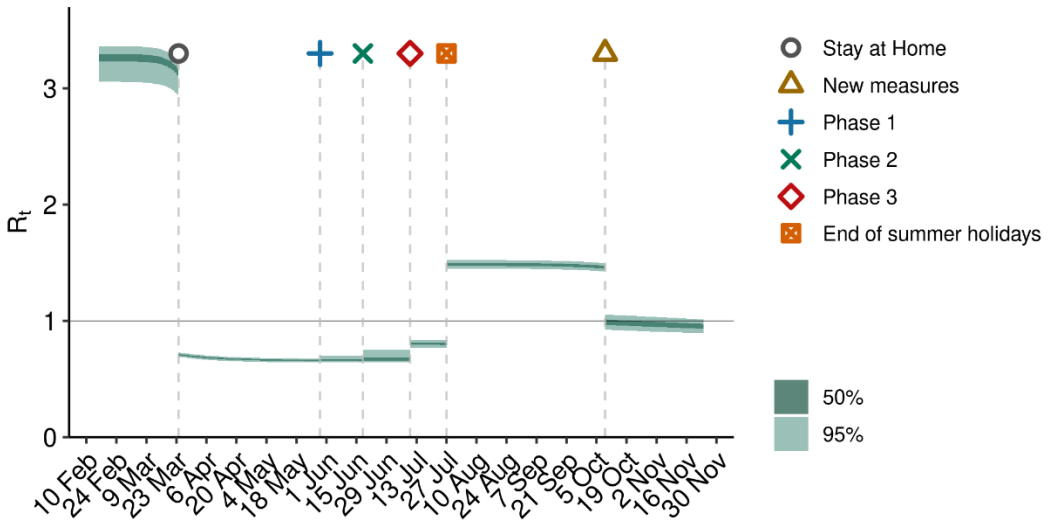
A short term forecast of the number of cases, ICU and hospital bed demand in the next two weeks is also provided, as the focus at this stage of the epidemic is the re-emergence of the virus in Scotland.

A new tranche of results are provided from the Scottish Contact Survey (SCS), to indicate how people's contacts are changing.

What the modelling tells us about the epidemic as a whole

Figure 1 shows how R_t has changed since February (including 50% and 95% confidence intervals). Before the "stay at home" restrictions were put in place R_t was above 1, and most likely to have been between 3 and 4 before any interventions were put in place.

Figure 1: Trends in R_t for Scotland, 2020.

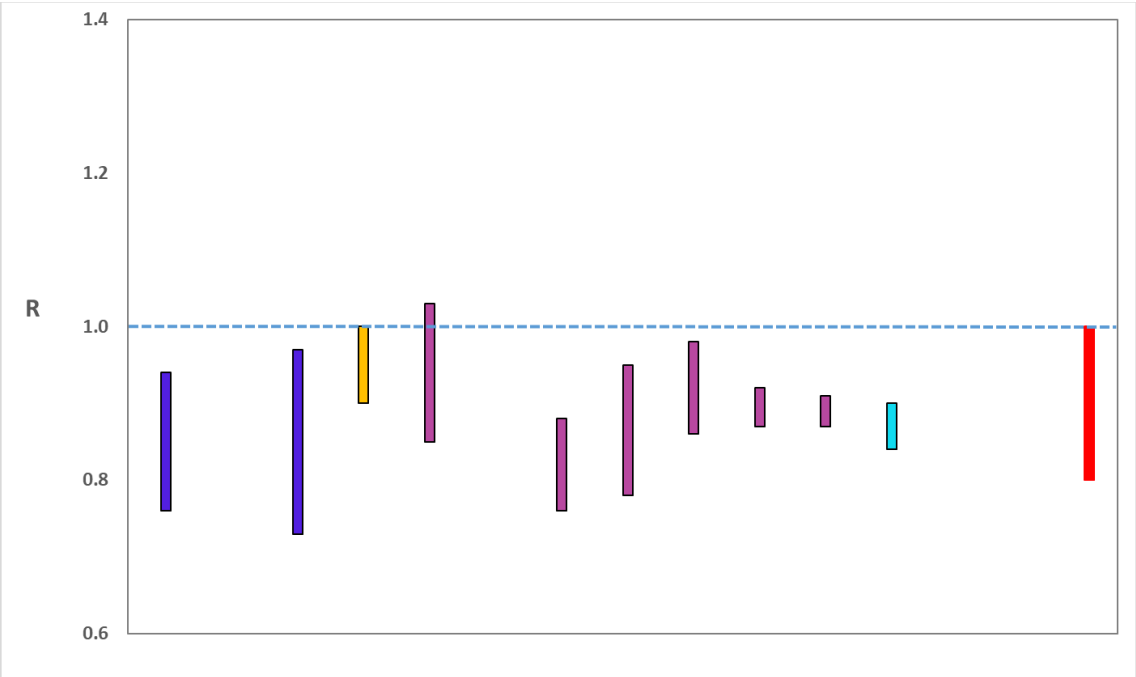


Source: Scottish Government modelled estimates using Imperial College model code; actual data from https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/vital-events/general-publications/weekly-and-monthly-data-on-births-and-deaths/deaths-involving-coronavirus-covid-19-in-scotland

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 02 December, was that the value of R_t in Scotland was

between 0.8 and 1.0. The R value estimated by the Scottish Government is within the consensus range (Figure 2).

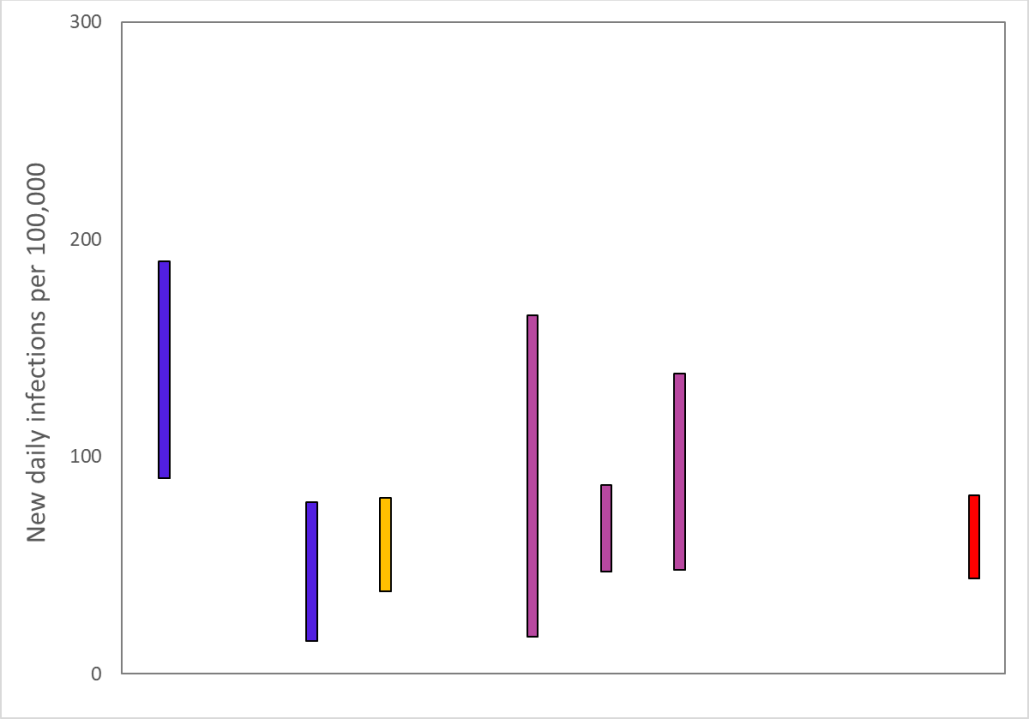
Figure 2. Estimates of R_t for Scotland, as of 02 December, including 90% confidence intervals, produced by SAGE. The blue bars are death-based models, purple use multiple sources of data and cyan use Covid-19 test results. The estimate produced by the Scottish Government (a semi-mechanistic model) is the 3rd 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 3). SPI-M's consensus view across these methods, as of 02 December, was that the incidence of new daily infections in Scotland was between 44 and 82 new infections per 100,000. This equates to between 2,400 and 4,500 people becoming infected each day in Scotland.

Figure 3. Estimates of incidence for Scotland, as of 02 December, including 90% confidence intervals, produced by SPI-M. The blue bars are death-based models 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 3rd from left (yellow), while the SAGE consensus range is the right-most (red).

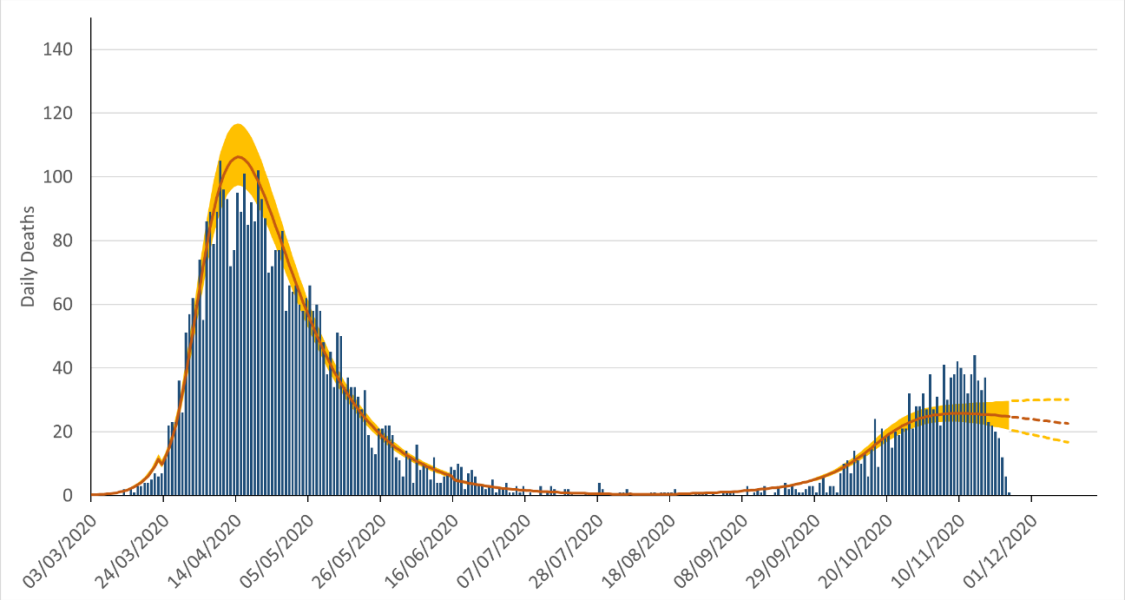


Source: Scientific Pandemic Influenza Group on Modelling (SPI-M).

The consensus from SAGE for this week is that the growth rate in Scotland is between -3% and -1% per day. Last week the growth rate was in the range -3% and 0%.

Figure 4 shows the epidemiological model forecasts of daily deaths produced by the Scottish Government, given the present set of interventions.

Figure 4. Scottish Government short-term forecast of the number of deaths from Covid-19 in Scotland, based on actual data (to 24 November).

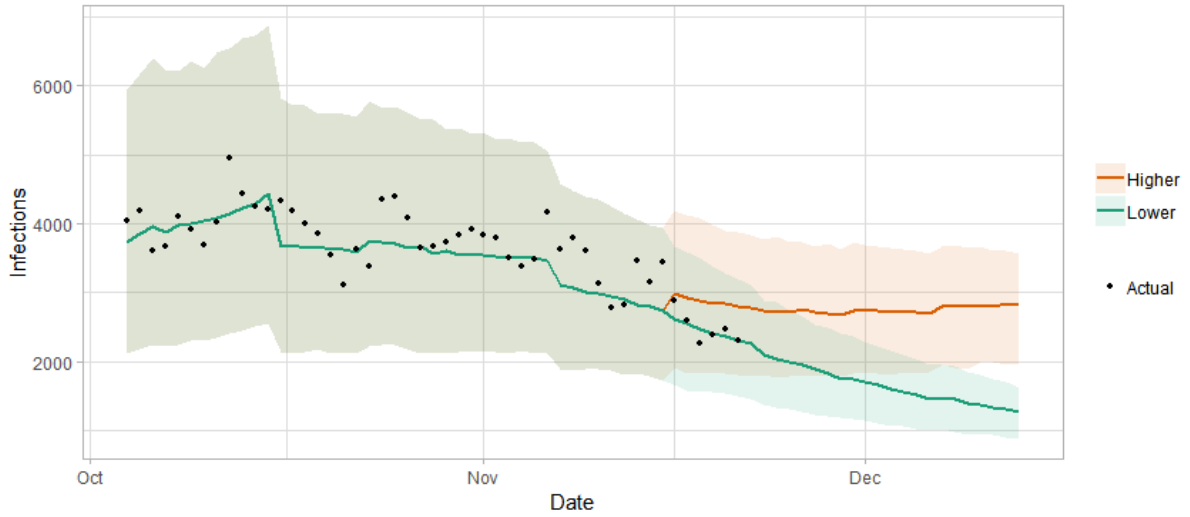


Source: Scottish Government modelled estimates using Imperial College model code; actual data from https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/vital-events/general-publications/weekly-and-monthly-data-on-births-and-deaths/deaths-involving-coronavirus-covid-19-in-scotland

The logistical model developed by Scottish Government to assess implications for health care demand (see previous Research Findings) has been adapted to produce a short/medium-term predictions of infections.

Figure 5 shows a "Lower" projection, which assumes the Rt value is currently slightly below 1 and there will be limited increase in transmission from winter conditions, and a "Higher" projection, which assumes that Rt is currently slightly higher (but still below 1), and it will increase as winter sets in.

Figure 5. Short term forecast of modelled total new infections, adjusting positive tests to account for asymptomatic and undetected infections, from Scottish Government modelling, positive test data up to 28 November.



What the modelling tells us about Hospital bed and ICU bed demand

Figure 6 shows the impact of the Lower and Higher scenarios on the number of people in hospital.

Figure 6. Short term forecast of modelled hospital bed demand, from Scottish Government modelling.

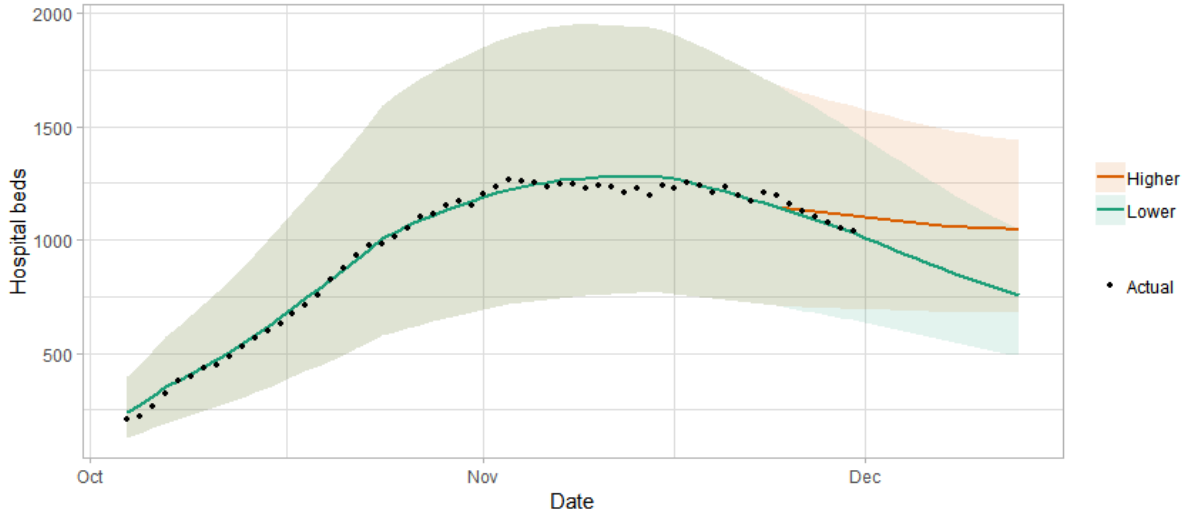
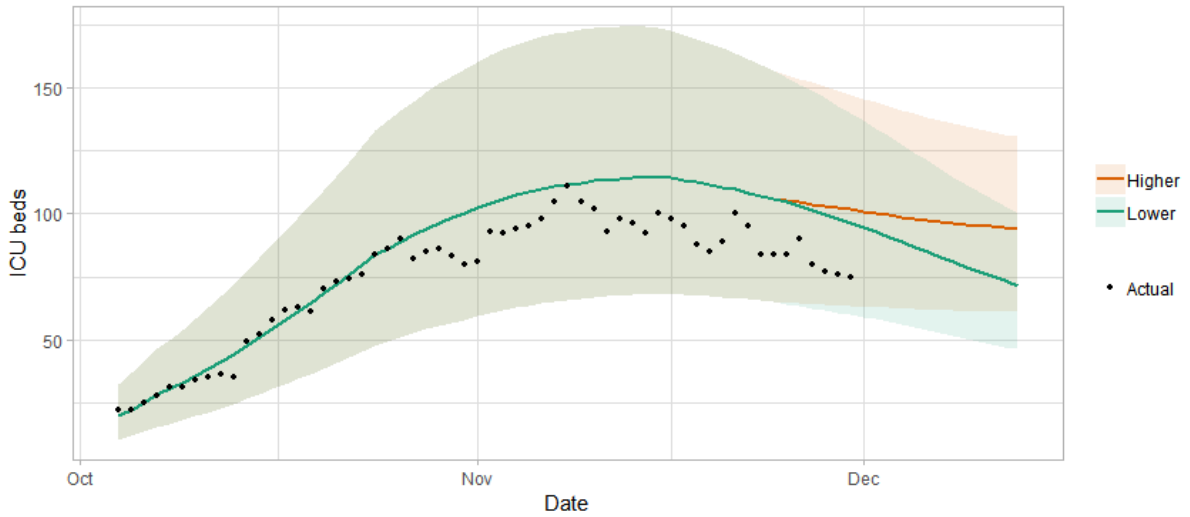


Figure 7 shows the impact of the Lower and Higher scenarios on ICU bed demand.

Figure 7. Short term forecast of modelled ICU bed demand, from Scottish Government modelling.



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

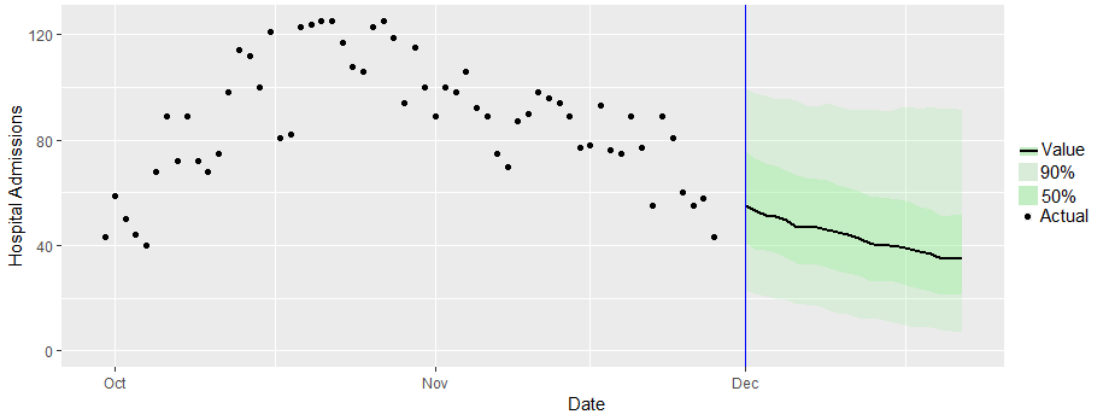
SAGE produce projections of the epidemic over the next three weeks[1] (Figure 8), combining estimates from several independent models (including the Scottish Government Government's logistics modelling, as shown in figures 5, 6 and 7). These projections are not forecasts or predictions. **They represent a scenario in which the trajectory of the epidemic continues to follow current trends and do not account for the impact of future policy or behaviour changes.** Nor do they include seasonal effects that might increase transmission.

The delay between infection, developing symptoms, hospitalisation and death means the projections cannot fully reflect changes in transmission that might have occurred over the past two to three weeks.

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.

[1] A three week projection up until Christmas is provided here, when relaxation of restrictions occurs.

Figure 8. SAGE medium-term projection of daily hospitalisations in Scotland, including actual hospitalisations (to 28 Nov) and 50% and 90% credible intervals. The blue vertical line indicates where the actual admissions data stops and the projection begins.



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

The average number of contacts per day are approximately 60% higher than they were at the beginning of the Stay-at-home-advice, and less than half the level pre-Stay-at-home-advice (UK comparison 10.8). Interactions between age groups have decreased since the end of August. This suggests the Protection Level restrictions are having an effect. Older people generally have fewer reported contacts than younger people, but this difference is largely from work and school contacts. There is a drop off in how many people are visiting different locations, particularly in the pubs category.

The Scottish Survey is split into two sample groups, Panel A and Panel B. These are updated every two weeks for each panel (alternating). The following visualisations combine both sample groups and show how their mean contacts change over time (see technical annex in issue 18 of the Research Findings). Data covering the periods from 12 – 19 August (Panel B week 1) and 24 – 30 September (Panel B week 4), have been removed due to anomalous entries.

There was a significant increase when schools returned in August, from 6 to 8 average contacts, however both Panels show a consistent reduction in the number of mean contacts between the end of August and mid-October. Half terms occurred from 5 October onwards while restrictions were introduced on the 9 October. For the panel A survey pertaining to the week beginning 29 October, the mean contacts

increased by 11% from 2 weeks prior. This increase is reflected in panel B where mean contacts have increased by 14% for the week beginning 5 November. This follows the end of half term which varies across Scotland, ending between 16 – 27 October. Since the introduction of protection levels, mean contacts have reduced by 12% from the week beginning 5 November to the week beginning 19 November as shown in Figure 10 for Panel B. In the prior week a similar decrease is also seen in Panel A (6%).

Figure 9: Mean Adult Contacts (truncated at 100) from SCS.

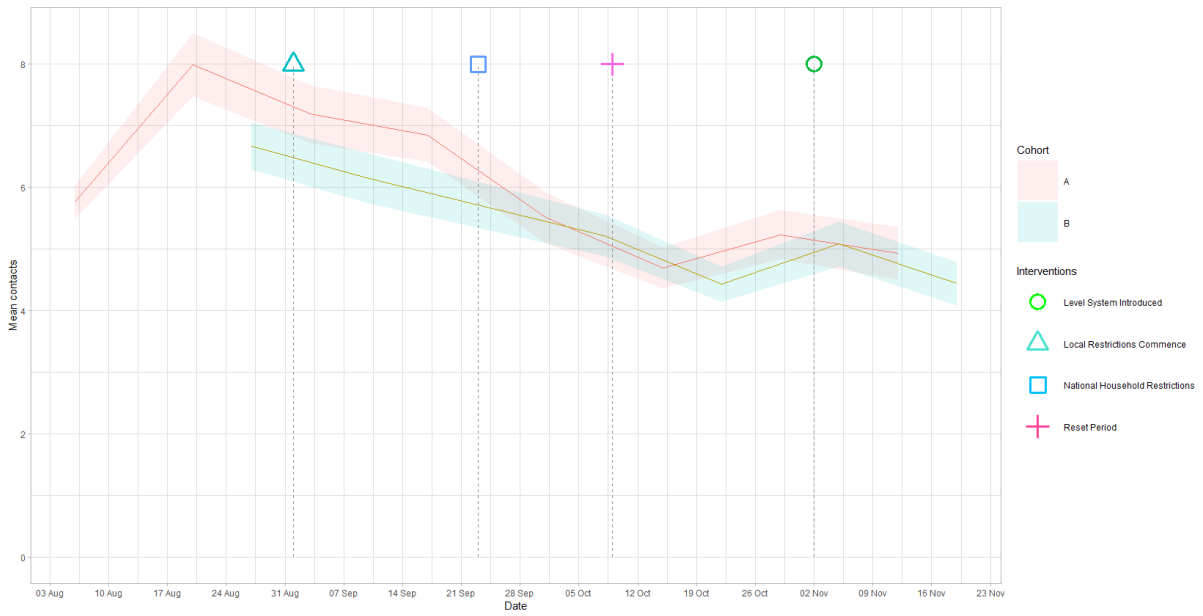
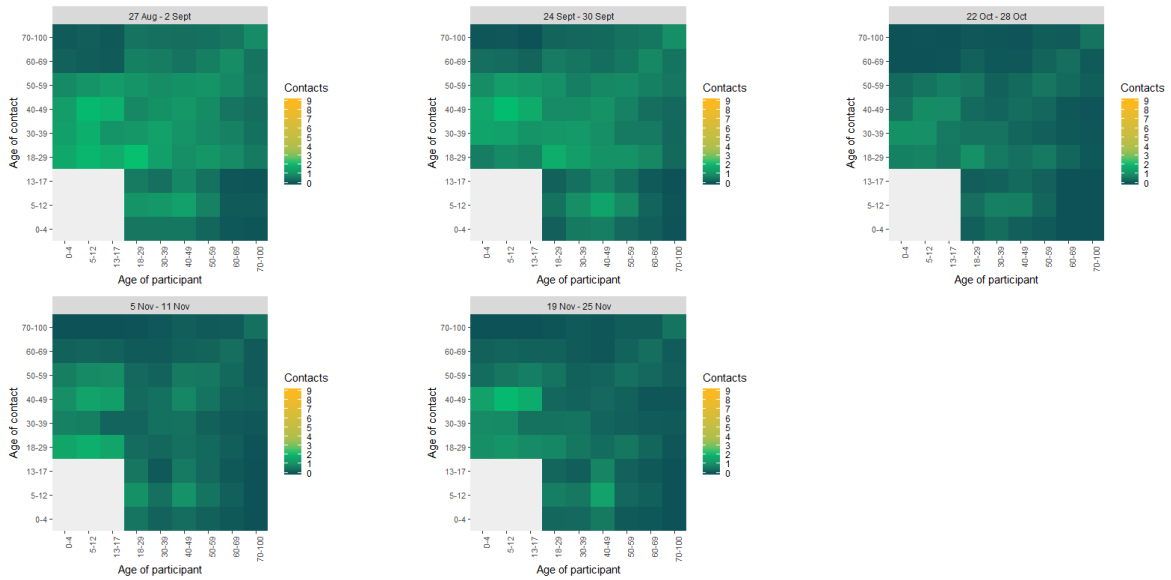


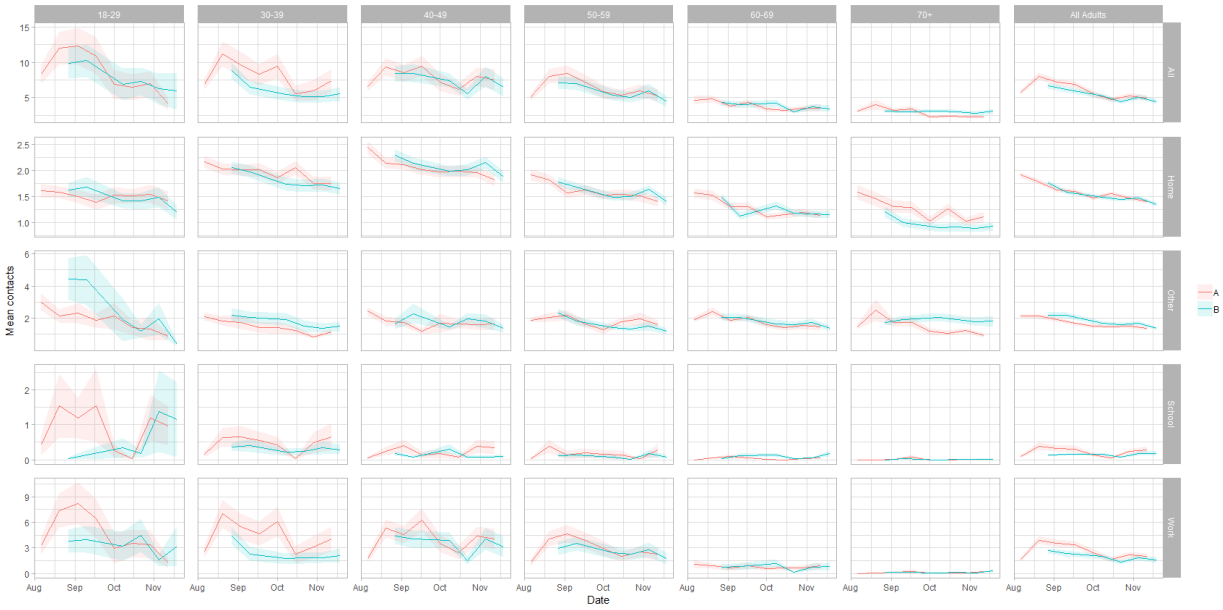
Figure 10: Mean contacts by age group from the start of August to the end November from SCS.



The heatmaps in Figure 10 show mean contacts by age group over time, from the start of August to the end of November. This illustrates that individuals initially had an increase in mean contacts however this has steadily reduced for all age groups until the end of October where all respondents had less contact with other age groups compared to the start of August. During the end of half term period (16 – 27 October) there was an increase in mean contacts within the younger age groups which is likely due to individuals returning to work and school. In the most recent survey (19 – 25 November), there has been a decrease in mean contacts between age groups which follows the implementation of the restrictions introduced on 9 November.

As seen in Figure 11, contacts are fewer in older age groups, with the oldest age group having similar levels of contact to the UK at the beginning of the Stay-at-home-advice (2.0 from CoMix). The youngest age group also shows similar levels of contacts to the UK average prior to the beginning of the Stay-at-home-advice (12.1 from POLYMOD[2]) until mid-September, this fell significantly at the start of October and remains the same for the most recent survey.

Figure 11: Average (mean) contacts for each panel per day by setting for adults in Scotland, truncated to 100 contacts per participant (from SCS).



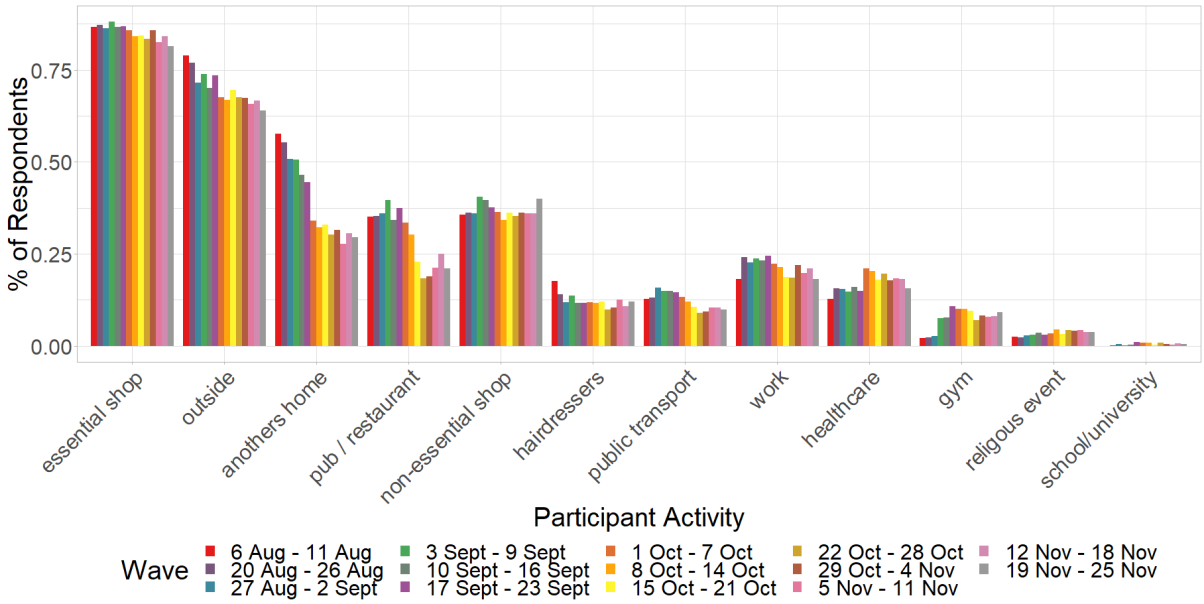
Both panels show similar behaviour with a downward trend over time in all settings from August to the start of November except for the age

[2] The UK POLYMOD figures from https://bmcmedicine.biomedcentral.com/track/pdf/10.1186/s12916-020-01597-8

group 18-29, which cannot be confirmed due to the large margin of error. For both panels however there was an increase in the work and school settings from the week beginning 29 October for panel A and in the week beginning 5 November for panel B (half term effect) however both panels have both shown a decrease in the most recent wave of the survey. The main difference between age groups is that younger people are having more contacts at work and at school. The middle age groups report a slight decrease in contacts in the other settings in the last 2 weeks and all age groups below 60 report fewer contacts in the home as set out in Figure 11.

As Figure 12 shows, the biggest change in behaviour has been the drop off in the proportion of people that have visited other people's homes since the commencement to the 1 October, dropping from 58% to 34%. There has been a gradual but less pronounced decrease since this date to 30% for the most recent survey. There has been a significant decrease during October for the number of people visiting pubs (21% in the week of 5 – 11 November, down from 34% for the week of 1 – 7 October) which will be largely due to the restrictions placed on hospitality, introduced on 9 October, and this remains consistent to date. The only increase in behaviour has been in the healthcare and gym settings from August to November.

Figure 12: Locations visited by participants at least for panel A and B (from SCS).



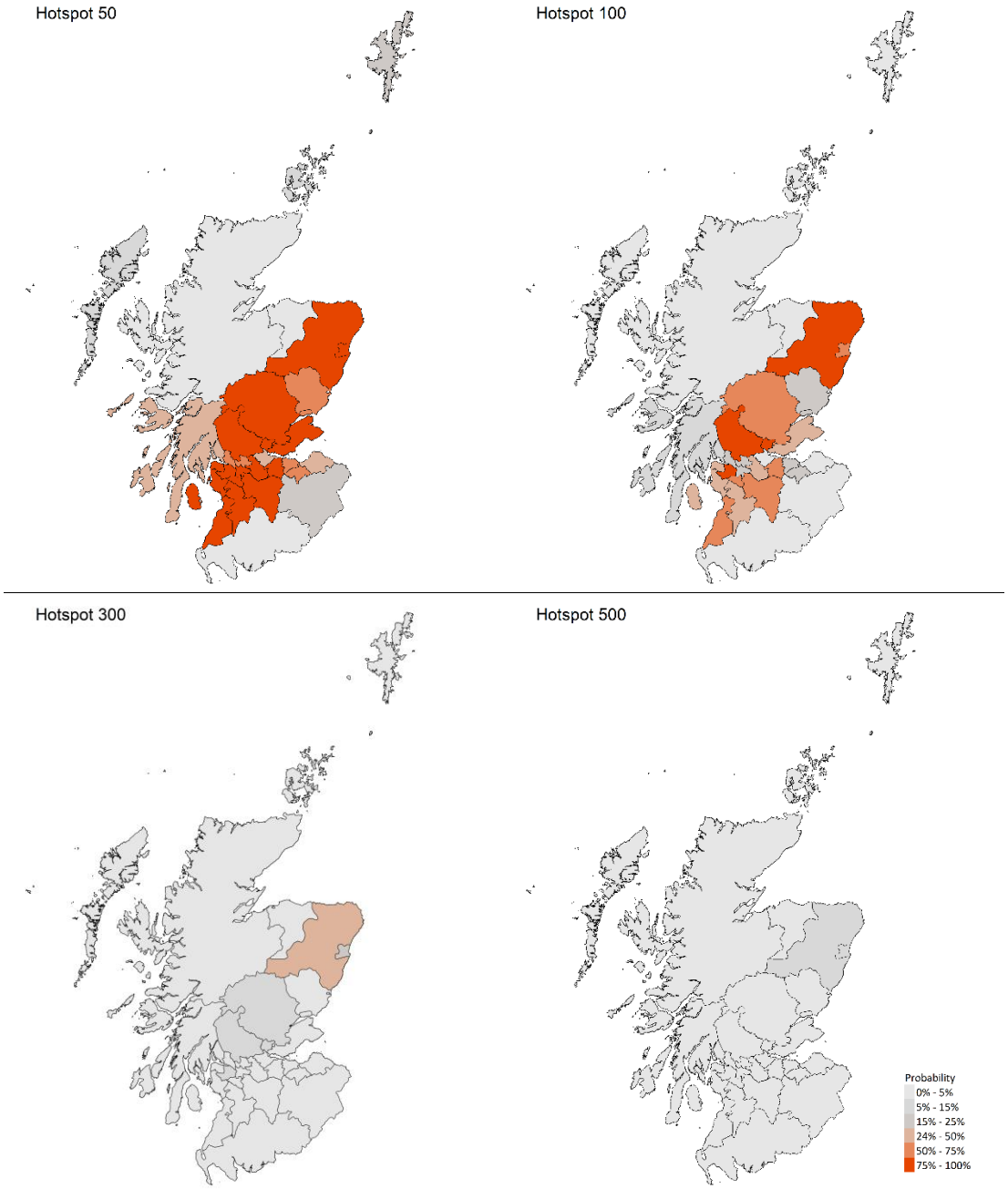
What we know about which regions are experiencing high levels of Covid

We use modelling based on Covid cases and deaths[3], conducted by Imperial College London, to give us an indication of whether a local authority is experiencing high levels of Covid. An area is defined as a hotspot if the two week prediction of cases (positive tests) per 100K population are predicted to exceed a threshold, e.g. 500 cases. See technical annex in issue 24.

Modelled rates per 100K (Figure 13) indicate that by the week of 13 – 19 December, 16 (down 5 in the last week) local authorities have at least a 75% probability of exceeding 50 cases, 4 (down 3) of those have at least a 75% probability of exceeding 100 cases and none have at least a 75% probability of exceeding 300 (or 500) cases.

[3] https://www.medrxiv.org/content/10.1101/2020.11.24.20236661v1

Figure 13. Probability of local authority areas having more than 50, 100, 300 or 500 cases per 100K (13 - 19 Dec 2020). Data updated on 01 December[4].



[4] https://doi.org/10.5281/zenodo.4302011

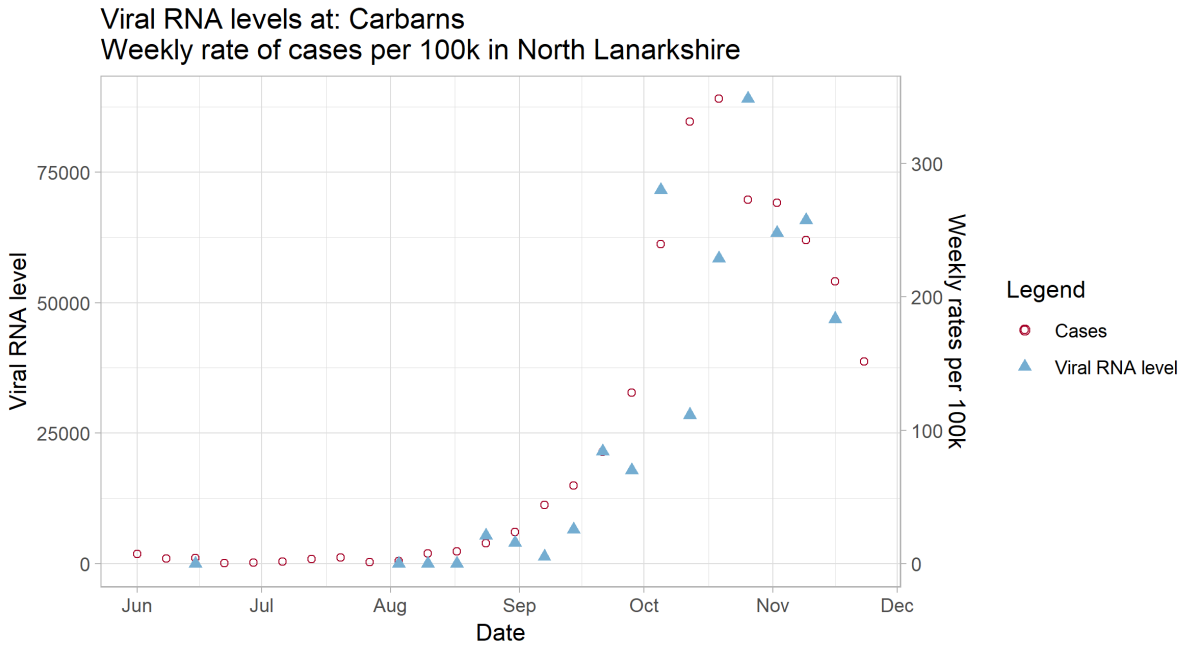
What can analysis of wastewater samples tell us about local outbreaks of Covid-19 infection?

Samples from Waste Water Treatment Works (WWTW) in Scotland have been analysed by the Scottish Environment Protection Agency (SEPA) to detect fragments of SARS-Cov-2 virus RNA in waste water. This is reported from lab analysis as gene copies per litre. The reported levels of SARS-Cov-2 found have been compared to trends in confirmed Covid-19 cases in the surrounding areas.

Figure 14 shows that the level of gene copies recorded at Carbarns WWTW and Shieldhall WWTW increased as the number of positive cases increased in North Lanarkshire and Glasgow City, respectively, from September to October. The concentration levels then came down as the number of confirmed cases in these locations reduced over the past month.

Analysis of Covid-19 viral concentrations in comparison to recorded positive tests shows similar trends to that in Figure 14 for a number of other outbreaks around Scotland. A comparison of viral RNA levels at each site and confirmed positive tests in the surrounding area is shown in Figure 15. While this approach may not provide an early indication of a developing outbreak, it gives us confidence that the outbreak has indeed been contained and we are not missing a substantial number of asymptomatic viral spreaders.

Figure 14: Temporal trend of the recorded weekly rates of positive Covid-19 tests in North Lanarkshire and Glasgow City from June to December 2020, and the normalised viral RNA levels at Carbarns WWTW and Shieldhall WWTW. Viral RNA levels have been normalised by flow rate, and the population of the WWTW catchment area, and an average has been taken over the samples reported each week. In this plot the red circles (weekly cases per 100,000) are scaled relative to the maximum sewage viral levels found at each WWTW. Further information is available in the technical annex of issue 26.



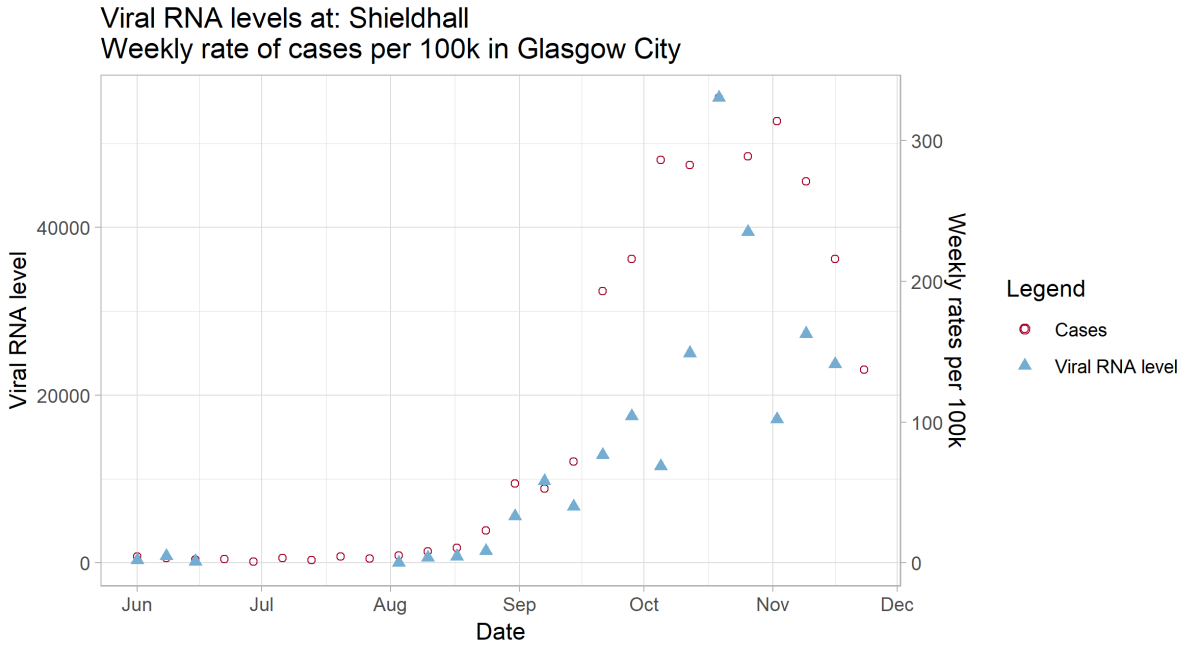
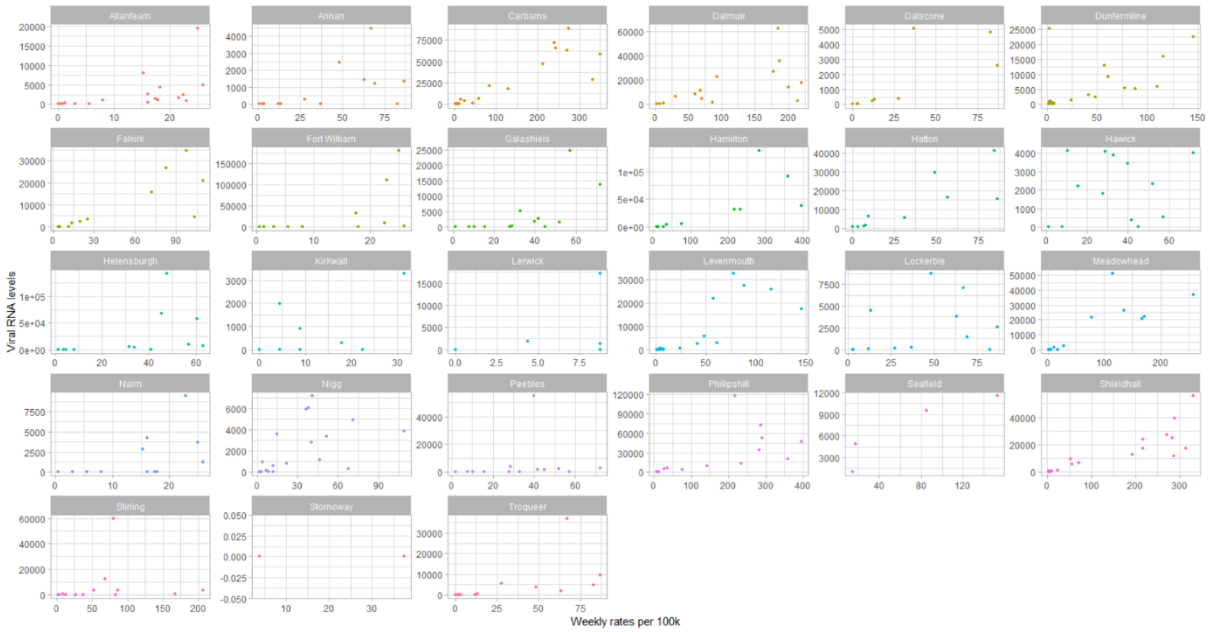


Figure 15: For each WWTW site where samples have been taken, the normalised viral RNA levels against the weekly rates of positive Covid-19 tests in the closest local authority from June to December 2020. Clusters of points in a diagonal line from the lower left corner to the upper right shows evidence of positive correlation between viral RNA levels and cases. Large population centres seem to have more favourable correlation, for example Carbarns. Local authorities with a more dispersed population, where the waste water is measured at relatively small sewage works and cases are recorded at local authority level, seem to show less evidence of correlation, for example Hawick in the Scottish Borders.



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 exceedance. R_t and growth rate will also be provided. Further information can be found at https://www.gov.scot/coronavirus-covid-19.

Technical Annex

Table 1. Probability of local authority areas having more than 50, 100, 300 or 500 cases per 100K (13 - 19 December 2020). Data updated on 01 December.

LA	P (Cases > 500)	P (Cases > 300)	P (Cases > 100)	P (Cases > 50)
Aberdeen City	10%	22%	61%	81%
Aberdeenshire	12%	32%	85%	98%
Angus	0%	0%	19%	55%
Argyll and Bute	0%	1%	10%	45%
City of Edinburgh	0%	0%	15%	56%
Clackmannanshire	2%	13%	88%	98%
Dumfries and Galloway	0%	0%	0%	2%
Dundee City	0%	0%	18%	59%
East Ayrshire	0%	2%	35%	76%
East Dunbartonshire	0%	0%	21%	62%
East Lothian	0%	0%	4%	42%
East Renfrewshire	0%	2%	67%	95%
Falkirk	0%	0%	2%	29%
Fife	0%	0%	32%	77%
Glasgow City	0%	0%	17%	78%
Highland	0%	0%	0%	2%
Inverclyde	0%	1%	45%	79%
Midlothian	0%	0%	22%	73%
Moray	0%	0%	0%	3%
Na h-Eileanan Siar	0%	0%	3%	8%
North Ayrshire	0%	2%	44%	84%
North Lanarkshire	0%	0%	44%	89%
Orkney Islands	0%	0%	2%	10%
Perth and Kinross	1%	7%	51%	79%
Renfrewshire	0%	5%	86%	98%
Scottish Borders	0%	0%	3%	25%
Shetland Islands	0%	0%	5%	15%
South Ayrshire	0%	1%	53%	89%
South Lanarkshire	0%	2%	60%	94%
Stirling	0%	5%	78%	96%
West Dunbartonshire	0%	0%	20%	62%
West Lothian	0%	1%	56%	94%

Tables 2 and 3 provide the underlying data used in the section above on "What the modelling tells us about Hospital bed and ICU bed demand". They are based on modelling undertaken by Scottish Government (for more information see research findings issue 1).

The purpose of these predictions is to support a decision on what measures are needed in different parts of Scotland. As part of the medium term modelling, these predictions are not intended as short term forecasts (less than two weeks, for which management information is more appropriate), but the initial weeks are provided for completeness.

As the middle, lower and upper ends of the range are presented for each health board, the aggregate cannot be used as a prediction of the number of beds required in Scotland as a whole.

Table 2. Estimated demand for ICU beds

Area	Cap. (double)[5]	07/12/20	14/12/20	21/12/20	28/12/20	04/01/21	11/01/21
Ayrshire and Arran	20	7 (0-11)	7 (0-10)	6 (0-10)	6 (0-9)	7 (0-9)	7 (0-9)
Borders	10	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Dumfries and Galloway	8	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Fife	20	7 (0-9)	7 (0-8)	7 (0-8)	7 (0-8)	7 (0-8)	7 (0-8)
Forth Valley	14	7 (0-8)	6 (0-8)	6 (0-8)	7 (0-8)	7 (0-8)	7 (0-8)
Grampian	32	11 (5-14)	10 (0-13)	12 (0-17)	15 (0-24)	15 (0-24)	16 (0-24)
Greater Glasgow and Clyde	76	35 (15-44)	33 (13-42)	31 (10-41)	30 (8-40)	30 (7-40)	31 (6-41)
Highland	16	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Lanarkshire	40	25 (10-34)	24 (8-32)	22 (7-31)	21 (5-31)	22 (5-31)	22 (0-32)
Lothian	55	12 (0-18)	11 (0-17)	11 (0-17)	11 (0-16)	11 (0-16)	11 (0-16)
Orkney	0	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Shetland	0	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Tayside	22	6 (0-9)	6 (0-9)	6 (0-8)	6 (0-8)	6 (0-8)	6 (0-8)
Western Isles	4	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)

* indicates that the middle of the range is less than 5. Values in this table give an interval, actual occupancy could be higher or lower.

[5] Total adult ICU beds

Table 3. Estimated demand for hospital beds

Area	Cap.	07/12/20	14/12/20	21/12/20	28/12/20	04/01/21	11/01/21
Ayrshire and Arran	203	108 (43-143)	105 (37-137)	104 (32-135)	104 (28-135)	107 (25-136)	109 (23-138)
Borders	118	12 (5-15)	11 (0-14)	11 (0-14)	11 (0-14)	12 (0-14)	12 (0-15)
Dumfries and Galloway	90	6 (0-8)	6 (0-7)	5 (0-7)	5 (0-7)	5 (0-7)	5 (0-7)
Fife	322	60 (17-98)	58 (15-94)	58 (13-91)	58 (12-90)	60 (11-91)	61 (10-92)
Forth Valley	144	53 (15-85)	51 (13-82)	54 (11-87)	57 (10-92)	58 (9-93)	60 (9-95)
Grampian	295	98 (32-151)	95 (27-144)	118 (24-195)	152 (21-270)	156 (19-274)	160 (18-277)
Greater Glasgow and Clyde	1,070	405 (161-541)	393 (138-519)	374 (109-509)	363 (86-509)	372 (78-516)	381 (72-522)
Highland	176	11 (0-21)	11 (0-20)	11 (0-21)	12 (0-22)	12 (0-22)	12 (0-22)
Lanarkshire	455	243 (102-310)	236 (88-298)	226 (70-292)	218 (55-292)	223 (50-296)	229 (46-299)
Lothian	487	164 (72-200)	159 (62-191)	158 (54-188)	159 (48-183)	163 (44-186)	167 (40-188)
Orkney	28	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Shetland	64	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)
Tayside	172	84 (37-104)	82 (31-100)	82 (28-98)	84 (25-98)	86 (23-99)	88 (21-100)
Western Isles	32	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)	* (0-5)

* indicates that the middle of the range is less than 5. Values in this table give an interval, actual occupancy could be higher or lower.

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