GSE Government Science & Engineering

GORS Government Operational Research Service

Scottish Government
Riaghaltas na h-Alba

Scottish Government Central Analysis Division

Coronavirus (Covid-19): modelling the epidemic in Scotland (Issue No. 112)

Background

This is a report on the Scottish Government modelling of the spread and level of Covid-19 in Scotland. This updates the previous publication on modelling of Covid-19 in Scotland published on 27th October 2022. The estimates in this document provide an overview of the situation regarding the virus and help the Scottish Government, the health service and the wider public sector plan ahead.

Key Points

- The reproduction rate R in Scotland is currently estimated as being between 0.9 and 1.1 as at 25th October. The lower limit has increased since the last publication. The upper limit is unchanged.
- The daily growth rate for Scotland is currently estimated as between -2% and 1% as at 25th October. The lower limit has increased since the last publication. The upper limit has decreased.
- EMRG was unable to reach a consensus on the incidence of new daily infections in Scotland as at 25th October.
- The most recent wave of the Scottish Contact Survey (27th October - 2nd November) indicate an average of 6.2 contacts. This has increased by 25% compared to the previous wave of the survey (13th October - 19th October) where average contacts were 5.0. Prior to the Covid-19 pandemic, the average daily contacts for adults in the UK were reported to be 10.8.
- Mean contacts have increased in all settings compared to the previous wave of the survey, with contacts in the other setting (contacts outside home, school and work) increasing by the most (22%).
- Mean contacts have increased in all age groups other than those in the 30-39 age group. The largest increase was seen in the 18-29 age

group, with an increase of 86%. Mean contacts in the 30-39 age group decreased by 25%.

- The largest increase in interactions compared to the previous wave of the survey was between those aged 18-29 and those aged 18 and under.
- Pubs and restaurants saw the largest increase in percentage of participants visiting compared to the previous wave of the survey, increasing from 55% to 58%. The percentage of participants visiting a work location had the largest decrease, dropping from 38% to 31%.
- The percentage of people wearing a face covering where they have at least one contact outside of the home has decreased from 22% to 20% since the last wave of the survey.
- The percentage of people who had taken at least one lateral flow test in the previous 7 days decreased from 26% to 21% since the last wave of the survey.
- The SPI-M-O consensus view is that by 6th December, daily hospitalisations from Covid-19 in Scotland are estimated to be between 7 and 53, and hospital occupancy is estimated to be between 240 and 906.
- Analysis by the Edinburgh University Roslin Institute indicates that there remains a substantial variation in geographical risk of infection when considering the average recorded census age and booster vaccination uptake.
- The data show a continued decline in reported tests across all deprivation deciles, and a recent rise in LFD positivity. There is no clear trend in positivity with respect to deprivation. The volume of testing remains very low.
- The distribution of lateral flow/LFD tests being reported continues to vary substantially by both age and deprivation status.
- Fewer tests are reported in younger adults across all deciles of deprivation, and for children in more deprived deciles.
- LFD positivity has sharply risen since about 12th September. However, this rise has plateaued in less deprived areas, but continues to rise in more deprived areas. With no deprivation-specific changes in testing volume overall, this is suggestive of disproportionately increased circulation of infection within more deprived communities.
- Nationwide, during the period 22nd October – 4th November, wastewater Covid-19 levels were between 34 to 62 million gene

copies per person per day (Mgc/p/d). Compared to the levels in the previous two-week period (6th – 20th October) of 40 to 78 Mgc/p/d this shows an overall decreasing trend.

Overview of Scottish Government Modelling

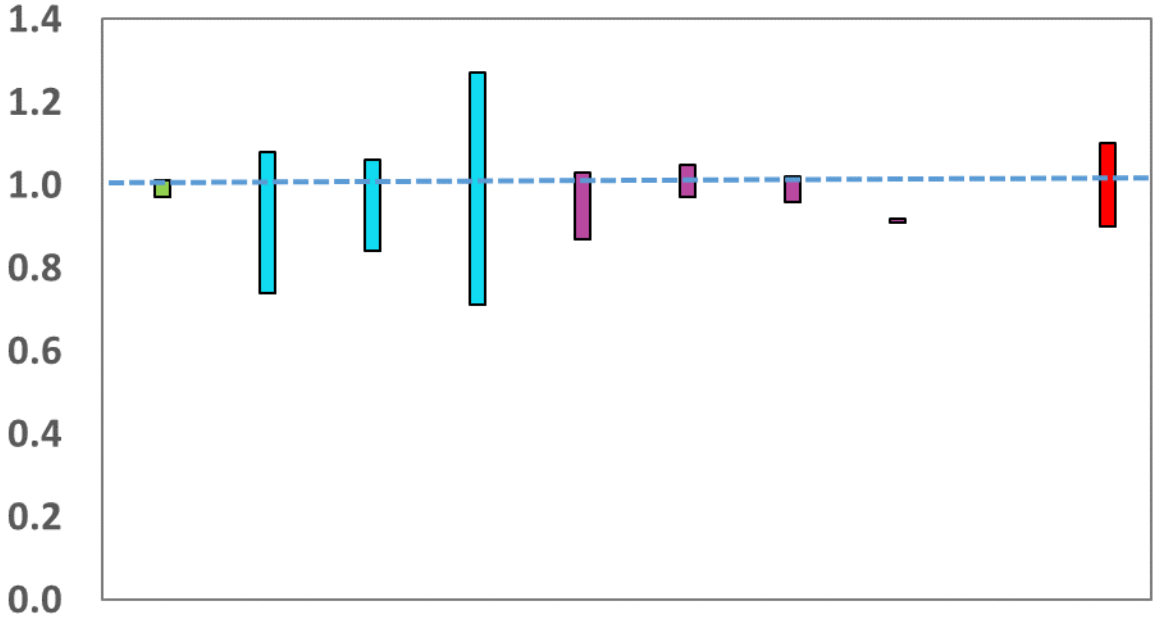
Modelling outputs are provided here on the current epidemic in Scotland as a whole, based on a range of methods. Because it takes a little over three weeks on average for a person who catches SARS-CoV-2 (the causative agent of Covid-19) to show symptoms, become sick and either die or recover, there is a time lag in what our model can tell us about any changes in the epidemic.

The Scottish Government presents its modelling outputs to the Epidemiology Modelling Review Group (EMRG). These outputs are included (shown in green) in Figure 1. Outputs from other modellers are shown in either cyan (for models based only on cases data) or purple (for models based on other data). The consensus range is the rightmost (in red).

The R value and growth rates are also estimated by several independent modelling groups based in universities and the UKHSA. Estimates are considered, discussed and combined at the EMRG, which sits within UKHSA. These are based on data up to 7th November.

The consensus view of the EMRG across these methods was that the value of R in Scotland is between 0.9 and 1.1 as of 25th October 2022 (Figure 1). The lower limit has increased since the last publication while the upper limit is unchanged. R is an indicator that lags by two to three weeks.

Figure 1: Estimates of Rt for Scotland as of 25th October, including 90% confidence intervals, produced by EMRG



Source: EMRG

The consensus from EMRG is that the growth rate in Scotland is between -2% and 1% per day as at 25th October. The lower limit has increased since the last publication while the upper limit has decreased.

EMRG was unable to reach a consensus view on the incidence of new daily infections in Scotland as at 25th October.

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

Scottish Contact Survey contact matrices are now published as open data. The dataset contains mean contacts between age groups for all waves of the survey since its inception in August 2020 and will be updated fortnightly to add data for the latest survey wave.

The most recent wave of the Scottish Contact Survey (13th - 19th October) indicate an average of 6.2 contacts. This has increased by 25% compared to the previous wave of the survey (13th October - 19th October) where average contacts were 5, as seen in Figure 3.

Prior to the Covid-19 pandemic, the average daily contacts for adults in the UK were reported to be 10.8 from the UK-wide POLYMOD study[1].

[1] https://bmcmedicine.biomedcentral.com/counter/pdf/10.1186/s12916-020-01597-8.pdf

Mean contacts have increased in all settings compared to the previous wave of the survey, with contacts in the other setting (contacts outside home, school and work) increasing by the most (22%).

Figure 2: Mean contacts per day for adults in Scotland (truncated to 100 contacts per participant)

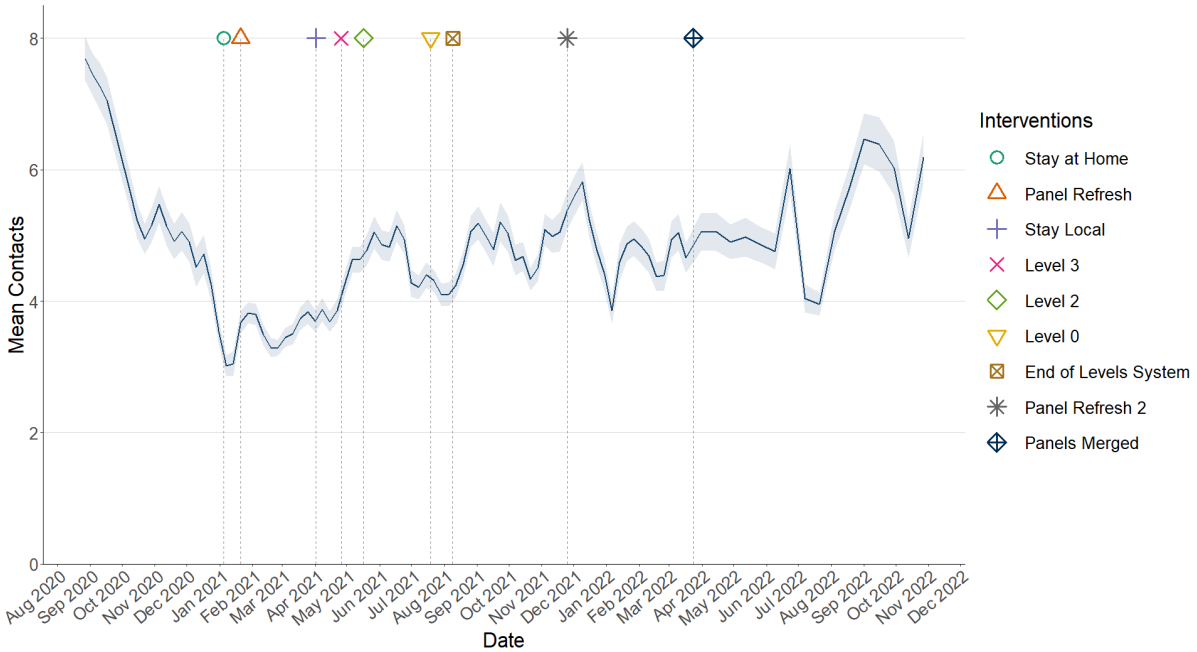
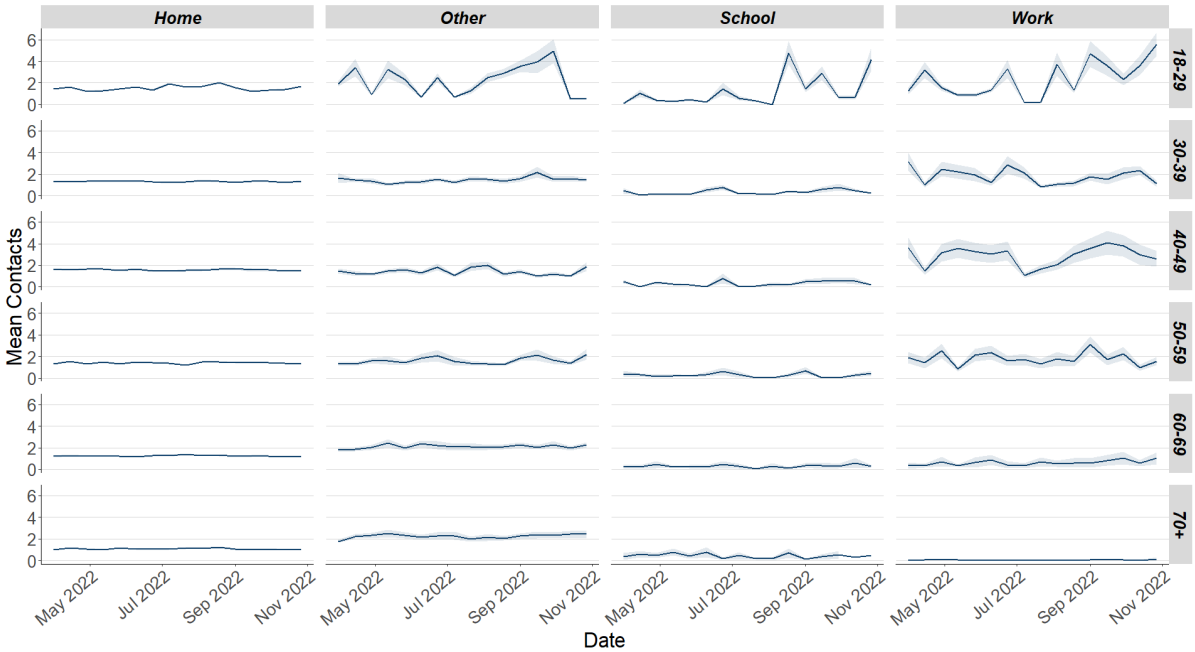


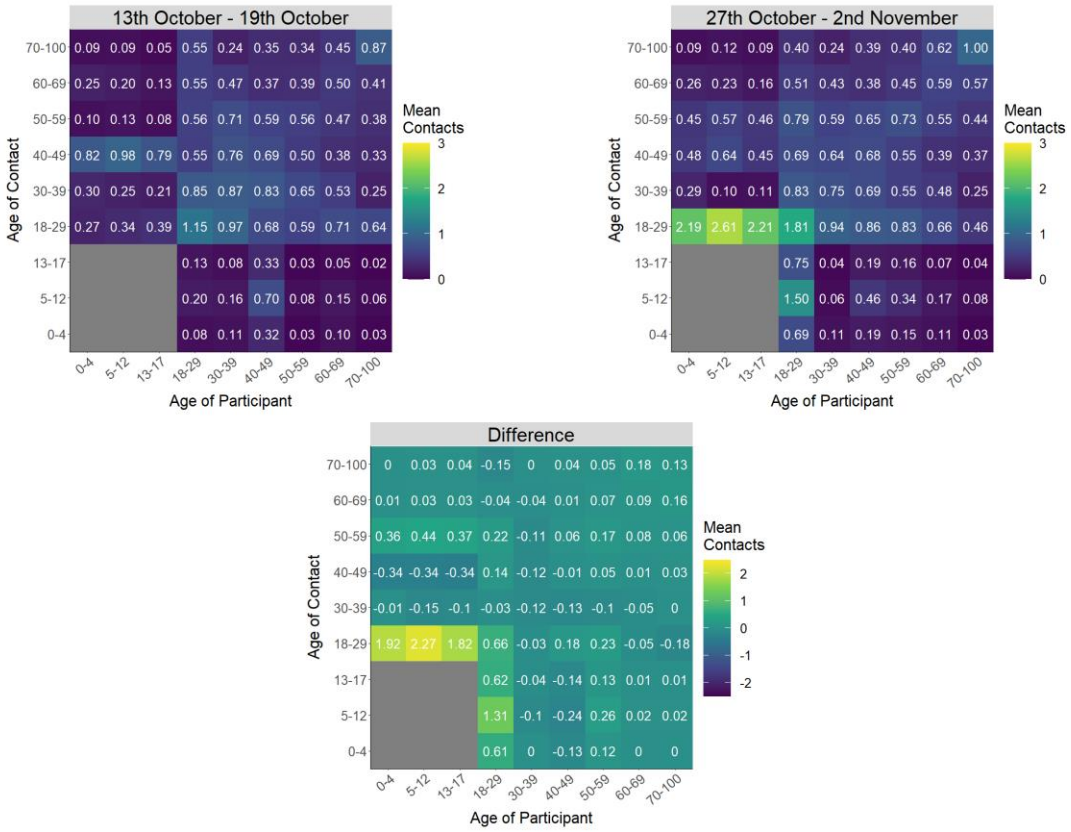
Figure 3 shows how contacts change across age group and setting. Mean contacts have increased in all age groups other than those in the 30-39 age group. The largest increase was seen in the 18-29 age group, with an increase of 86%. Mean contacts in the 30-39 age group decreased by 25%.

Figure 3: Mean contacts per day for adults in Scotland (truncated to 100 contacts per participant) by age group and setting



The heatmaps in Figure 4 show the mean overall contacts between age groups for the surveys relating to 13th - 19th October and 27th October - 2nd November and the difference between these periods. The largest increase in interactions compared to the previous wave of the survey was between those aged 18-29 and those aged 18 and under.

Figure 4: Mean contacts per day between age groups (truncated to 100 contacts per participant)



Pubs and restaurants saw the largest increase in percentage of participants visiting compared to the previous wave of the survey, increasing from 55% to 58%. The percentage of participants visiting a work location had the largest decrease, dropping from 38% to 31%.

Figure 5: Locations visited by participants at least once

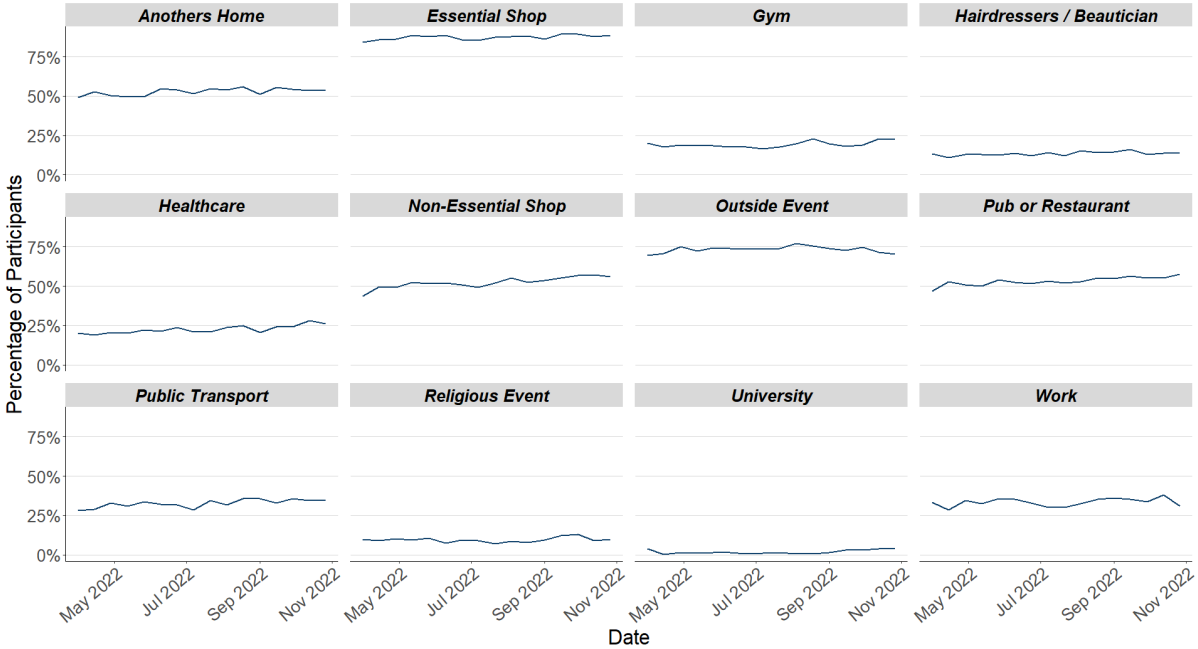
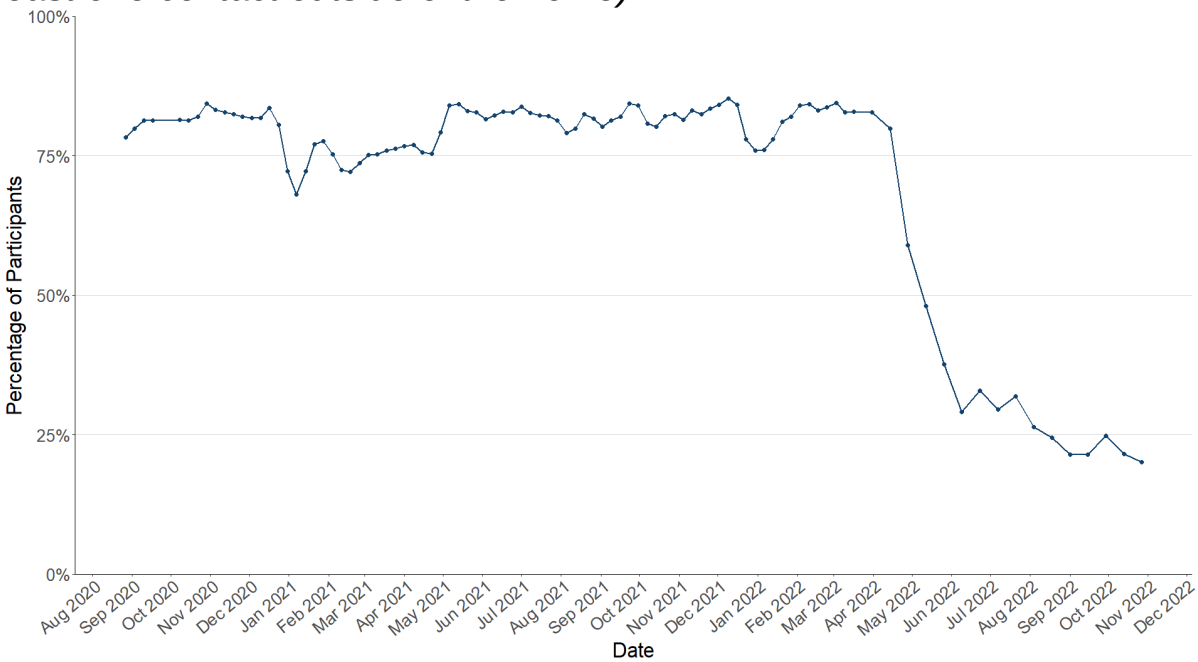


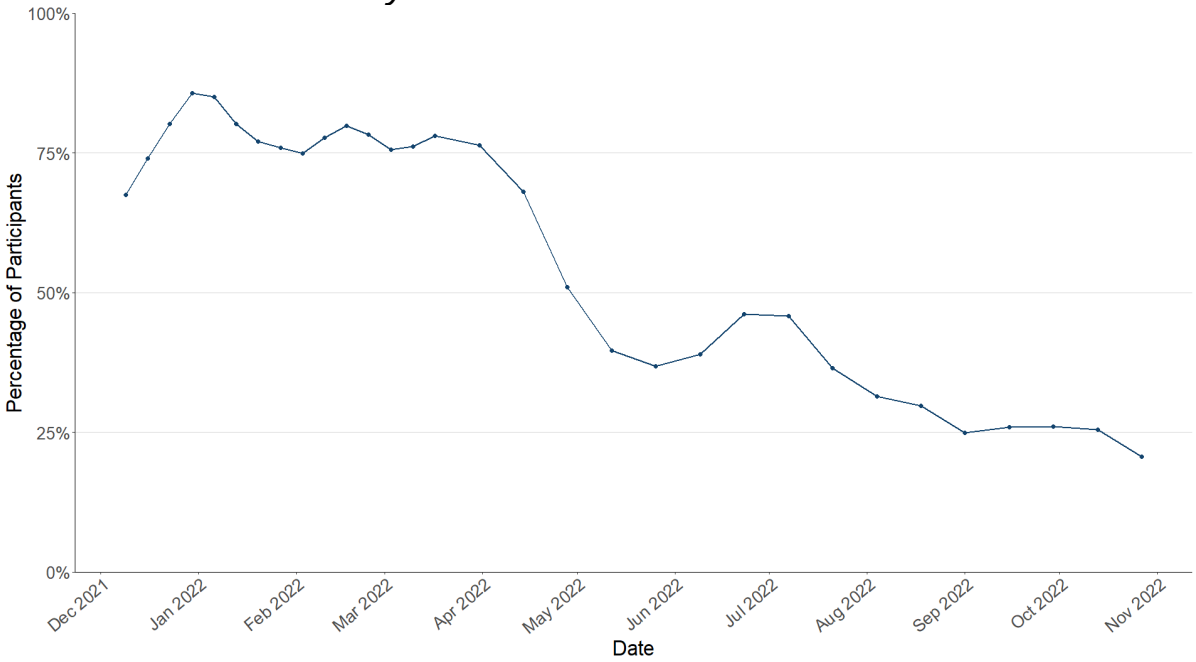
Figure 6 shows the percentage of people wearing a face covering where they have at least one contact outside of the home. This has decreased from 22% to 20% since the last wave of the survey.

Figure 6: Percentage of participants wearing a face covering (with at least one contact outside of the home)



The percentage of people who had taken at least one lateral flow test in the previous 7 days decreased from 26% to 21% since the last wave of the survey.

Figure 7: Percentage of participants who had taken at least one lateral flow test in the last 7 days



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

SPI-M-O produces projections of the epidemic (Figure 8 and Figure 9), combining estimates from several independent models. 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 recent data and do not include the effects of any future policy or behavioural changes. The delay between infection, developing symptoms and the need for hospital care means they cannot fully reflect the impact of behaviour changes in the two to three weeks prior to 7th November. The projections include the potential impact of vaccinations over the next few weeks. Modelling groups have used their expert judgement and evidence from UKHSA, Scottish Universities & Public

Health Scotland, and other published efficacy studies when making assumptions about vaccine effectiveness.

Figure 8: SPI-M-O medium-term projection of daily hospitalisations in Scotland, at 50% and 90% credible intervals

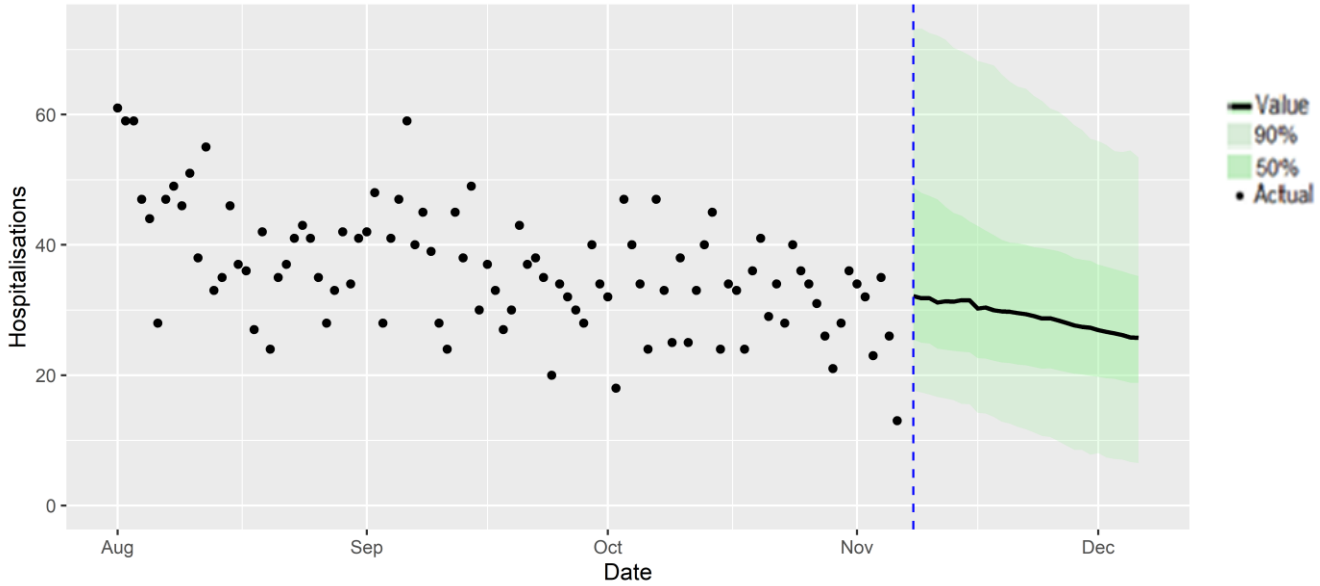
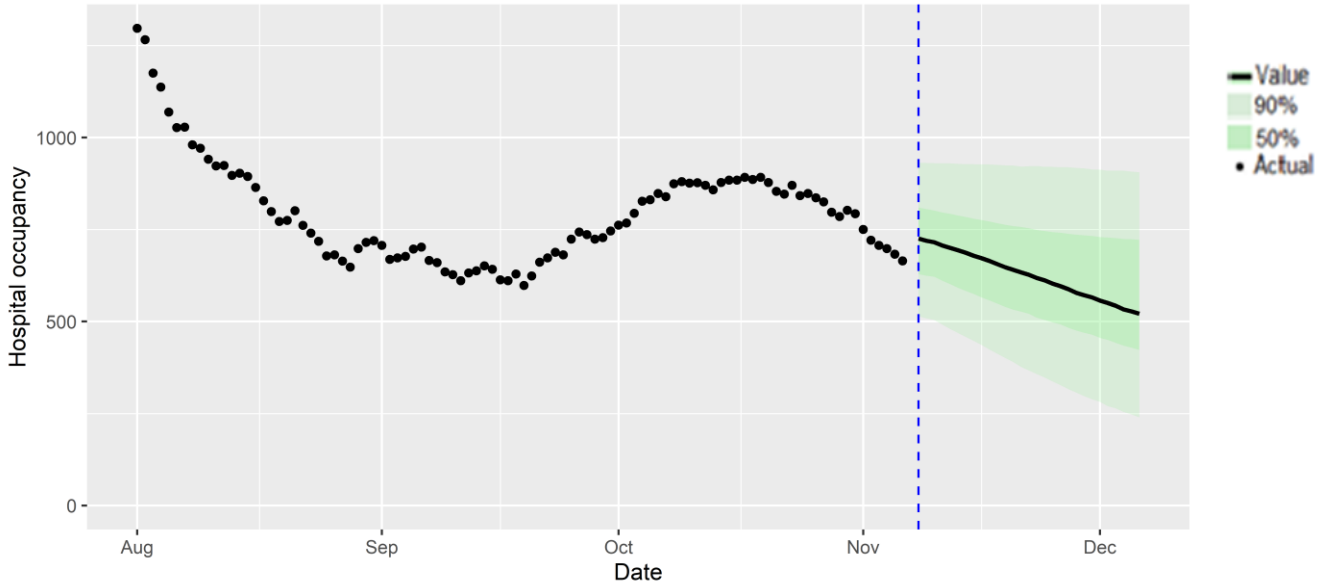


Figure 9 shows the SPI-M-O consensus on hospital occupancy. Hospital occupancy is determined by the combination of admissions and length of stay, the latter of which is difficult to model with confidence.

Figure 9: SPI-M-O medium-term projection of hospital occupancy in Scotland, at 50% and 90% credible intervals



The SPI-M-O consensus view is that by 6th December, daily hospitalisations from Covid-19 in Scotland are estimated to be between

7 and 53, and hospital occupancy is estimated to be between 240 and 906.

Summary of spatial analysis of Covid-19 spread in Scotland

Researchers at the Edinburgh Roslin Institute have conducted spatial analysis of Covid-19 spread in Scotland. A summary of findings from data uploaded up to 27th October 2022 is included here.

Rates of LFD testing are stabilising, albeit at very low levels (0-1 LFD tests reported, per week, per 1,000). PCR testing has fallen (from already very low levels) in recent weeks, with positivity rising.

The distribution of lateral flow/LFD tests being reported varies substantially by both age and deprivation status, with many fewer tests reported in younger adults across all deciles of deprivation, and for children in more deprived deciles. The high level of LFD positivity in the latter category is marked, and when compared to the high number of positives amongst the least deprived, suggests that ascertainment may be lower in younger people in deprived areas.

The sharp rise in LFD positivity since 12th Sept 2022, especially in moderate deprivation deciles and amongst working age adults (Figure 10) is suggestive of increased circulation, and continues to rise for individuals living in the most deprived areas. However, this rise has plateaued in less deprived areas. With no deprivation-specific changes in testing volume overall (with the exception of decile 6 where positives have in fact slightly risen), this is suggestive of disproportionately increased circulation of infection within more deprived communities.

Figure 10: Variation in testing outcomes comparing Lateral Flow and PCR testing considering age and deprivation status of the data zone of record based on data in week ending 22nd October 2022.

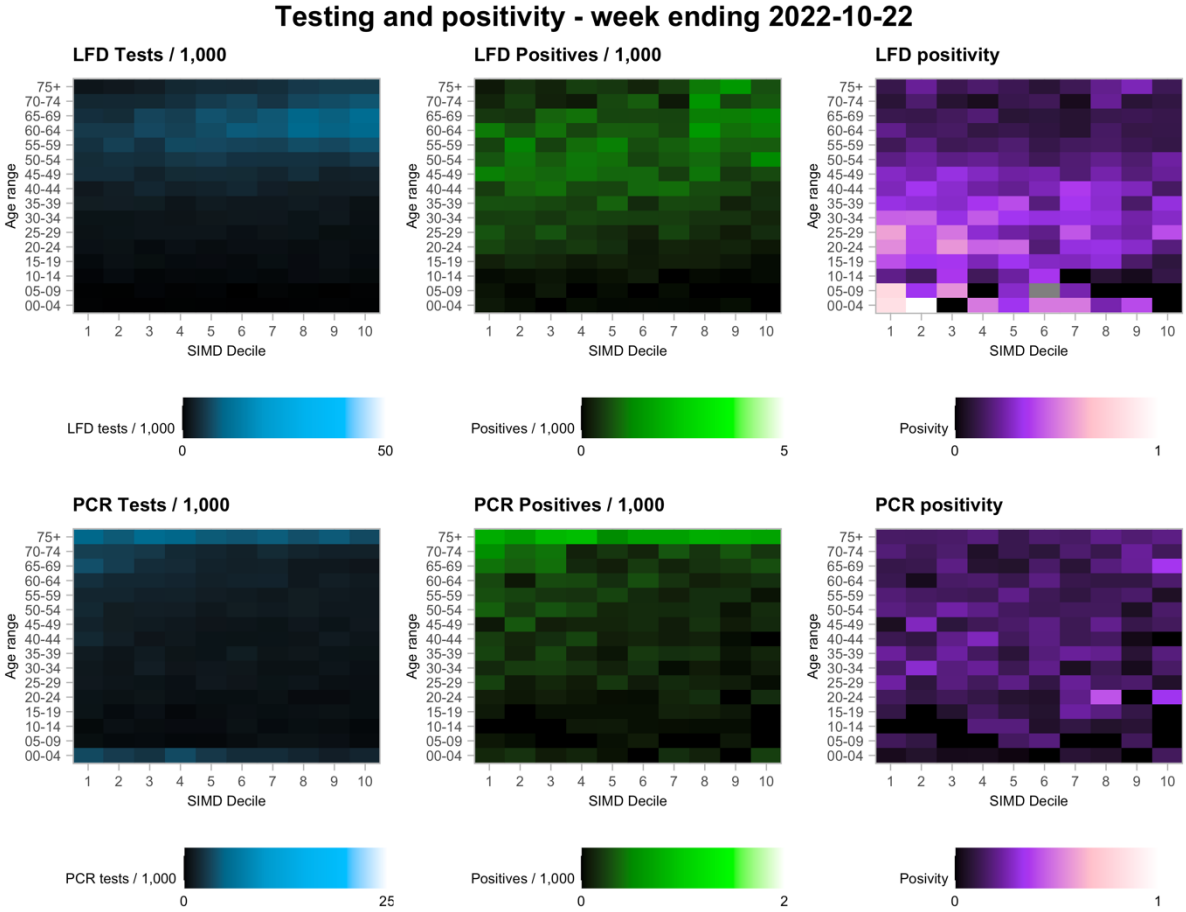
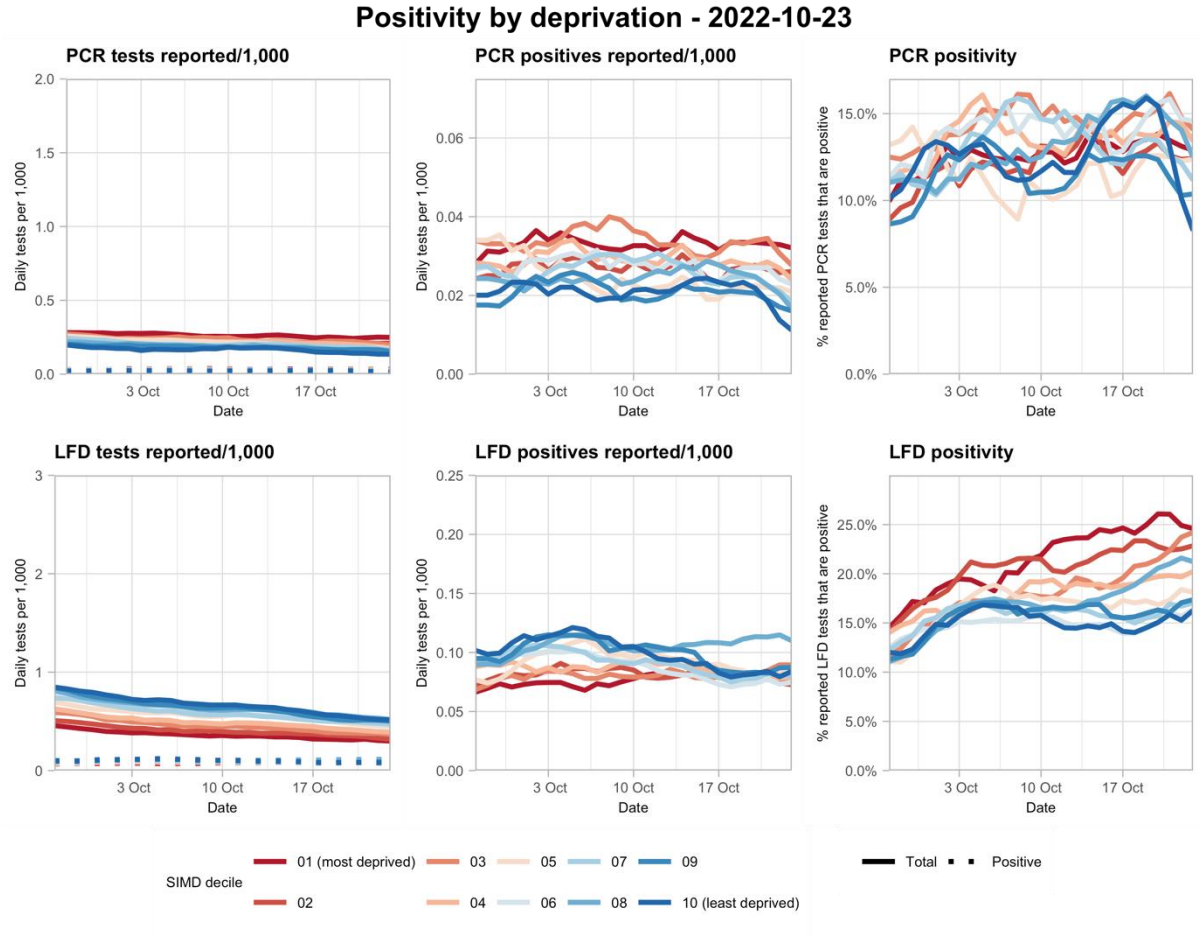


Figure 11: Variation in testing outcomes comparing Lateral Flow and PCR testing, separated by deprivation



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

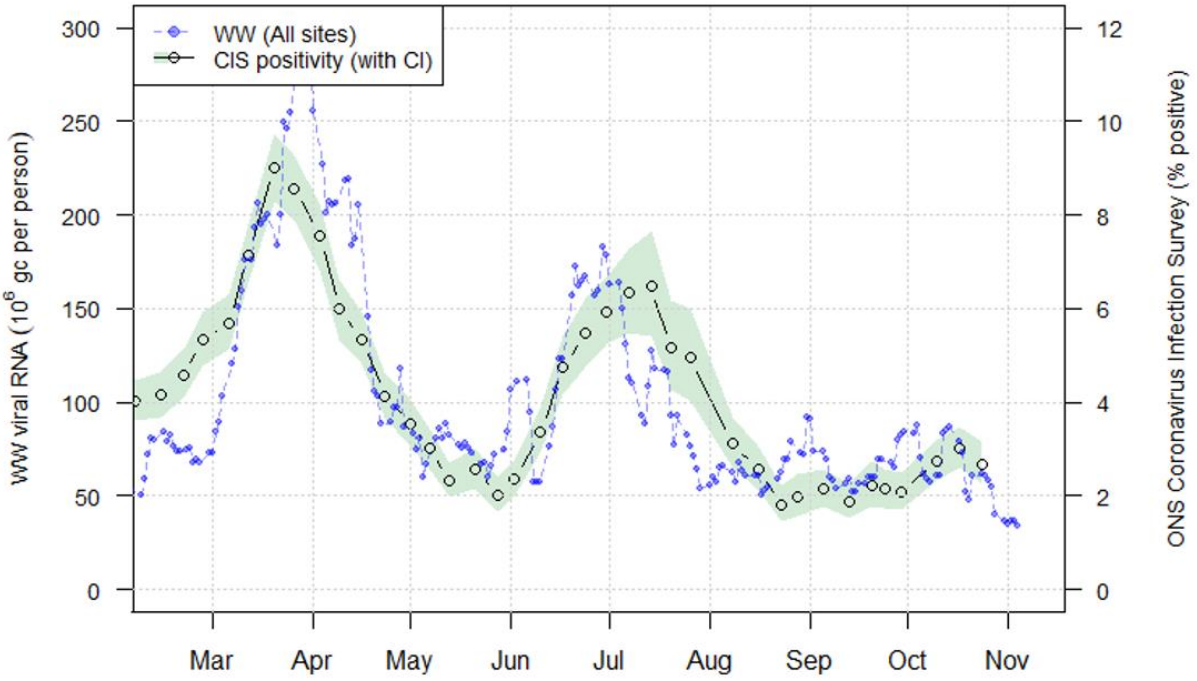
Levels of Covid-19 RNA in wastewater collected at a number of sites around Scotland are adjusted for population and local changes in intake flow rate (or ammonia levels where flow is not available). See the Technical Annex in Issue 34 of Scottish Government Research Findings for the methodology. These reports are based on the most recent data available. Future updates to data may lead to small retrospective changes.

Nationwide, during the period 22nd October – 4th November, Wastewater Covid-19 levels were in the range of 34 to 62 million gene copies per person per day (Mgc/p/d), albeit most recent data could not yet be fully normalised due to missing flow and ammonia data. Compared to the levels in the previous two-week period (6th – 20th October) of 40 to 78 Mgc/p/d, this shows an overall decreasing trend, in line with most recent changes seen in the ONS Coronavirus Infection

Survey in mid-October. Daily hospital admissions (7-days average) have remained stable during the last four weeks.

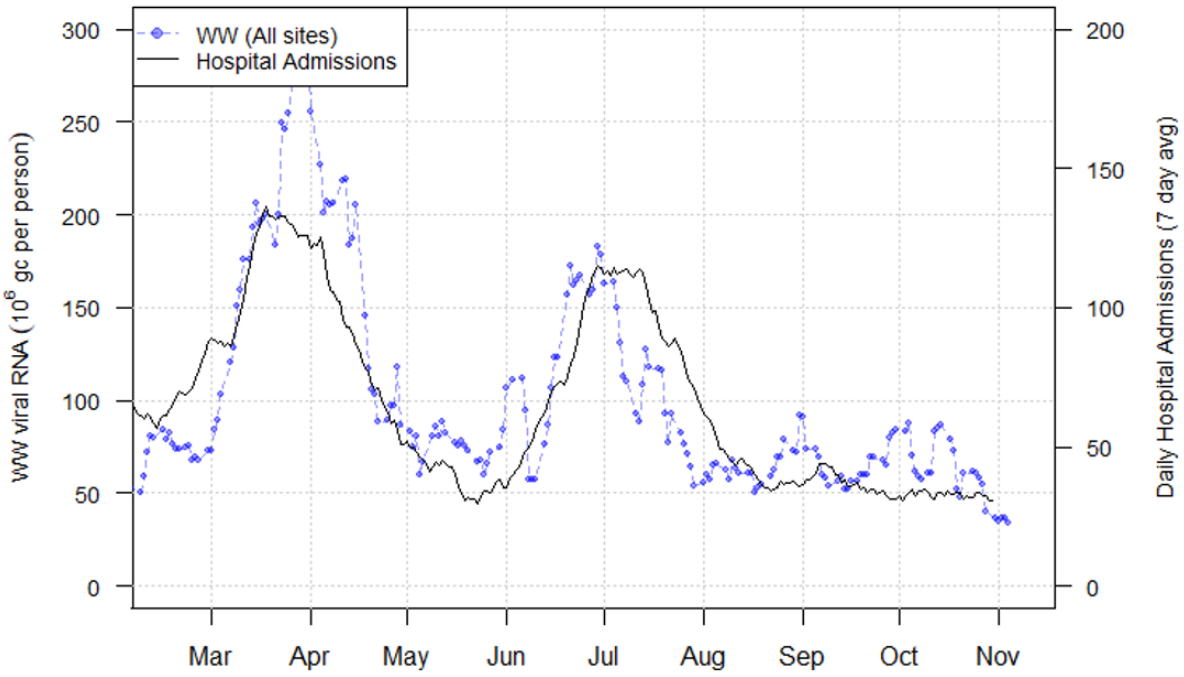
In Figure 12, we show national wastewater Covid-19 levels up to 4th November 2022 with the ONS Coronavirus Infection Survey (CIS) estimates of Covid-19 prevalence superimposed. In Figure 13, we show national wastewater Covid-19 levels up to 4th November with PHS estimates of suspected Covid-19 related hospital admissions data.

Figure 12: National running average trends in wastewater Covid-19 as of 4th November[2]



[2] For this graph, a wastewater RNA average using the last 7 days of data is computed at every sampling date. Prevalence estimates and 95% confidence intervals from the ONS Coronavirus Infection Survey are overlaid, with a scale chosen to approximately match post-July trends in WW Covid-19.

Figure 13: National running average trends in wastewater RNA as of 4th November[3].



Looking to the future

What may happen in the future around SARS-CoV-2 is uncertain and therefore there are a number of possible Covid-19 futures that may occur in the future. For example, the current Omicron wave may dissipate leaving low levels of Covid-19, or a new variant may emerge potentially having vaccine escape or increased severity, or people's behaviours may change. One approach to this uncertainty is to model alternative versions of the future through the development of different Covid-19 scenarios.

Given what we know about Covid-19 these possible futures range from a world where immunity reduces Covid-19 hospitalisations and ICU to low levels, through to variant world where a variant with immune escape enters Scotland and Covid-19 hospitalisations and ICU could increase. In between these two extremes there could be possible futures where people's behaviour becomes polarised between those who continue with Covid-19 precautions e.g. hand washing etc. and those who do not.

The scenarios we provide in the next section look at what could happen for planning purposes, not to forecast what will happen. The

[3] For this graph, a wastewater RNA average using the last 7 days of data is computed at every sampling date. Suspected Covid-19 related hospital admission data from PHS is overlaid, with a scale chosen to approximately match historic trends in WW RNA.

assumptions are based on our most up to date knowledge, but do not include the effect of future changes in treatment of Covid-19 e.g. widespread use of antivirals or changes in behaviour in response to high levels of infections e.g. in variant world. Therefore, in the extreme scenarios the peak may be lower than suggested if behaviour or restrictions changed.

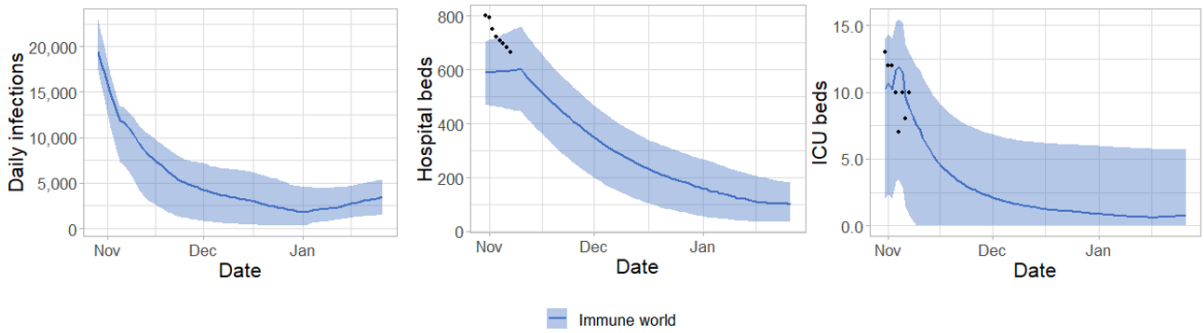
There is no linear progression between the worlds and all are plausible. Each world inherently contains a different threat level requiring a different approach to management.

Immune World

In this possible future vaccines and natural immunity are effective at keeping Covid-19 at low levels. New variants may emerge in Scotland but for the foreseeable future infections are based around Omicron.

Infections may decrease from current levels over the coming weeks and months to very low levels. Likewise, hospital and ICU occupancy may follow this trend relieving the pressure on healthcare services. Issues with new variants are not considered in this world and therefore levels of infections remain low.

Figure 14: Potential infections, hospital occupancy and ICU occupancy trajectory in Immune World



In Immune world, Covid-19 in Scotland reduces below epidemic levels, becoming endemic. Cases of Covid-19 therefore spring up only as rare outbreaks, which are controlled through public health measures. People's lives return to something close to normality e.g. physical distancing is not needed but people still choose to self-isolate and hygiene is good. As vaccines are effective, take-up of first/second/third doses are good and boosters become part of an annual cycle like flu.

The numbers of people who need medical treatment or hospitalisation for Covid-19 remain low.

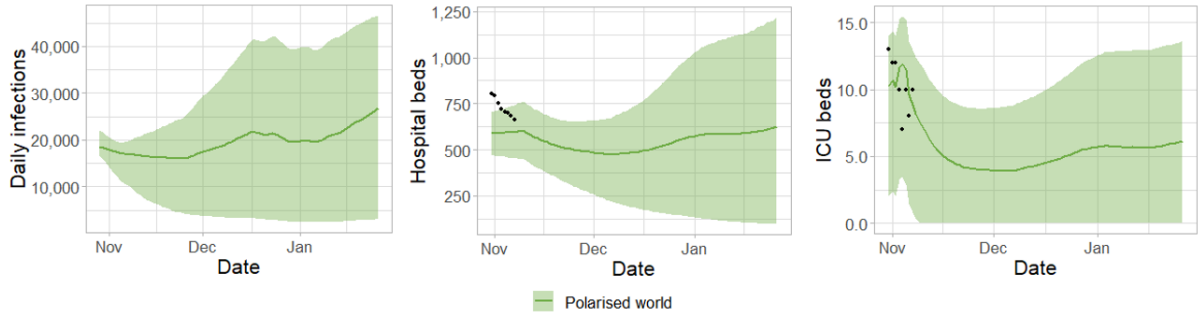
The focus moves away from Covid-19 response and into recovery. This includes addressing learning losses, treating Long Covid and working through the hospital backlog. Wellbeing measures improve with reduced anxiety and increased happiness. Those from the highest risk groups feel they can reintegrate without government interventions. The economy continues to recover from the effects of Covid-19. Travellers do not face significant issues with trips overseas.

Polarised world

In this world, vaccines and natural immunity are effective at reducing infections. The approach followed relies on individual risk assessment and behaviours. However, society becomes polarised as some continue to take up vaccines and follow guidance while others are more reluctant. Covid-19 becomes a disease associated with those who do not or cannot get full vaccine benefit and do not or cannot adopt a risk based approach.

Impacts on hospital/ICU occupancy are uncertain but levels may be higher than what may happen in Immune world (see Figure 15).

Figure 15: Potential infections, hospital occupancy and ICU occupancy trajectory in Polarised World



Cases of Covid-19 spring up and are hard to control in those who are not vaccinated or vulnerable. People's lives return to a "new normal" but,

due to polarised groups in society with some following and some not following guidance, infections remain.

Vaccines are effective so older and more vulnerable people come forward for future doses in high numbers.

The focus remains on Covid-19 and the shift onto recovery is slower. Existing learning losses are harder to rectify and continue to accrue due to infections within education settings. The hospital backlog is difficult to address as hospitals are still dealing with Covid-19 cases. The population becomes polarised in to those whose wellbeing improves e.g. lower risk people and those whose wellbeing deteriorates e.g. higher risk or poorer people whose levels of anxiety increase as Covid-19 circulates. They continue to experience greater illness, greater poverty or disruption to their income. The economy continues to be impacted from the effects of Covid-19.

Variant world – vaccine escape with same severity as Delta

In this possible future, a variant with vaccine escape emerges in Scotland presenting a challenge even for fully vaccinated people. This new variant leads to increased transmission, but not to increased severity compared to previous variants. In this scenario, other NPIs may need to be put in place for a short time. This world is similar to what has happened in Scotland with the emergence of Omicron.

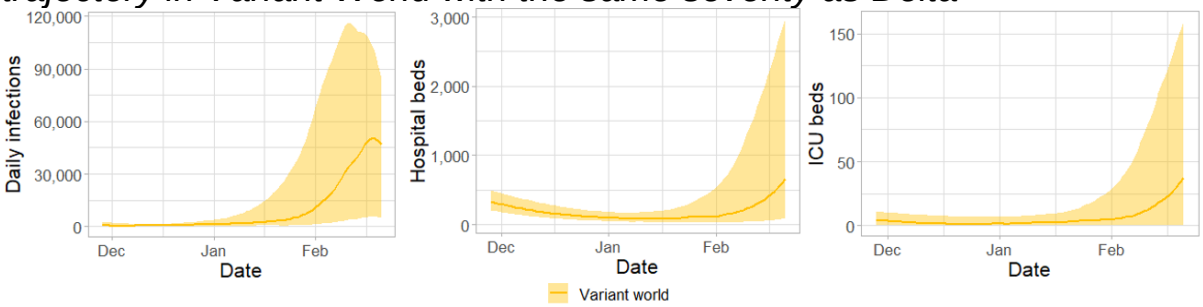
Omicron may be reduced to low levels within Scotland as a new variant takes over. This causes a new wave of Covid-19 infections as well as increases in hospital and ICU occupancy. People's lives are disrupted due to the increasingly high levels of infections leading to time off work ill or isolating.

To show the potential impact assume a new variant appears in Scotland over the festive period. The timing is uncertain and a potential new variant may appear sooner than this or significantly later but has currently been lined up over the festive period to show illustratively what could happen. The new variant may cause Omicron infections to decrease significantly or disappear entirely (and these are not shown).

The new variant is modelled with similar transmissibility and vaccine escape as Omicron with severity characteristics similar to Delta. It could lead to high levels of infections leading to hospital occupancy rising above capacity restrictions. With sustained high levels of infection we

could again see increased staff absences in a number of sectors that were affected by this in the recent Omicron wave.

Figure 16: Potential infections, hospital occupancy and ICU occupancy trajectory in Variant World with the same severity as Delta



The focus remains on Covid-19 and it is hard to shift on to recovery. Continued infections within education settings and staff shortages may impact schools. The Covid-19 strain on hospitals is high due to the very high numbers of infections and workforce pressures grow making it difficult to address the hospital backlog. Wellbeing measures deteriorate with people reporting low happiness and general 'tiredness with it all'. The economy continues to be impacted from the effects of Covid-19 with many people off work. Travellers may not want to come to the UK as the new variant sweeps through.

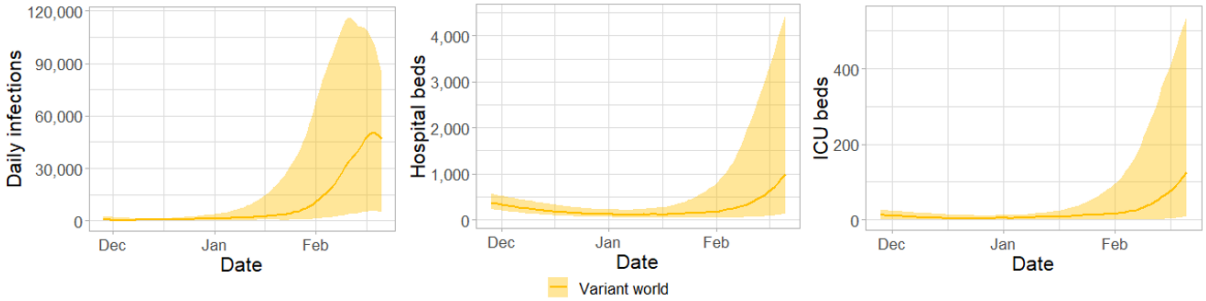
Variant world – vaccine escape with increased severity compared to Delta

As with the other example of Variant world, a new variant appears in Scotland in the Scotland over the festive period. The timing is uncertain and a potential new variant may appear sooner than this or significantly later but has currently been lined up over the festive period to show illustratively what could happen.

The new variant may cause Omicron infections to decrease significantly or disappear entirely (and this is not shown on the graph). It is modelled with similar transmissibility and vaccine escape as Omicron with severity characteristics 50% higher than Delta, purely for illustrative purposes.

It could lead to high levels of infections leading to hospital occupancy rising significantly. With sustained high levels of infection, we could again see increased staff absences in a number of sectors that were affected by this in the recent Omicron wave.

Figure 17: Potential infections, hospital occupancy and ICU occupancy trajectory in Variant World with the increased severity compared to Delta



The focus remains on Covid-19 and it is hard to shift on to recovery. Continued infections within education settings and staff shortages may impact schools. The Covid-19 strain on hospitals is high due to the very high numbers of infections and workforce pressures grow making it difficult to address the hospital backlog. Wellbeing measures deteriorate with people reporting low happiness and general 'tiredness with it all'. The economy continues to be impacted from the effects of Covid-19 with many people off work. Travellers may not want to come to the UK as the new variant sweeps through.

What next?

Archiving of models is currently being undertaken via the Data Science Scotland GitHub organisation. Details of the Scottish Contact Survey contact matrices are available. See the Technical Annex of issue 96 for details of other archived models.

Technical Annex

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

Table 1 provides population weighted daily averages for normalised wastewater Covid-19 levels in the weeks ending 28th October and 4th November 2022, with no estimate for error. This is given in Million gene copies per person per day. Coverage is given as percentage of inhabitants in each local authority covered by a wastewater Covid-19 sampling site delivering data during this period.

Table 1. Average Covid-19 wastewater levels (Mgc/p/d)[4].

Local Authority (LA)	w/e 28th October	w/e 4th November	Coverage
Aberdeen City	54	46	99 %
Aberdeenshire	35	31	41 %
Angus	73	46	68 %
Argyll and Bute	29	9	23 %
City of Edinburgh	49	50	98 %
Clackmannanshire	50	35	92 %
Dumfries and Galloway	19	15	39 %
Dundee City	91	59	100 %
East Ayrshire	34	43	72 %
East Dunbartonshire	35	33	99 %
East Lothian	44	42	74 %
East Renfrewshire	13	16	95 %
Falkirk	42	54	96 %
Fife	38	33	82 %
Glasgow City	24	22	98 %
Highland	49	21	48 %
Inverclyde	42	13	98 %
Midlothian	48	46	88 %
Moray	46	108	70 %
Na h-Eileanan Siar	15	3	21 %
North Ayrshire	26	23	92 %
North Lanarkshire	41	28	94 %
Orkney Islands	13	17	34 %
Perth and Kinross	31	30	38 %
Renfrewshire	52	17	97 %
Scottish Borders	44	30	56 %
Shetland Islands	7	1	29 %
South Ayrshire	47	36	88 %
South Lanarkshire	31	33	90 %
Stirling	15	8	63 %
West Dunbartonshire	31	24	98 %
West Lothian	40	22	88 %

[4] Coverage as for week ending 4th November 2022.

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

This document is also available from our website at www.gov.scot.
ISBN: 978-1-80525-222-1

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

Produced for
the Scottish Government
by APS Group Scotland
PPDAS1194162 (11/22)
Published by
the Scottish Government,
November 2022

ISBN 978-1-80525-222-1

Web Publication

PPDAS1194162 (11/22)