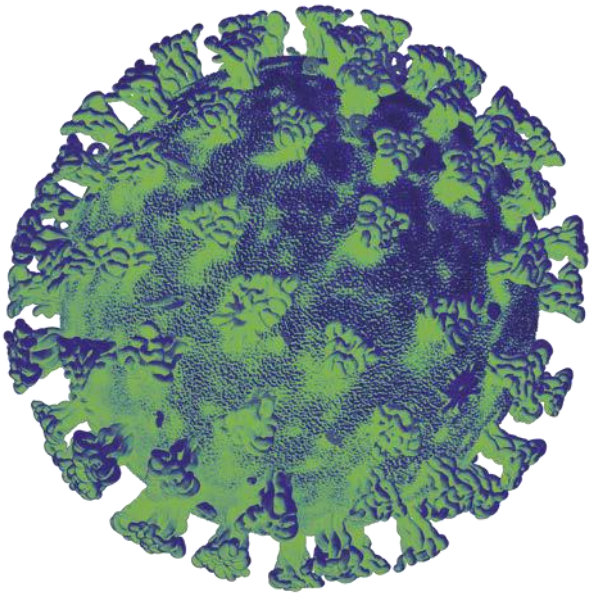
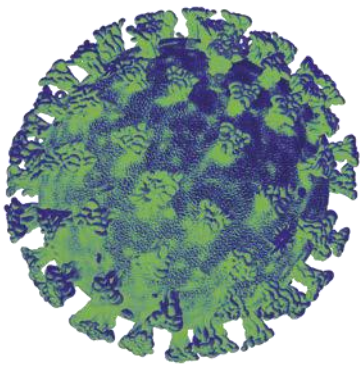
Llywodraeth Cymru
Welsh Government

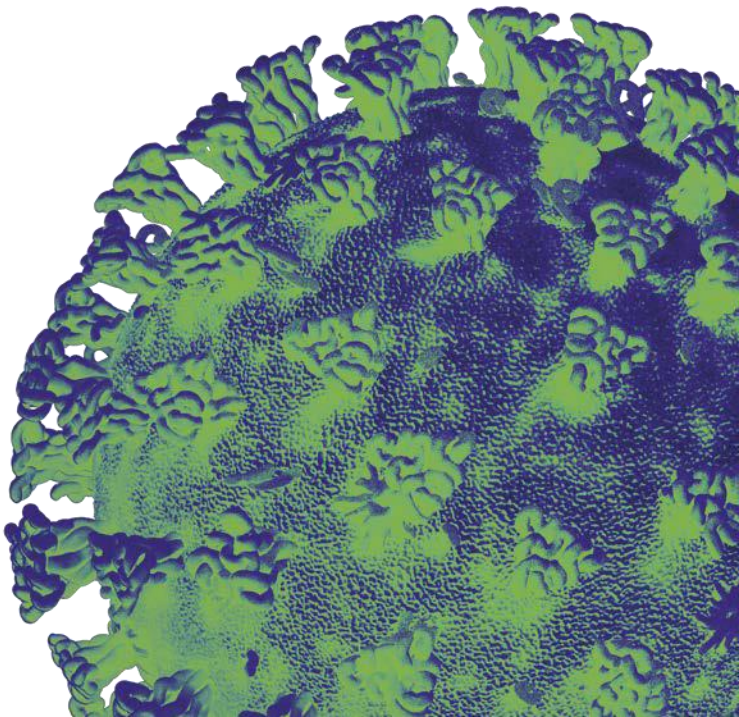
Technical Advisory Group

Modelling Retrospective

June 2022







DRAFT - NOT WELSH GOVT POLICY

Modelling Retrospective

Welsh Government COVID-19 TAG Policy Modelling Subgroup

Models can provide insights and assist with policy making decisions when appropriately constructed and understood.[1] Modelling can provide a way of understanding possible outcomes and enable the government to prepare for and respond to a range of scenarios.

It is important to note that the model outputs are not predictions or forecasts. Key uncertainties include level of adherence to, and choice of, population protections, vaccine effectiveness, waning immunity and evolution of variants; it is too difficult to predict future behaviour changes, new responses, developments in treatment and control or the direction of evolution of the virus. Rather, the models are used to capture plausible key assumptions about the complex way epidemics progress in a formal mathematical framework, and then use this framework to explore future scenarios based on those assumptions. The range of scenarios can be used to explore 'what-if' interventions, express uncertainties in key outcomes, and identify the factors most strongly related to those uncertainties. In other situations, the models were used to generate 'projections' over a short period, which represent the likely future trajectory under the assumption that levels of protections and behaviours associated with them remain the same.

With that in mind, it is still a useful exercise to compare historic COVID-19 modelling in Wales with actual COVID-19 data. The aim of this paper is to retrospectively investigate and understand where there have been similarities and differences between the models and actual experience. There have been a considerable number of refinements to the models over time as our understanding of the pandemic increased and these are outlined below.

Early in the pandemic, we did not have specific models of COVID-19 in Wales; rather we simply used a population proportion of models produced at England or UK level, for instance by Imperial College London.[2] However in June 2020, a policy modelling group was established to discuss different models and scenarios and to commission some bespoke modelling for Wales, which was produced by Swansea University and other academic groups. This paper focuses on the model scenarios that were produced specifically for Wales and were published by the Welsh Government Technical Advisory Cell.

Often, model scenarios are produced at a time of maximum uncertainty – when we have seen an inflection point in cases and are starting to see steep growth; where we have experienced case growth but are not certain at what point it will peak; or at times when a new variant is starting to become dominant and the dynamics of spread change. Often, a few weeks later, as scenarios are refined, when we have more data and a better understanding of what is happening, and more accurate model parameters are available. So, at these times of uncertainty, the model

[1] EconPapers: A framework for communicating the utility of models when facing tough decisions in public health (repec.org)
[2] Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf

scenarios were generally produced to cover a wide window of outcomes trying to represent this uncertainty, and these were subsequently refined over time.

Often a scenario would be selected as being the most likely scenario (MLS), and one selected as a reasonable worst case (RWC). The MLS was the consensus central estimate of what might happen and would be used for non-critical planning; whereas the RWC was meant to be a challenging scenario (with around 5-10% probability of occurring) that the NHS and other organisations would use to plan what their resource requirements may be, and to be able to scale up their response. In general, the outcomes in the different RWCs were not met, in part due to the implementation of population protections. However, the wave seen in winter 2020-21 was close to the September 2020 RWC for some indicators. It is worth noting that at this time the likelihood of a new variant with such high transmissibility was not as well understood. Therefore, our most pessimistic scenarios were tempered by some experts saying they did not expect a large second wave at all, and that they did not expect the virus to mutate quickly and become more transmissible or more severe, as happened with the emergence of the Alpha (‘Kent’) variant in late 2020.

The following charts show the COVID-19 models for Wales published by the Technical Advisory Cell of the Welsh Government over the course of the pandemic.

Figure:1: Actual PCR -confirmed COVID-19 cases vs. Swansea University models at different points in time

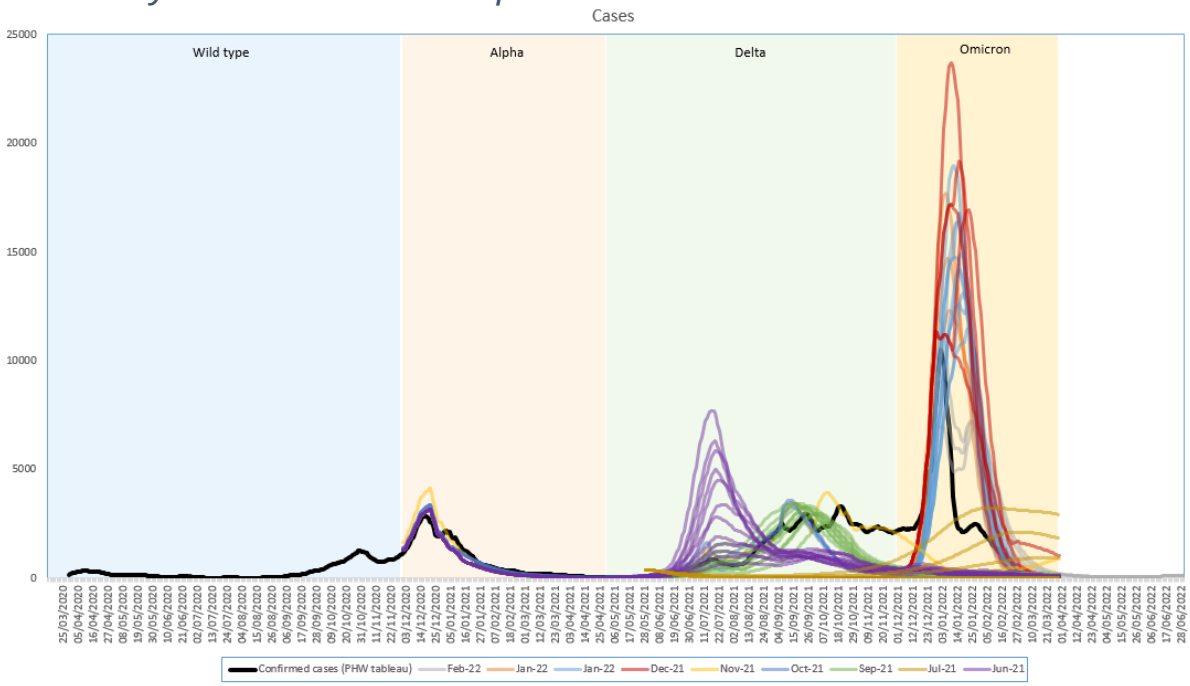


Figure 2: Actual COVID-19 deaths vs. models at different points in time

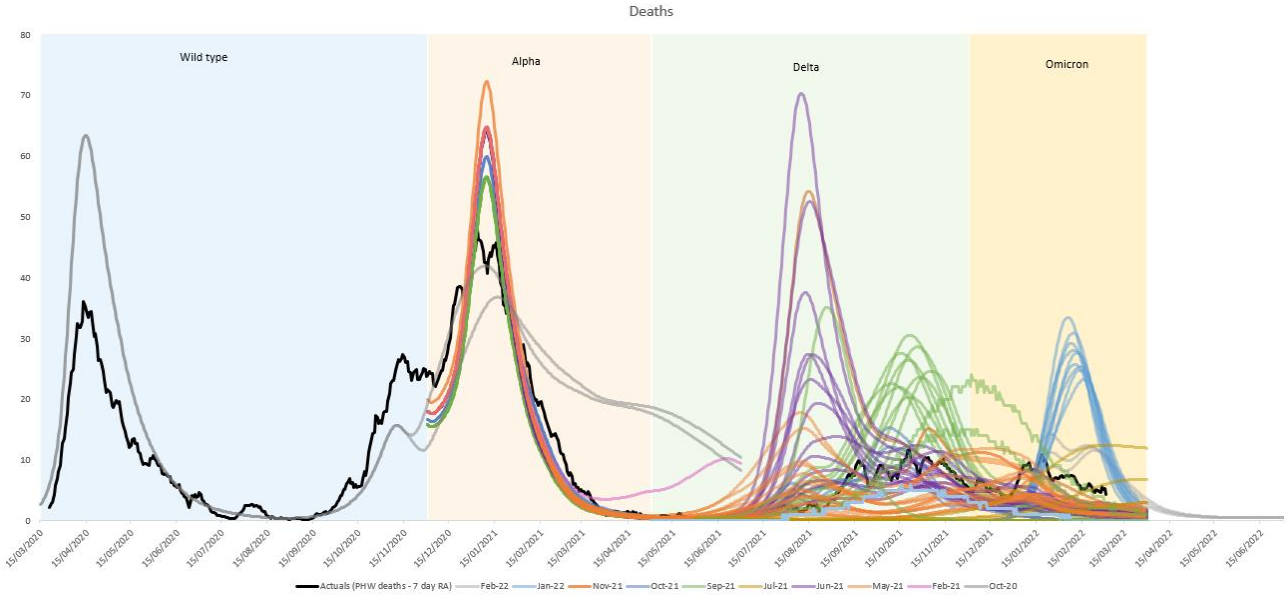
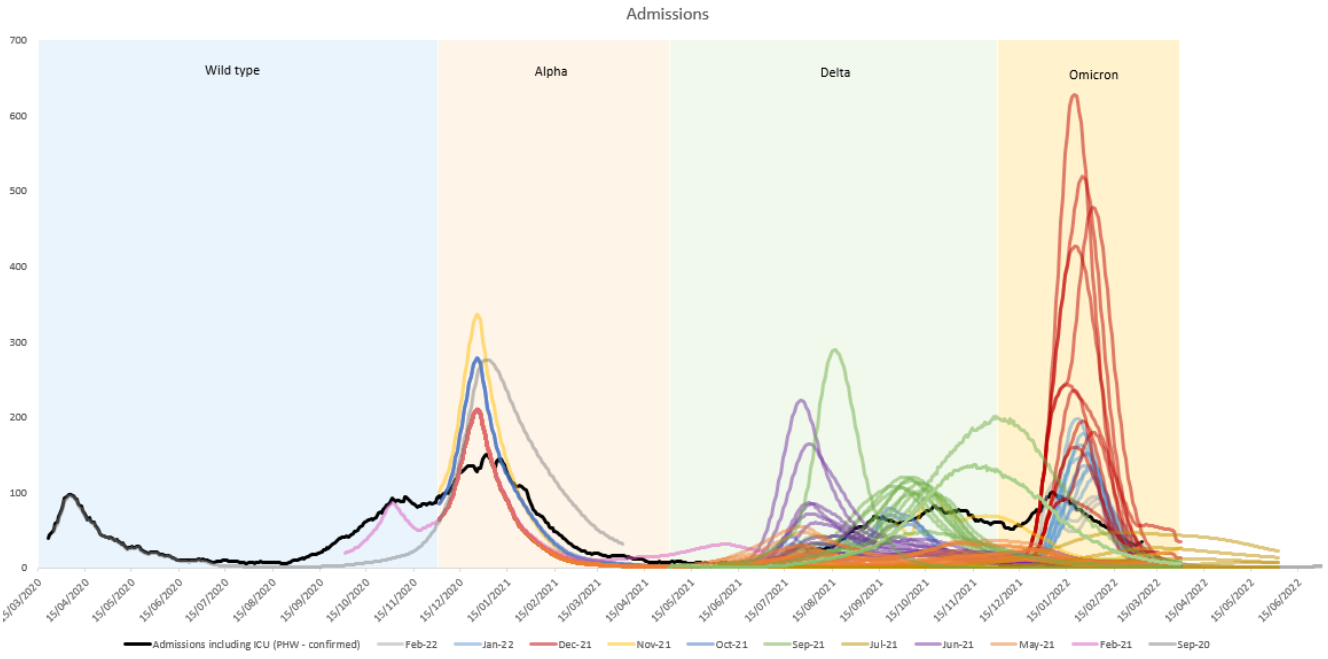
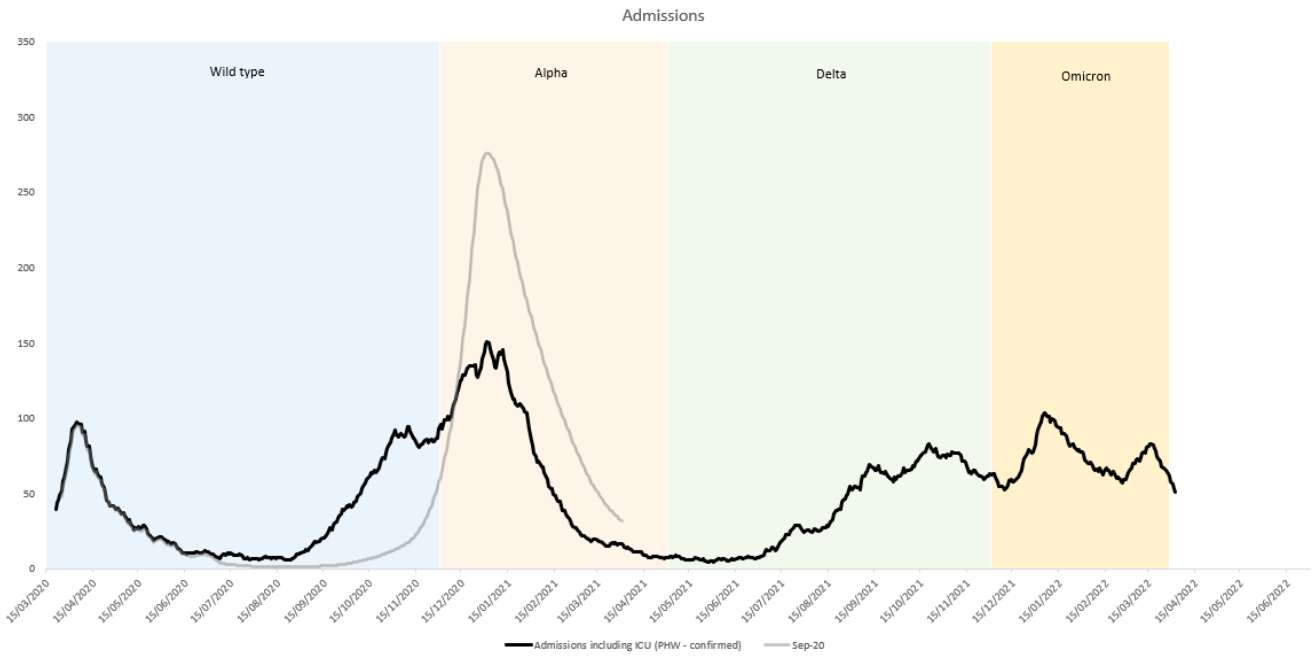


Figure 3: Actual confirmed COVID-19 admissions vs. models at different points in time



September 2020

Figure 4: Actual confirmed COVID-19 admissions vs. September Swansea University model

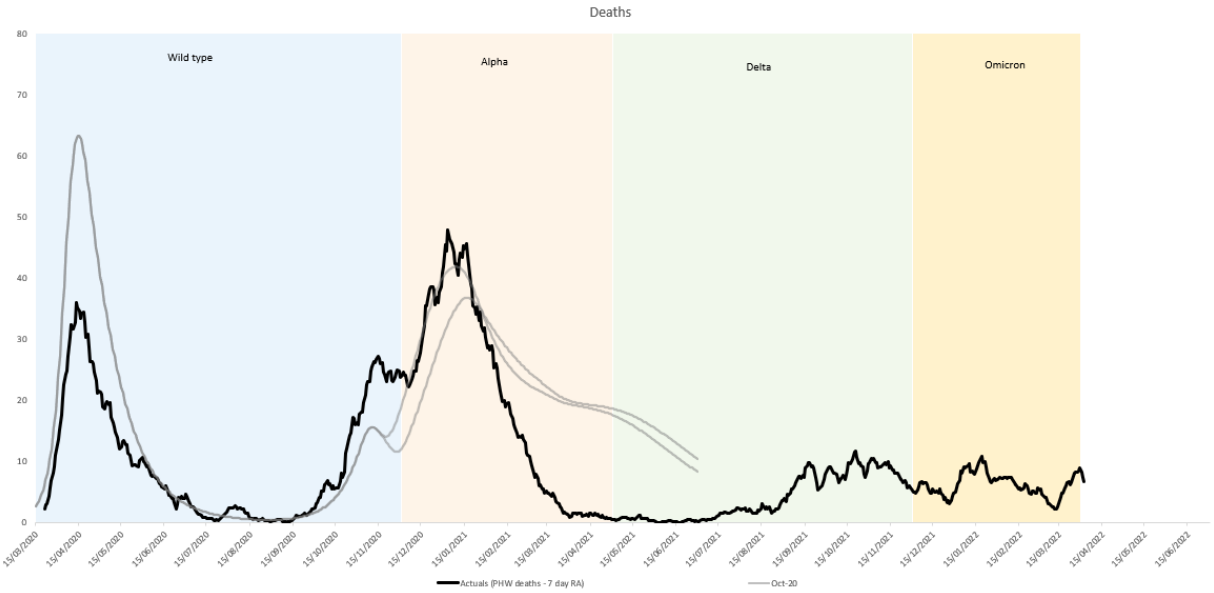


A realistic worst case (RWC) scenario for the winter period 2020/2021 was produced to give an indication of a realistic possible outcome that should be considered.[3] This was constructed during a period of very low prevalence (around 25 COVID-19 cases per day), and rare deaths and hospital admissions. The main question was what likely second wave would be produced if mixing behaviour increased given the total exposure and immunity built up during the first wave. In this RWC scenario produced, the total numbers of COVID-19 admissions and deaths of 18,200 and 6300 respectively were estimated to occur between 1 July 2020 and 31 March 2021; the actuals data indicates the numbers admissions and deaths during that time period were 15,200 and 4,000 respectively. So this RWC provided an early warning for the substantial potential of a winter second wave. The winter period included early short, sharp interventions (Firebreak), bringing the actuals down, but also included the emergence of the more transmissible Alpha ('Kent') variant in mid-December 2020.

Firebreak October 2020[4]

[3] technical-advisory-group-new-worst-case-scenario-for-winter.pdf (gov.wales)
[4] technical-advisory-group-fire-breaks_2.pdf (gov.wales)

Figure 5: Actual COVID-19 deaths vs. October Swansea University model



From 6pm on Friday 23 October 2020 to the start of Monday 9 November 2020, a firebreak lockdown was enforced throughout Wales. The aim was to reduce contact rates and thus reduce the spread of COVID-19 infection. In advance of the lockdown, the impacts of the firebreak were modelled to comparatively consider the mortality outcomes based on a two or three week firebreak. As predicted by the models, there was a significant effect on the transmission rate, and subsequent case/hospitalisation/death rates for the period of the short intervention. The observed Rt value dropped almost immediately from 1.4 to 0.8, consistent with the model “very good” scenario of firebreak impact. All models prepared prior to the firebreak made it clear that the measures were only temporary, and a return to pre-firebreak levels would be expected. The pre-firebreak published models estimated a ‘re-set’ time following the initiation of the firebreak at which the epidemic situation would return to a similar point to that at the date of onset of the intervention. This was estimated by the models as 35-42 days for a 21 day Firebreak. Following the actual 17 day firebreak, the observed re-set time was 38 days.

Following the interruption of the firebreak, winter transmission rates returned to pre-firebreak levels. Models were subsequently produced to inform the lockdown decisions in December 2020. These models were the first to include a new variant, Alpha (at the time known as the “Kent” variant). Wales went back into lockdown on 20 December 2020.

February 2021

Figure 6: Actual COVID-19 deaths vs. February 2021 and previous October 2020 Swansea University models

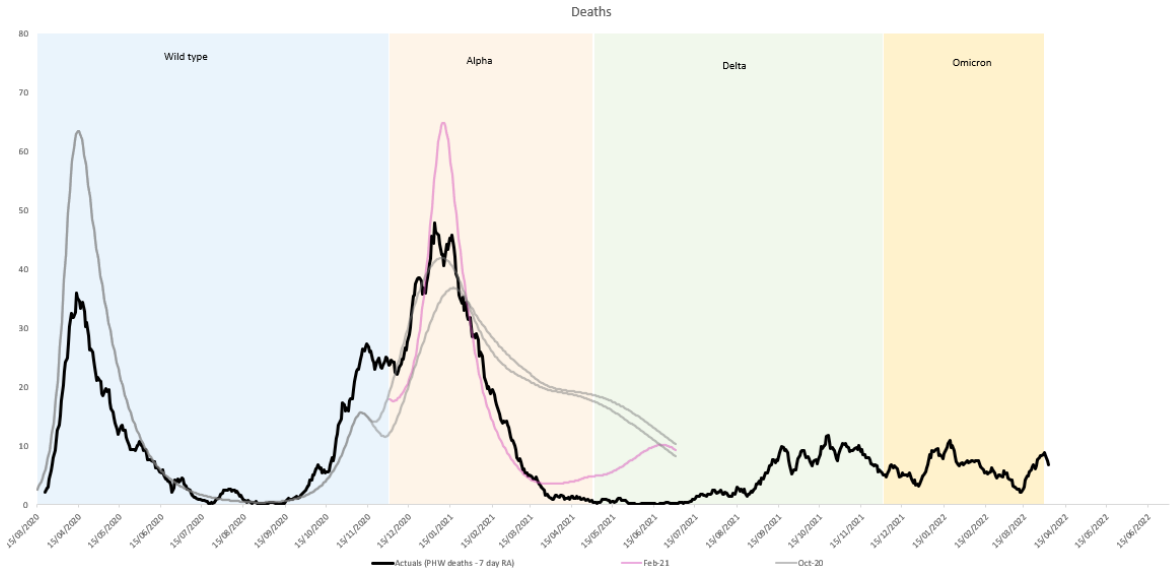
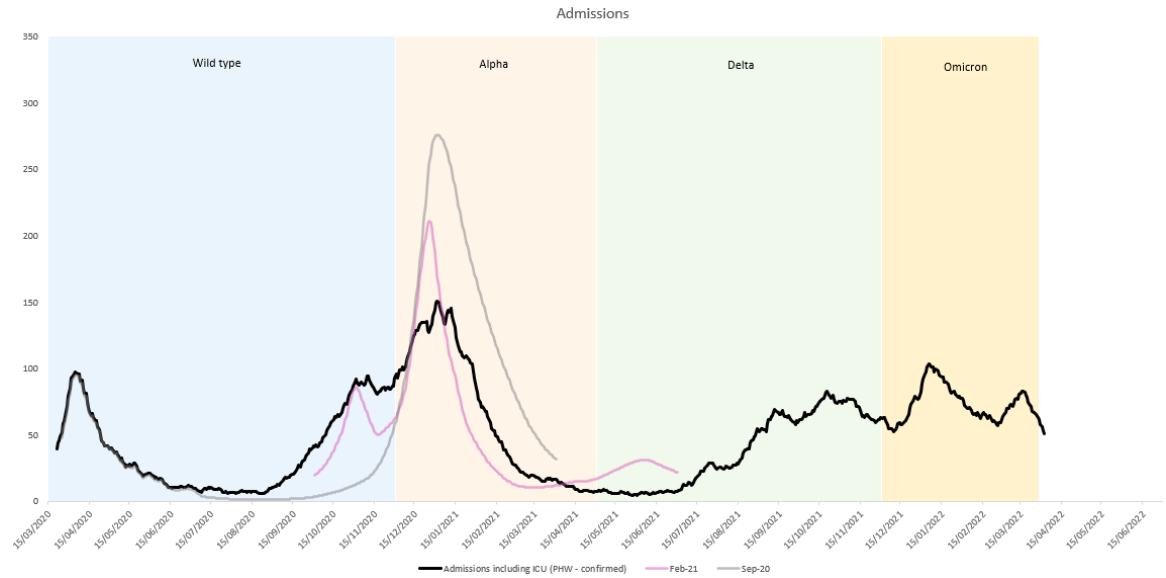


Figure 7: Actual confirmed COVID-19 admissions vs. February 2021 and previous September 2020 Swansea University models



By early 2021, the complexity of the epidemic dynamics were increasing, generating even greater uncertainty for future trajectories. At this point there were strong population protections in place minimising COVID-19 transmission, the virus was evolving, and the impact of the virus was changing dramatically with the roll out of vaccines in the most vulnerable age groups.

Nevertheless, as with successive iterations of scenarios modelled, a variety of scenarios were produced based on different assumptions of what might happen. Specifically, these estimated the impacts of different hypothetical new variant characteristics, level of adherence to restrictions, levels of restrictions imposed and

efficiency of vaccines (and doses) on COVID-19 infection, transmission, hospitalisation and deaths.

A wide range of these scenarios were generated and discussed weekly at the TAC Modelling Subgroup. Of these scenarios, a reasonable worst case and most likely scenario were selected.[5] In practice, these were updated regularly as new information came in. For illustration here we look at the February 2021 reasonable worst case (RWC), under this scenario the vaccine efficacy was assumed 60% (low efficacy), the new Alpha variant assumed to add 0.6 to the R number (highly transmissible), schools were kept open, and adherence to restrictions was assumed less than observed in previous lockdowns (low adherence). At this point we also selected a most likely scenario (MLS), the scenario where schools were fully open, the vaccine efficacy 75% (medium efficacy), the new variant added 0.6 to the R number (highly transmissible), and adherence to restrictions is as previously experienced (good adherence). In reality, we saw an outcome closer to the MLS.

In the proposed RWC, between 22 February 2021 and 30 June 2021, the total numbers of cases and deaths were estimated to be 194,161 and 3,496. The proposed MLS estimated cases and deaths at 57,866 and 806. The actual figures for the period were 15,743 and 306.

[5] technical-advisory-cell-modelling-update-12-february-2021.pdf (gov.wales)

May – July 2021

Figure 8: Actual COVID-19 deaths vs. May 2021 and previous February 2021 Swansea University models

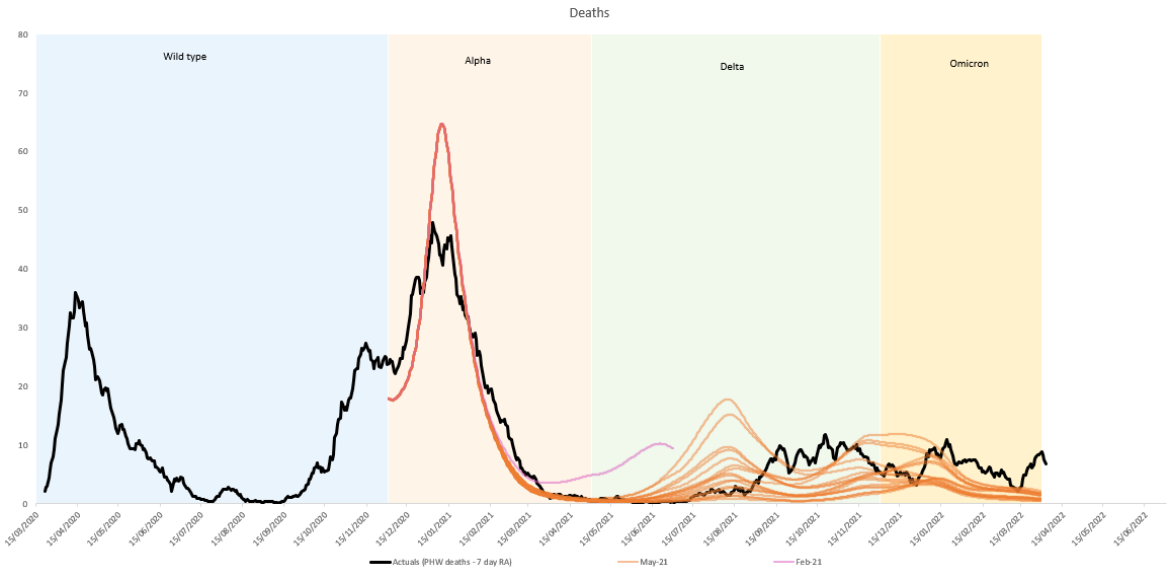


Figure 9: Actual confirmed COVID-19 admissions vs. May 2021 and previous February 2021 Swansea University models

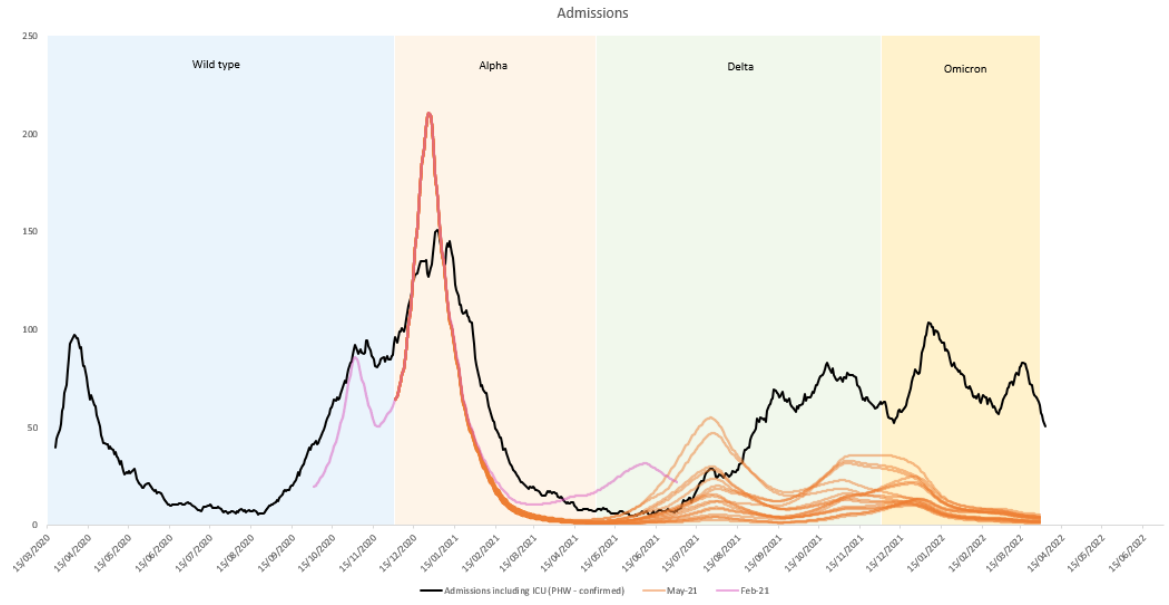


Figure 10: Actual PCR-confirmed COVID-19 cases vs. June 2021 Swansea University model

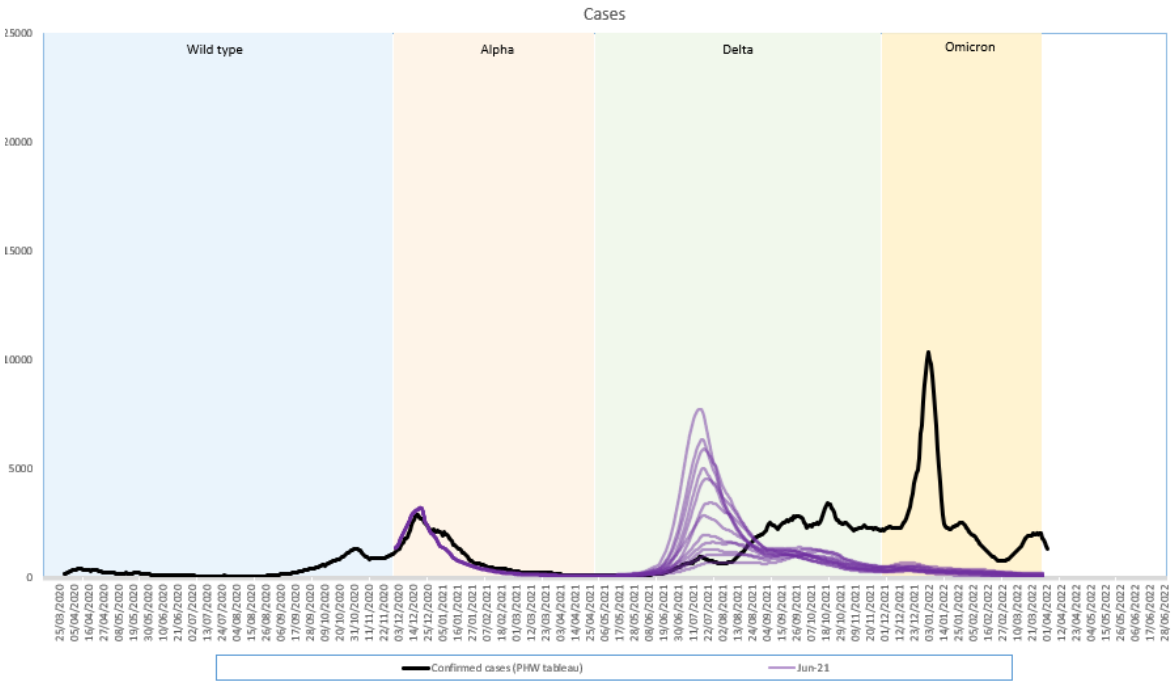


Figure 11: Actual COVID-19 deaths vs. June and previous May 2021 Swansea University models

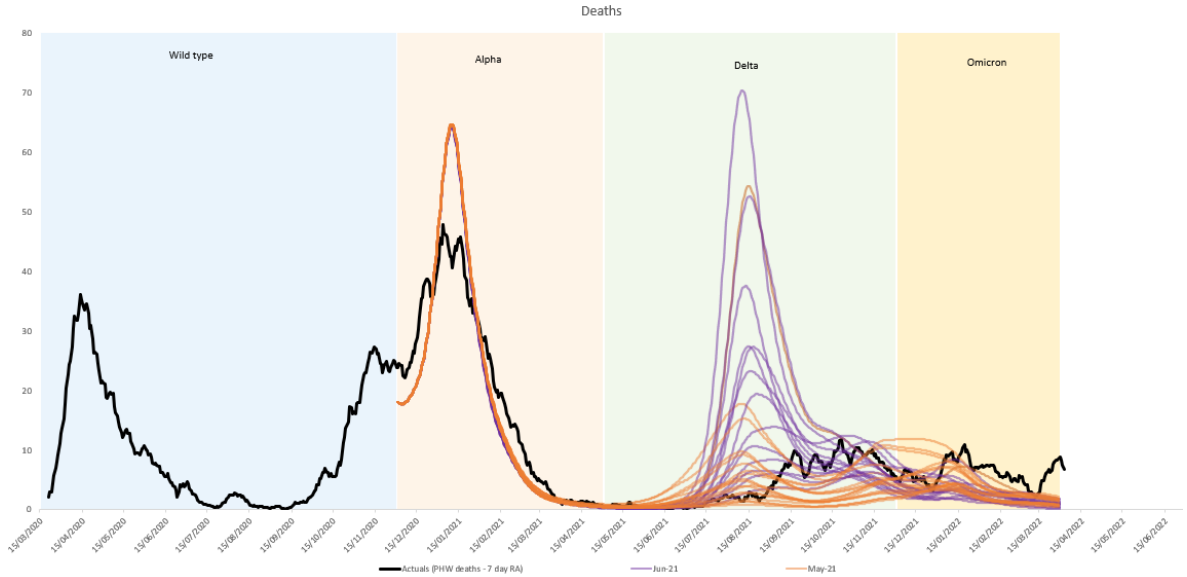


Figure 12: Actual confirmed COVID-19 admissions vs. June 2021 and previous May 2021 Swansea University model

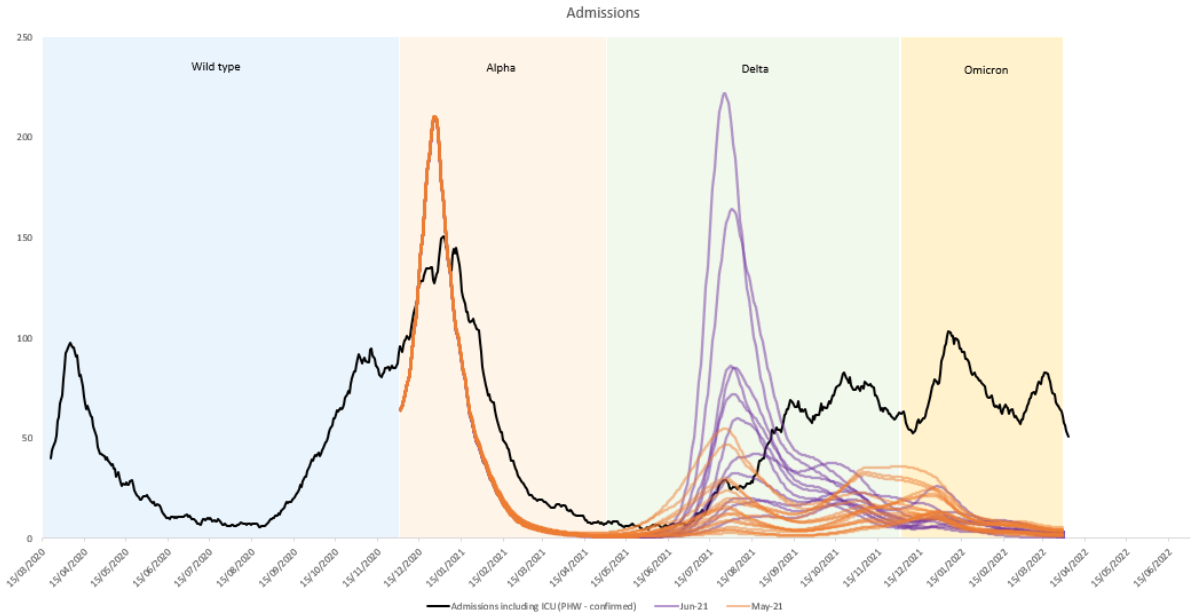


Figure 13: Actual PCR-confirmed COVID-19 cases vs. July 2021 and previous June 2021 Swansea University model

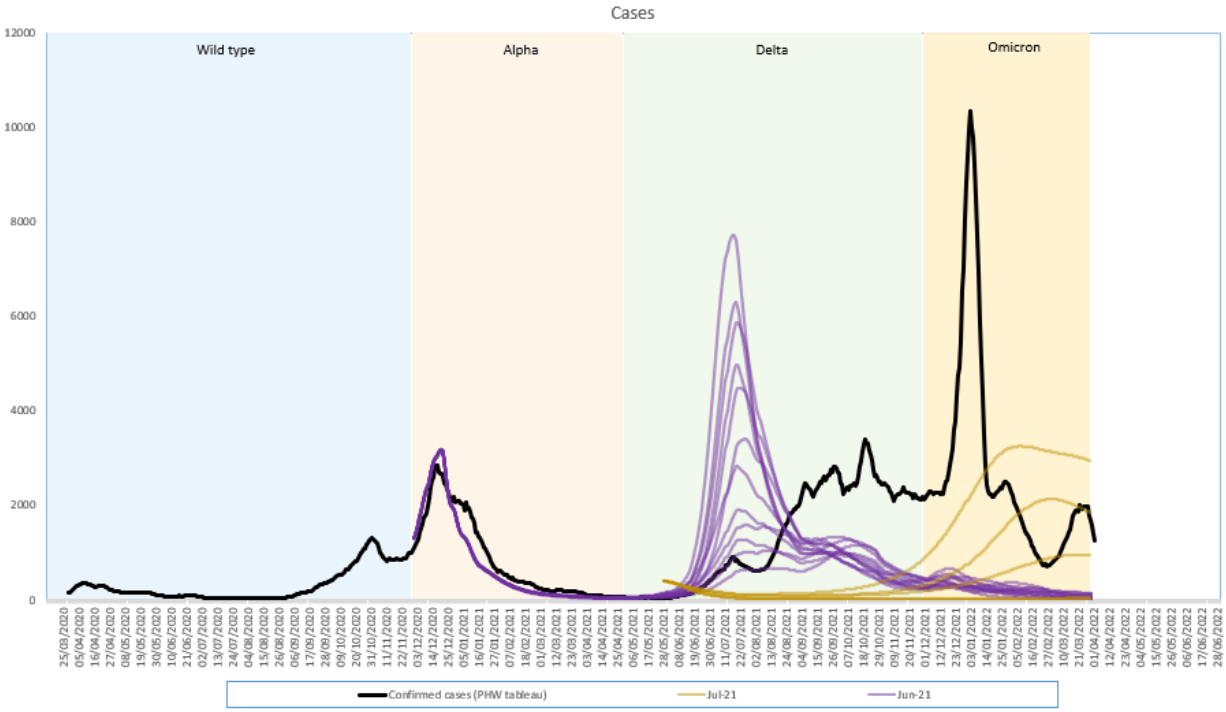


Figure 14: Actual COVID-19 deaths vs. July 2021 and previous June

2021 Swansea University models

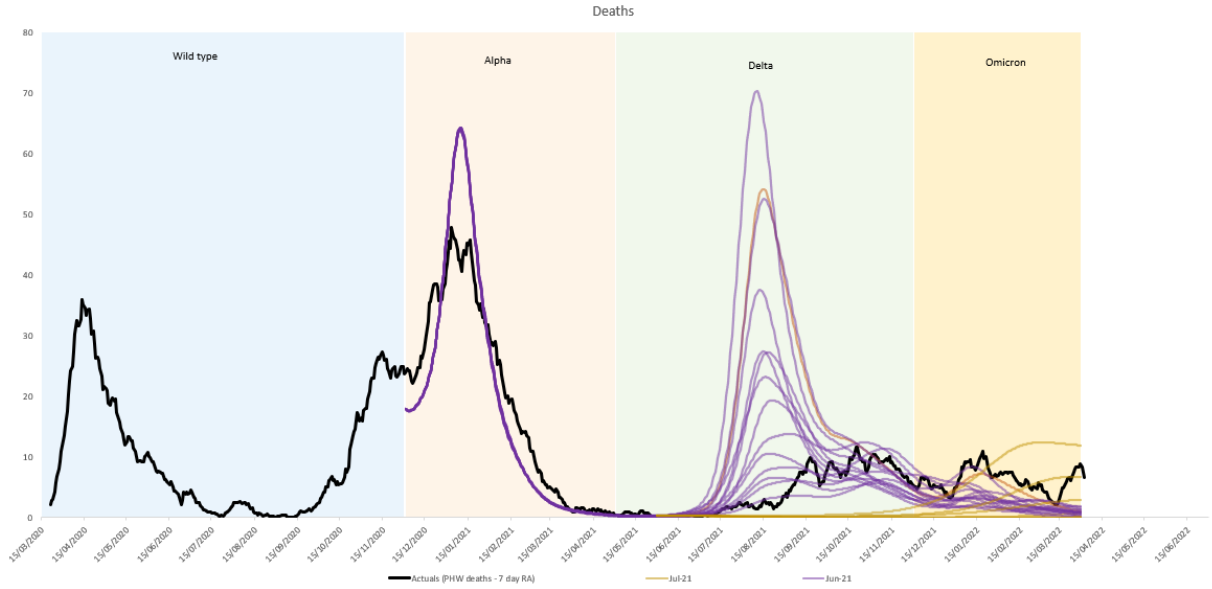
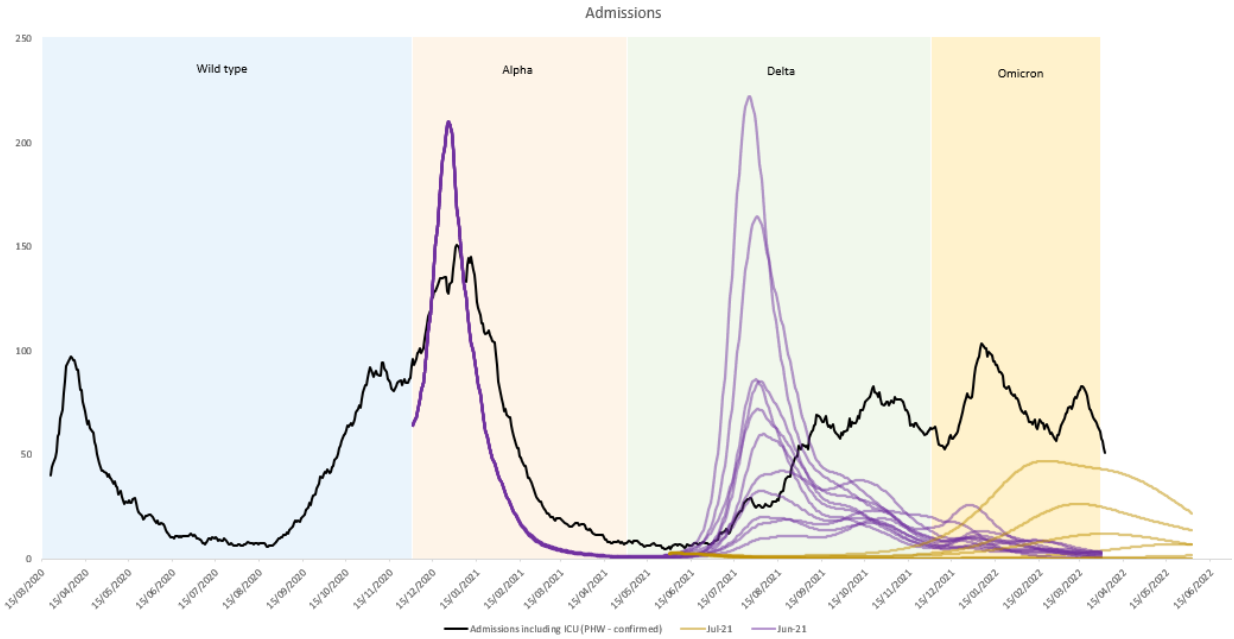


Figure 15: Actual confirmed COVID-19 admissions vs. July 2021 and previous June 2021 Swansea University models



This period (May to June 2021) was characterised by the roadmap opening out of lockdowns, extensive vaccine roll-out, and the emergence of another more transmissible variant. Model scenarios were produced at regular intervals.

In May 2021 a paper was published that compared scenarios for COVID-19 in Wales from April 2021 to March 2022.[6] As with previous and subsequent iterations of the scenarios, there was uncertainty around the impact of new variants, impacts of vaccine efficacies and individuals' ability to continue to follow restrictions and to continue to adopt protective behaviours (adherence). This set of outputs included refinements based on additional data relative to the February 2021 paper scenarios.

The paper published in June 2021 considered scenarios from June 2021 to March 2022.[7] The key areas of uncertainty were: the level of adherence to social distancing and other restrictions; the impact of vaccines on transmission and whether they would remain effective against the emergence of the Delta variant; the impact of Delta and other potential new variants, and the possibility of waning immunity.

A RWC scenario was selected at mid-vaccine effectiveness, low adherence to restrictions, and high delta variant transmissibility (80% more transmissible than Alpha). In contrast, a MLS was selected with good adherence to restrictions, central vaccine efficacy, and low Delta transmissibility (30% more transmissible than the Alpha variant). The trajectory of actual cases was closer to the MLS, as were deaths and admissions.

By July 2021, we were focusing on the opening up of most restrictions, and the potential left for further waves of infection, given that vaccine uptake had been very high. All model scenarios projected large increases in cases following opening up, as the virus (more transmissible due to Delta) spread through the younger, as yet unvaccinated, population. These scenarios generally showed a peak in cases in late July and a (smaller than previous) peak in hospitalisations and deaths in August 2021.

In actuality, the numbers at these time points did not reach levels in most model scenarios; cases, deaths and admissions were closer to the lower end of the varying levels projected. However, the large peak expected in the models did actualise soon after – with the wave accelerating in August and peaking in September to October 2021. Under the model scenarios, the assumption was that once measures were lifted, contact rates would rapidly rise. The delay in the peak represented a delay before this was realised. This may have been due to cautious behaviour, or summer contact patterns (with schools closed) but also has been attributed to the 'pingdemic' where cases increased, and due to very widespread availability of testing and efficiency of test and trace, there were record numbers of people isolating. This likely slowed the resurgence of transmission after opening up, although cases continued to climb without any other restrictions on transmission. By mid-summer, isolation rules were relaxed (in vaccinated individuals and under 18s).

The actuals data for confirmed COVID-19 cases was tracking around the middle of the 'Delta high, good adherence, high vaccine effectiveness' and the 'Delta low, low

[6] technical-advisory-group-policy-modelling-update-5-may-2021.pdf (gov.wales)
[7] technical-advisory-group-policy-modelling-update-25-june-2021.pdf (gov.wales)

adherence, low vaccine effectiveness' scenarios. COVID-19 hospitalisations and deaths were still very low and were closest to the most optimistic of scenarios.

September – October 2021

Figure 16: Actual PCR-confirmed cases vs. September 2021 and previous July 2021 Swansea University models

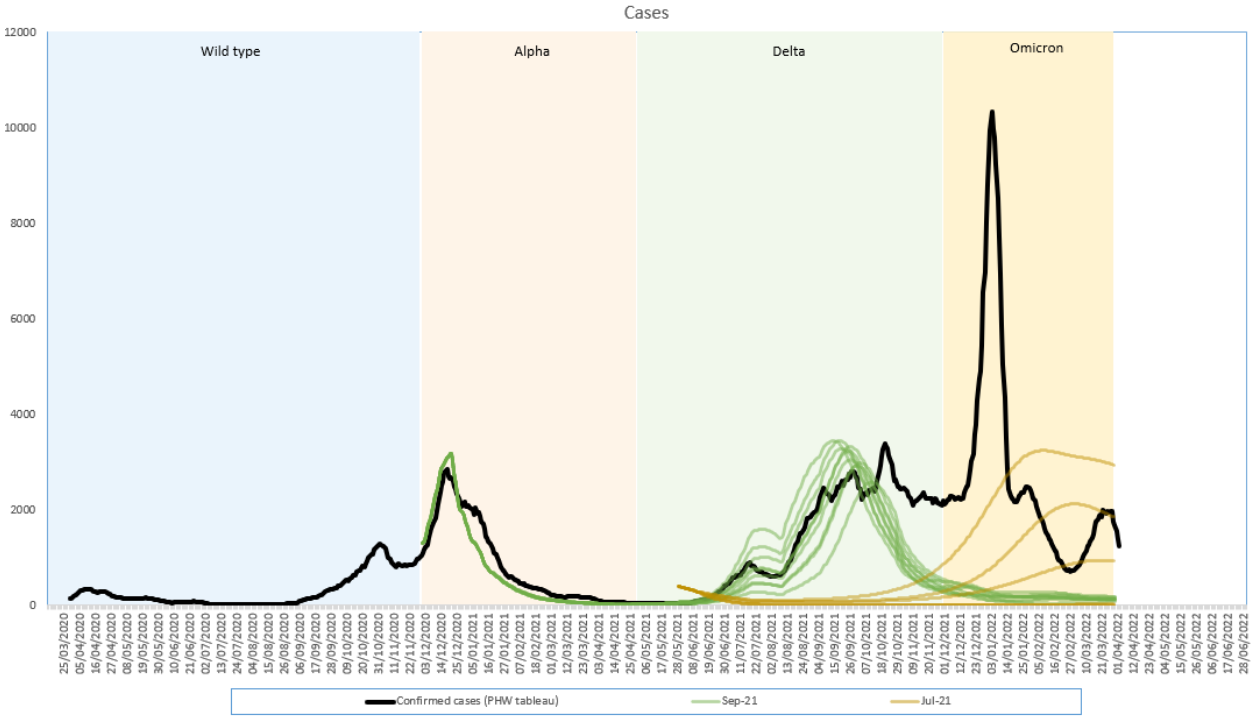


Figure 17: Actual COVID-19 deaths vs. September 2021 and previous July 2021 Swansea University model

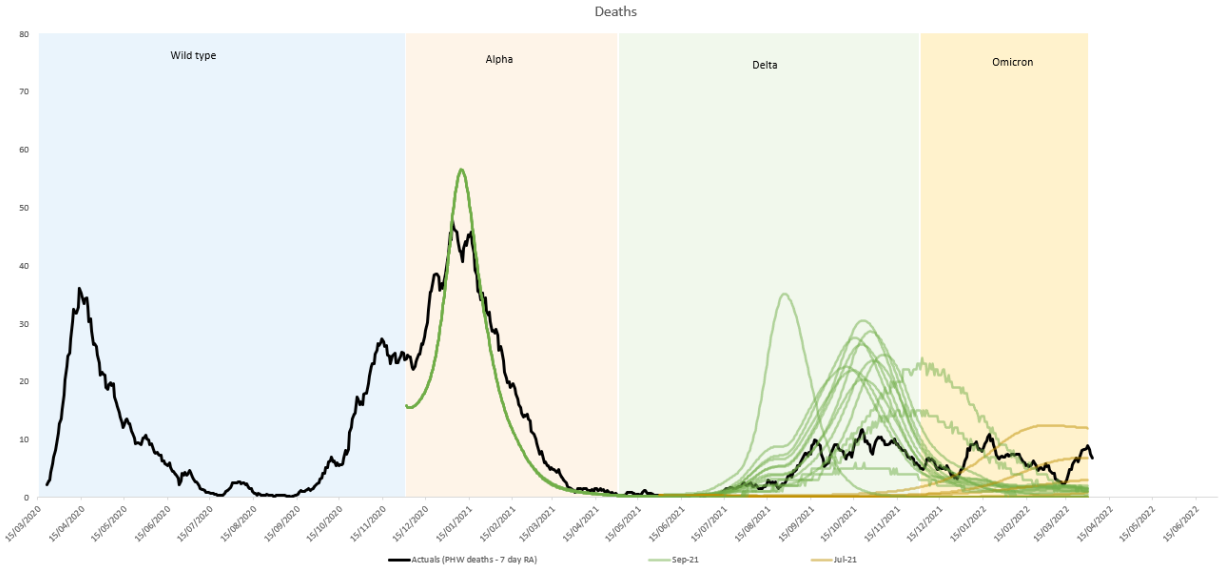


Figure 18: Actual confirmed COVID-19 admissions vs. September 2021 and previous July 2021 Swansea University models

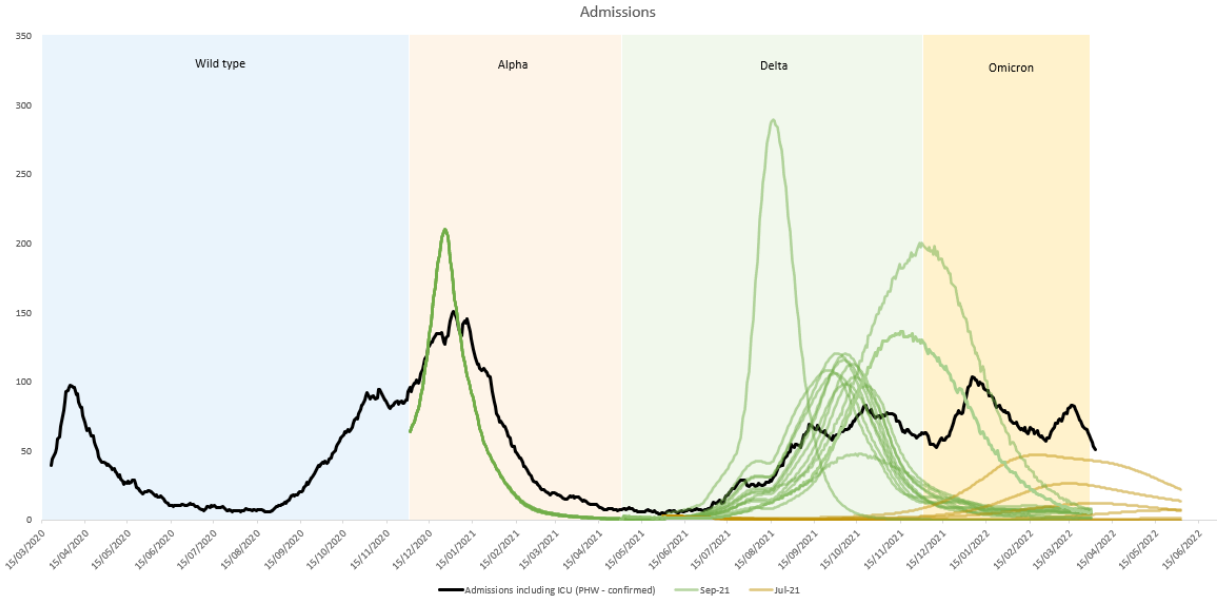


Figure 19: Actual PCR-confirmed cases vs. October 2021 and previous September 2021 Swansea University models

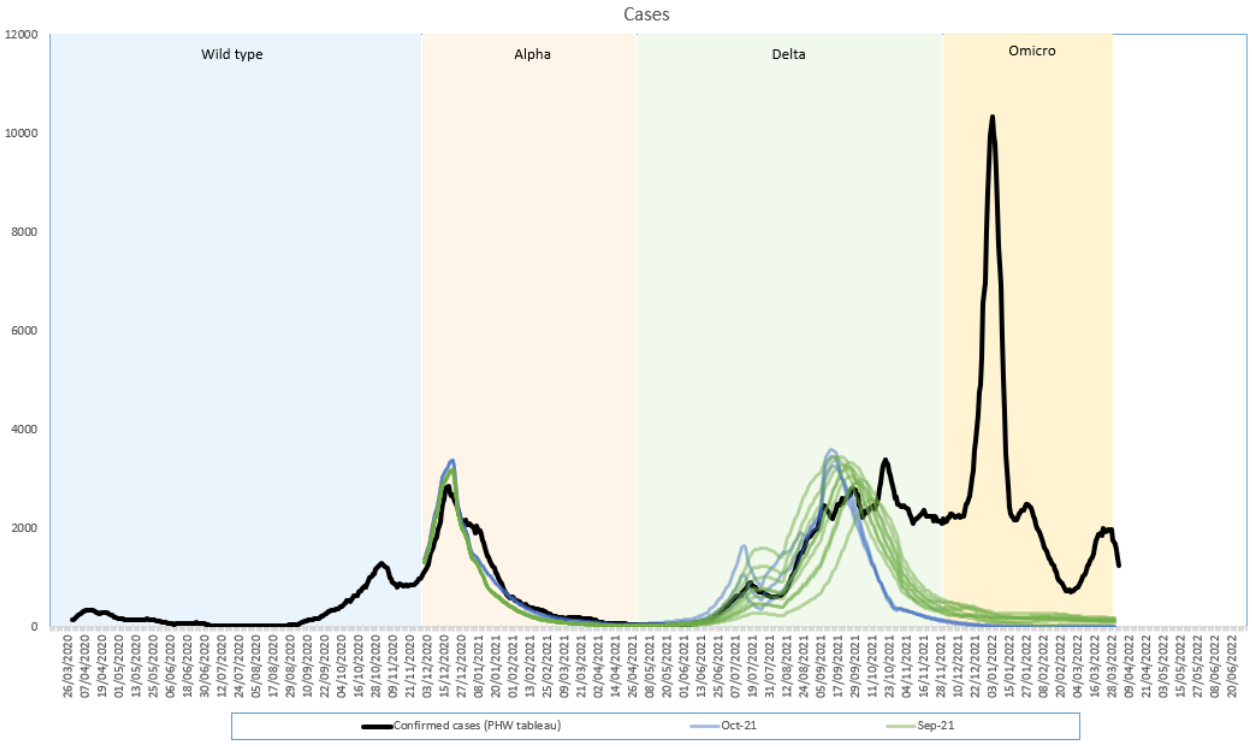


Figure 20: Actual COVID-19 deaths vs. October 2021 Swansea University model and previous September 2021 Warwick/JUNIPER model

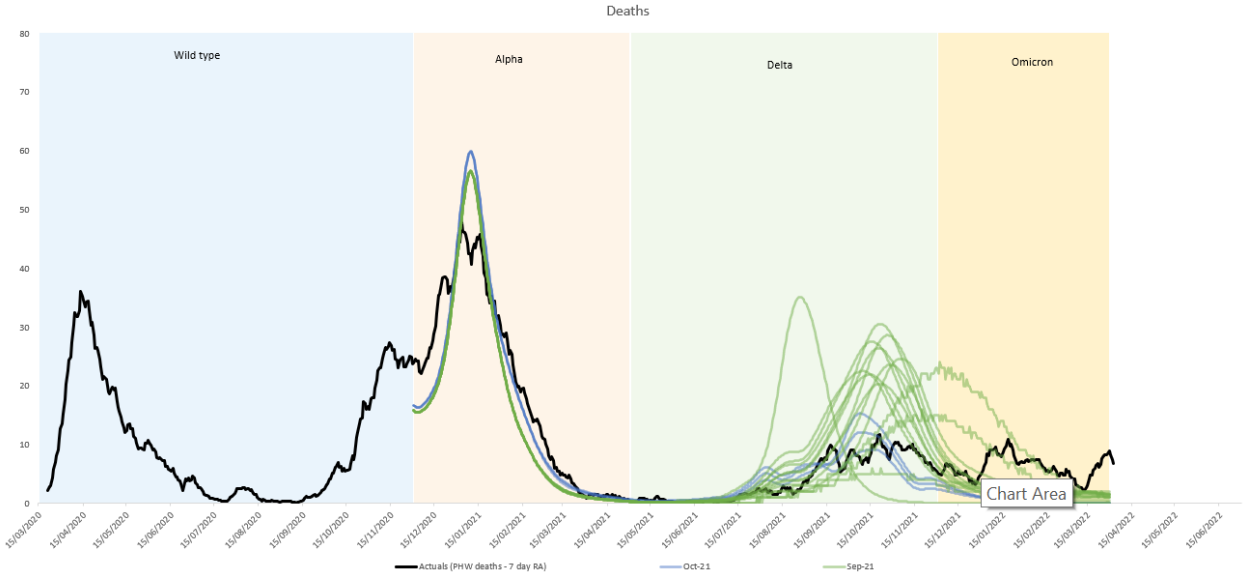
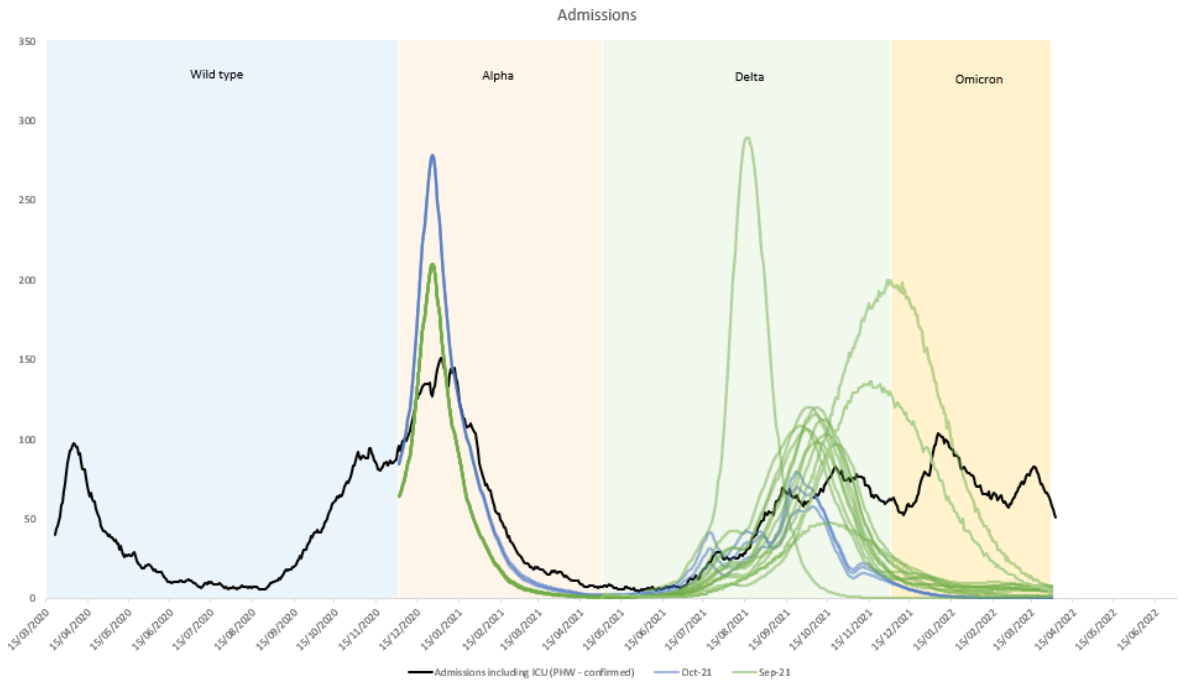


Figure 21: Actual confirmed COVID-19 admissions vs. October 2021 Swansea University model and previous September 2021 Warwick/JUNIPER model



By September 2021, much of the modelling focus was on how long the 'Delta' wave would be sustained. In this policy modelling update, a range of different scenarios

were produced.[8] These were designed to reflect different possible levels of transmissibility of the Delta variant, different levels of adherence to restrictions and different levels of vaccine effectiveness. The uncertainty in model estimates at that time were driven by the uncertainty in these three factors. The models estimated a peak in late September to mid-October followed by a fall in COVID-19 cases, assuming that we would see acquired population immunity effects. However, the actual number of cases remained at a plateau, relatively consistent level in the short term, perhaps due to waning immunity amongst the population (**likely**). All Swansea University model scenarios estimated likely peaks in COVID-19 hospitalisations and deaths in October 2021, though hospitalisations and deaths did not reach the peaks estimated and were below even the more optimistic scenarios, likely reflecting strong vaccine effects.

Scenarios produced by models from University of Warwick/JUNIPER, Imperial University and the Academy of Medical Sciences were included in the September 2021 modelling update paper for comparison – timing and severity of peaks varied between models, demonstrating the variability and underlying uncertainty within the models.

Previous reports looked at difference levels of 'adherence' to restrictions by comparing the number of contacts an individual has compared to pre pandemic levels. For an October 2021 update, it was decided that since there were few restrictions and the date fitted closest to 'good adherence', this assumption would be used and fixed in the future. Transmissibility of the Delta variant was assumed to be 80% higher than the previously dominating Alpha variant, or highly transmissible; evidence suggested transmissibility of Delta at 40%-80% higher. These assumptions were used in addition to consideration of a range of vaccine efficacies to produce the range of scenarios.[9] The plateau of cases (rather than a decline) was investigated with waning immunity scenarios, and increased mixing scenarios.

[8] technical-advisory-group-policy-modelling-update-24-september-2021.pdf (gov.wales)
[9] technical-advisory-group-policy-modelling-update-14-october-2021.pdf (gov.wales)

November 2021

Figure 22: Actual PCR-confirmed COVID-19 cases vs. November 2021 and previous October 2021 Swansea University models

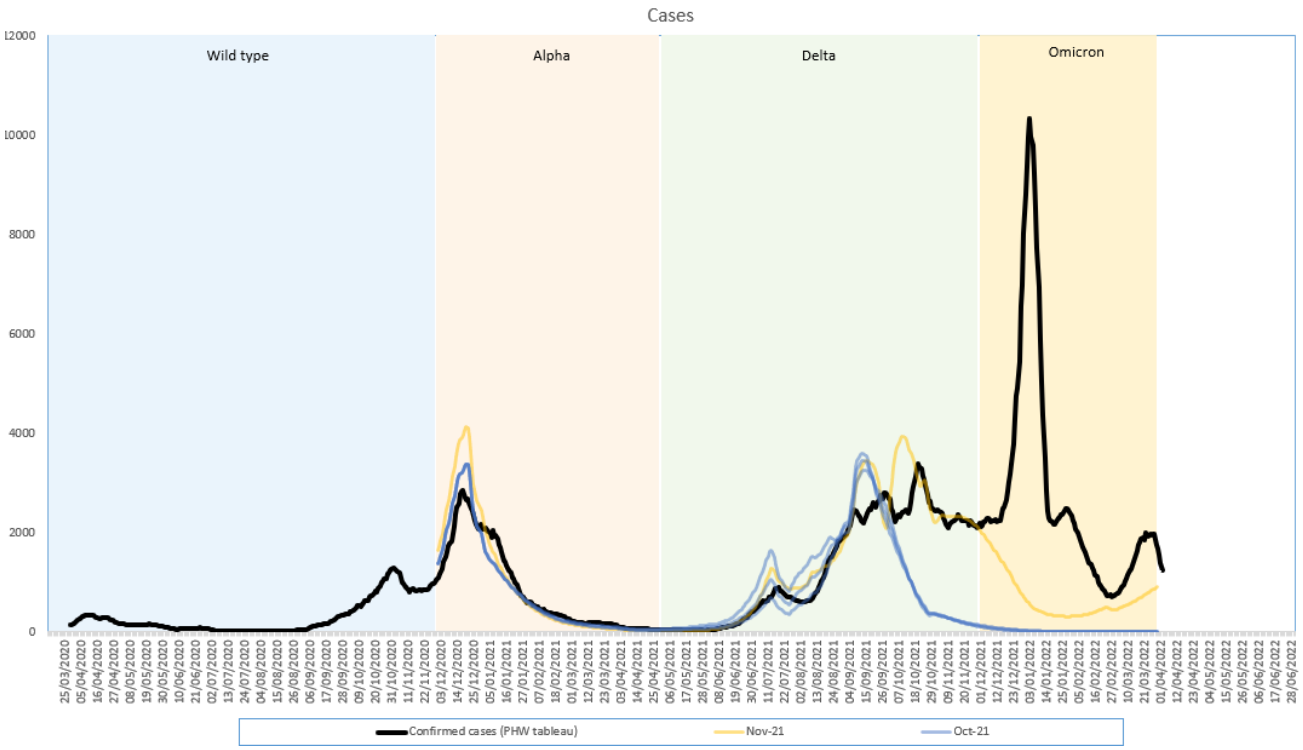


Figure 23: Actual COVID-19 deaths vs. November 2021 and previous October 2021 Swansea University models

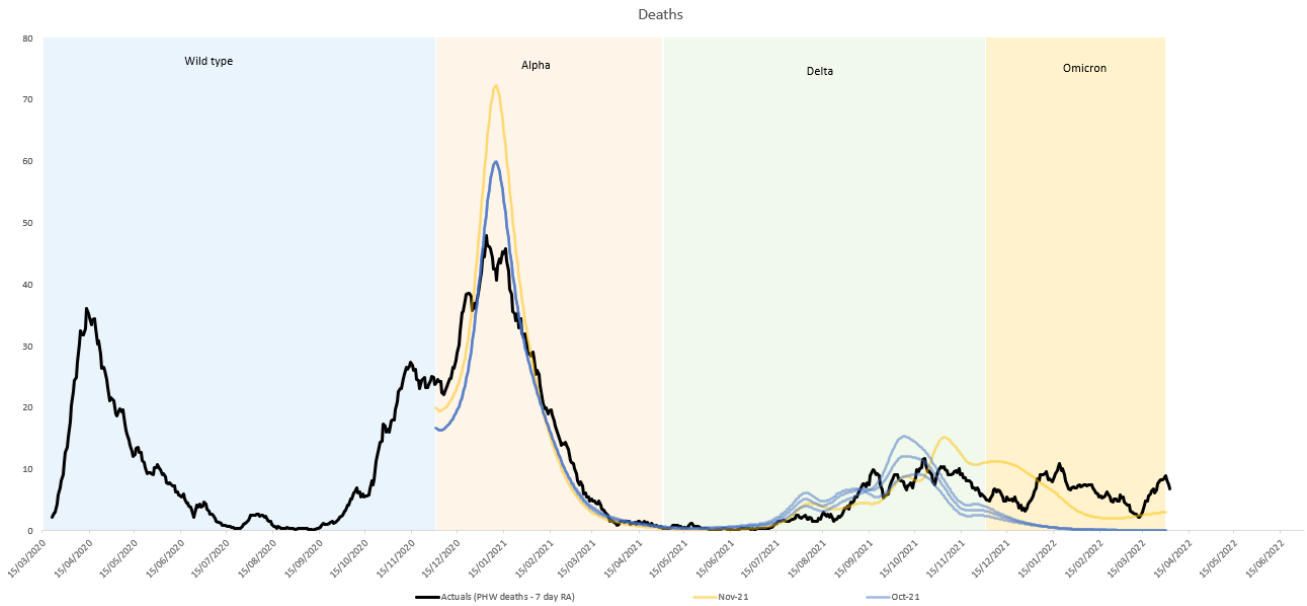
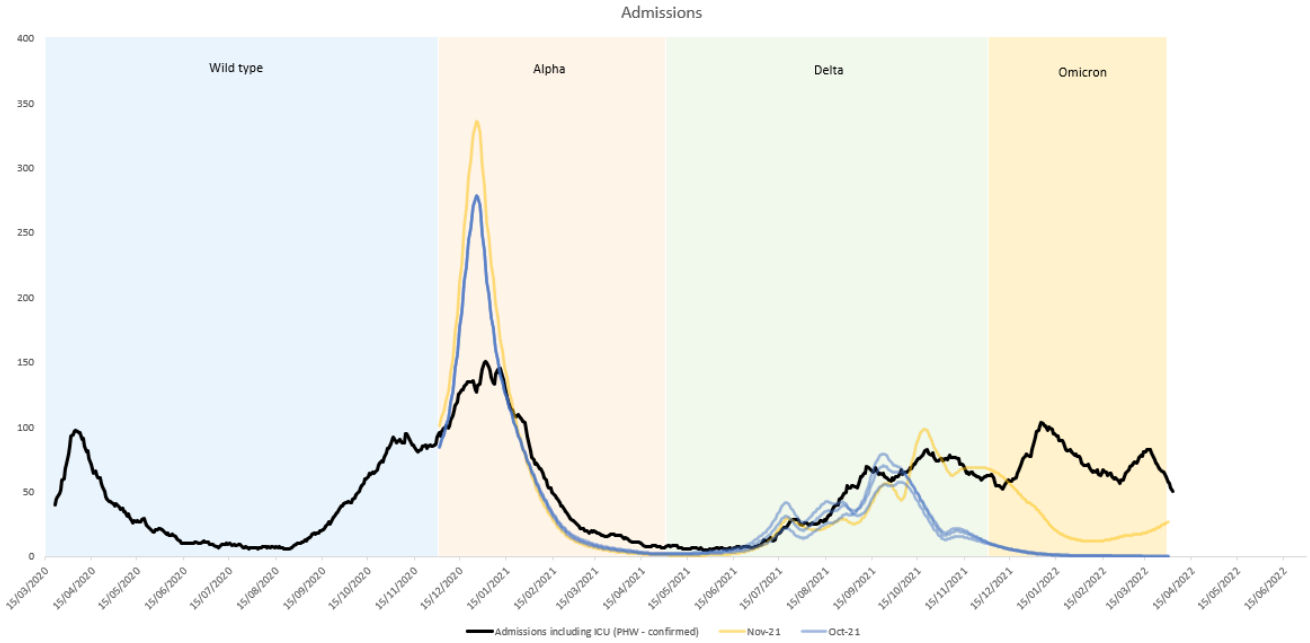


Figure 24: Actual confirmed COVID-19 admissions vs. November 2021 and previous October 2021 Swansea University models



In this policy modelling update, Omicron was a known new variant but scenarios were produced before the Omicron variant was identified. As such, the following peak in number of cases due to Omicron was neither anticipated nor included in the scenarios at that stage and modelling focussed on the behaviour of the various metrics (cases, deaths etc.) caused by the Delta variant.

The most likely scenario (MLS) was selected from the Swansea University epidemiological model. The assumptions chosen for the MLS were a highly transmissible Delta variant (80% more transmissible than the previously dominant Alpha variant), good adherence to restrictions, and low vaccine effectiveness (70% against infections, 91% against hospitalisations/ICU, and 95% against deaths).[10] The low vaccine efficacy for this scenario was chosen not only because it fitted best to the data, but also because it fitted to the PHE surveillance estimates for vaccine effectiveness very well.

On this occasion, along with our Swansea University COVID-19 modelling scenarios, we also gratefully received Wales-specific modelling from academic colleagues at Warwick University who provided COVID-19 modelling to the SPI-M group. A realistic worst case scenario (RWC) was chosen from scenarios provided by University of Warwick/JUNIPER group. Actual cases performed worse than the RWC because the scenario was not designed to include the new Omicron variant, and only considered Delta. However, COVID-19 deaths and admissions were more pessimistic under the ('Nov-21') RWC than the actual outcomes.

A comparison of the ('Nov-21') RWC versus actuals data charts for COVID-19 cases, deaths and admissions are shown in the appendix.

[10] technical-advisory-group-policy-modelling-update-30-november.pdf (gov.wales)

December 2021[11,12]

Figure 25:Actual PCR-confirmed cases vs. December 2021 and previous November 2021 Swansea University models

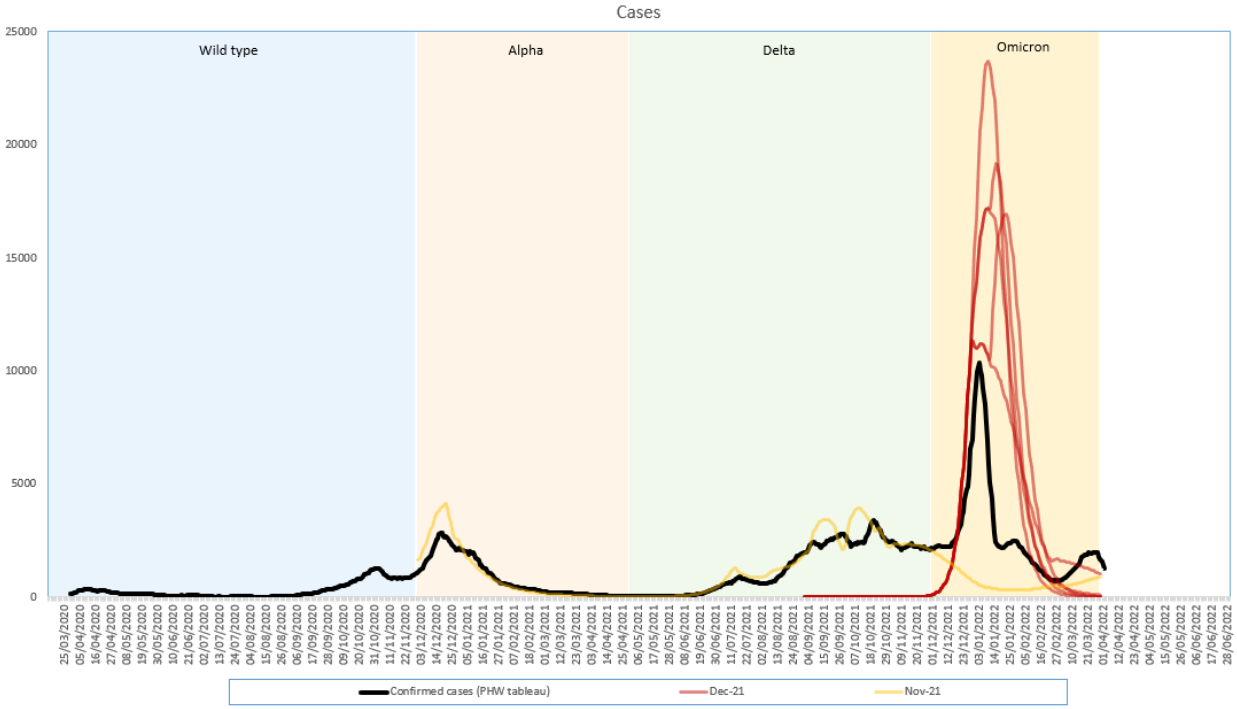
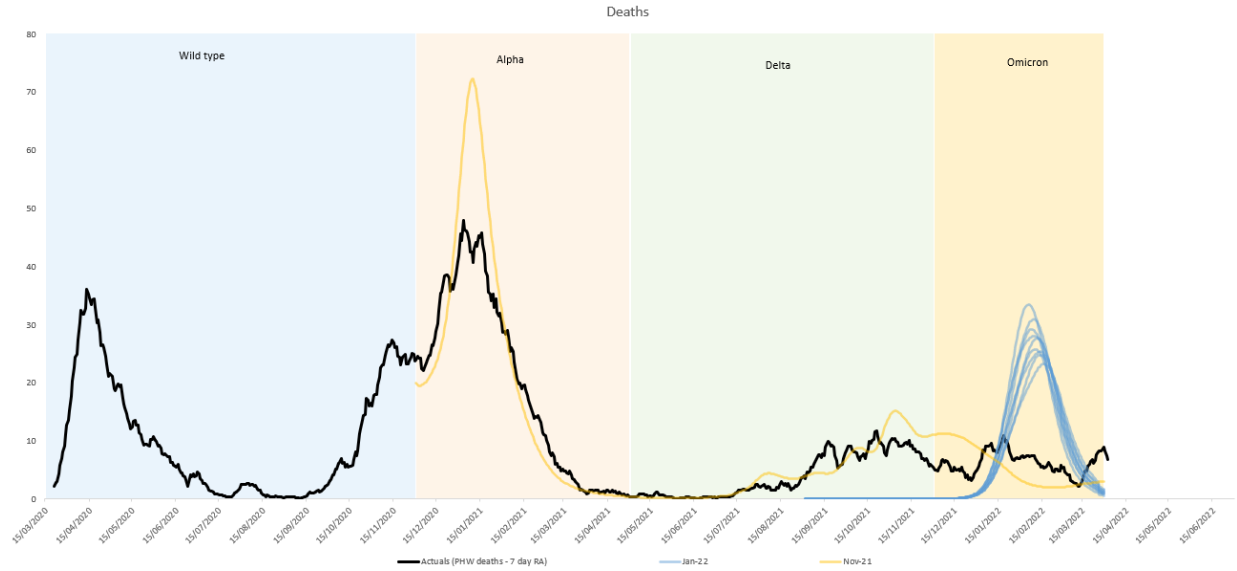
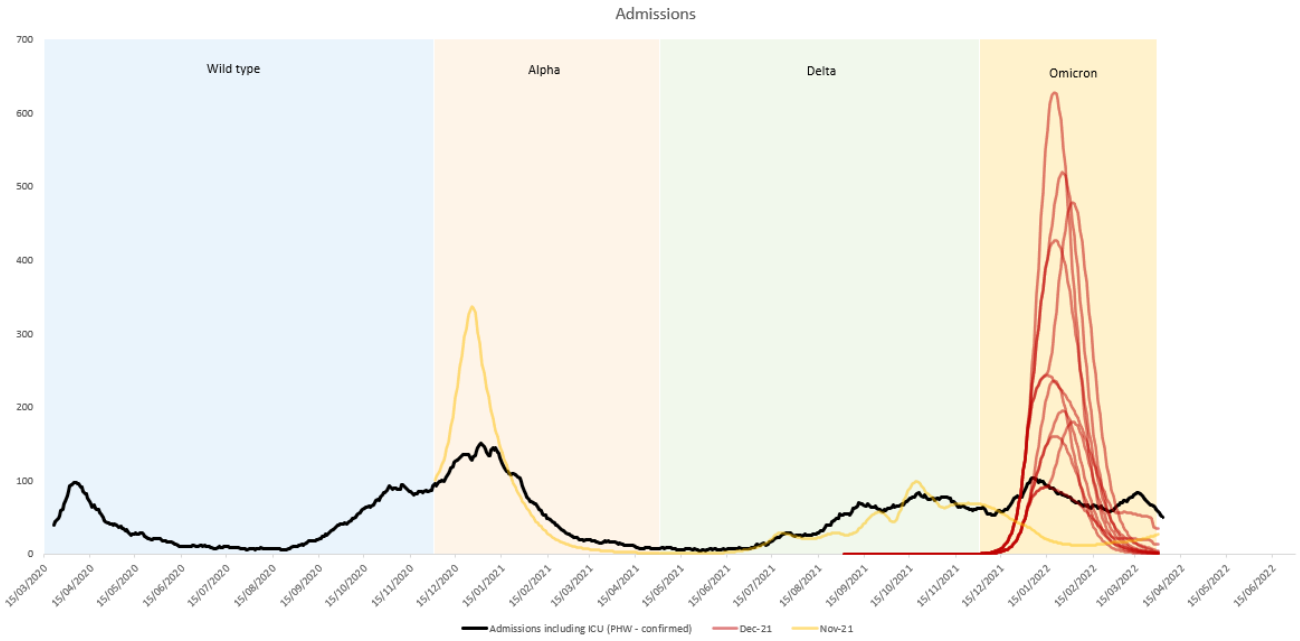


Figure 26: Actual COVID-19 deaths vs. January and previous November 2021 Swansea University models



[11] technical-advisory-group-policy-modelling-update-17-december-2021.pdf (gov.wales)
[12] technical-advisory-group-policy-modelling-update-11-january-2022.pdf (gov.wales)

Figure 27: Actual confirmed COVID-19 admissions vs. December 2021 and previous November 2021 Swansea University models



A rapid modelling response was required in December 2021 due to the emergence of the omicron variant. Transmissibility was extremely high, with the likelihood of significant immune escape (loss of protection from previous infection). Escape from vaccine effects were much more uncertain. Omicron became the dominant variant within weeks and scenarios were quickly generated. All scenarios agreed that a large wave of infections would be expected, but the uncertainty focused on how this would be reflected in severe clinical effects, and hospital burden. Scenarios were created featuring high and low severity assumptions where high severity had a case to hospitalisation ratio of 2.5% (similar to the recent experience with Delta) and low severity had 1%. High severity scenarios were particularly concerning, due to the very high transmissibility and potential immune escape of omicron. However, by 23 December 2021, evidence was available to rule out the high severity scenario. It was determined that the low severity scenario was a closer reflection of actual experience for Omicron relative to the Delta variant, however considerable uncertainty remained, especially given the very high expected transmissibility.

Additionally, the models were also then refined (‘Jan-22) to account for accelerated booster rollouts that were not previously included (along with higher R0, from 5.1 to 6.5, to reflect early observed exponential increase in omicron against the background of previous exposure to delta).

Variation in the scenarios allowed for different outcomes depending on Alert level chosen. It was eventually decided that Wales would move to Alert level 2 from 26 December 2021 for 4 weeks before returning to Alert level 0. Prior to this, models allowed for a consideration of what outcomes would be if Alert level 2 were held for two or four weeks, if Alert level 4 were chosen, and if there was an unmitigated scenario. Taking the 22 December 2021 “low severity” model scenario with four weeks of level 2 restrictions (similar to what was enacted), the model scenarios

produced case peaks of about 12,500 cases by mid-January, level far higher than had been seen at any point prior. COVID-19 hospital admission model scenarios peaked at 125 at the end of January, ICU admissions at 5 at the end of January, and deaths at about 25 by mid-February 2022. Actual COVID-19 case numbers peaked at very similar numbers, though slightly earlier. Clinical event numbers in January / early February 2022 peaked at levels of about 75% of the model for admissions and 50% of the model outputs for ICU and deaths, indicating actual omicron impact was lower the more severe the outcome. Notably, the model underestimates the total hospital *occupancy* at these time points, which likely represents a period of increased nosocomial transmission.

We note that following the initial omicron wave, there have been further periods of increased and prolonged transmission. This may reflect rapid waning immunity to re-infection for omicron, and these scenarios are being included in most recent model updates.

Summary

There has been inevitable uncertainty in the modelling of COVID-19 cases, deaths and admissions behaviour when considering the future trajectory the pandemic may take. This uncertainty has centred on emergence (both in terms of timing and scale) and transmissibility of variants, adherence to and choice of restrictions, waning immunity and vaccine effectiveness. Much of this uncertainty was communicated in the range of modelling scenarios produced throughout the pandemic. However, the actual outcome has sometimes differed even from the most optimistic or pessimistic of the scenarios produced – generally the actual outcome has been ‘better’ than the optimistic scenarios rather than worse than the pessimistic scenarios. Where the actual outcomes are worse than the scenarios presented, this is generally mainly because of a new variant that has arisen that was not necessarily anticipated. As time goes on more is learnt about the variants and their impacts, and the models are refined and re-run accordingly. Nevertheless, uncertainty around future variant evolution remains.

Despite these uncertainties, it has been observed that modelling can provide a useful estimate of a picture of the future; modelling the spread of COVID-19 provides an invaluable means of projecting forwards to try and better understand what could happen, aid policy decision making, and help plan more effectively for the future in both the short and long term.

Appendix: Reasonable Worst Case (RWC) Scenarios versus Actuals

Figure 28: Actual PCR-confirmed COVID-19 cases vs. modelled RWC at different points in time

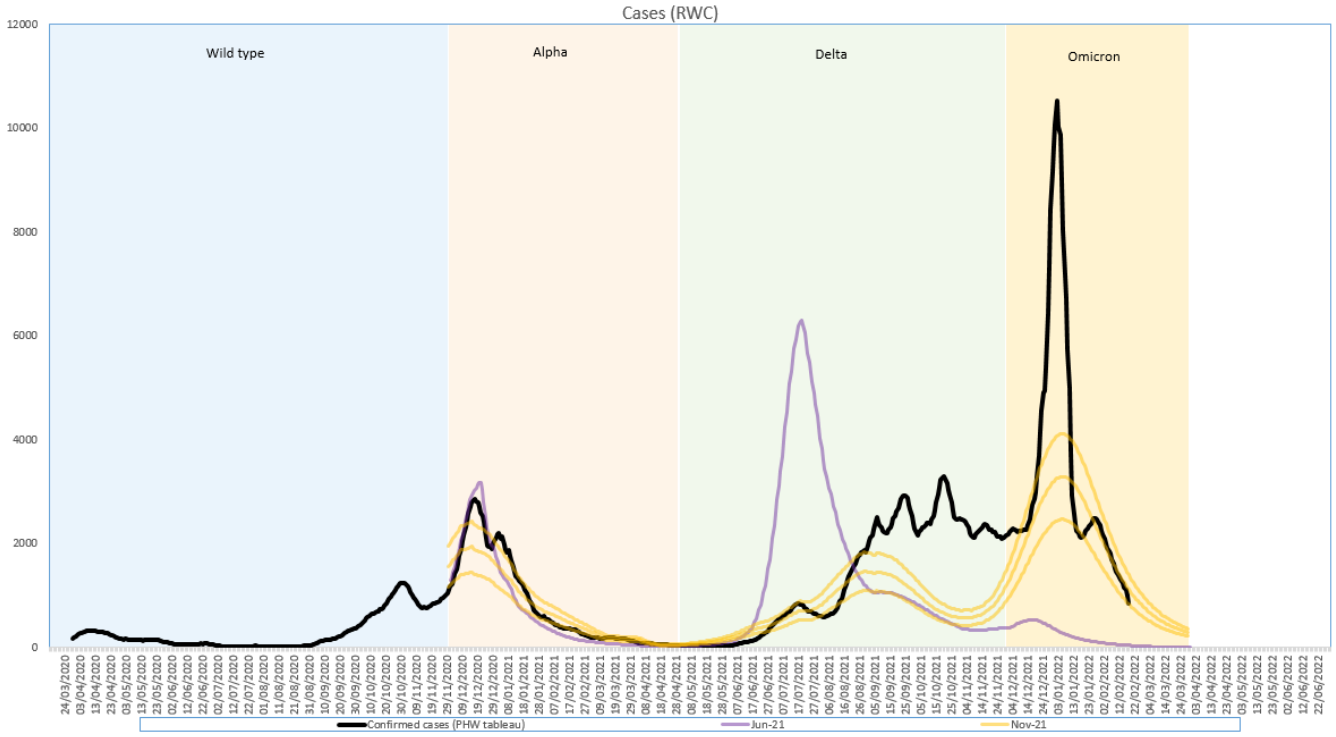


Figure 29: Actual COVID-19 deaths vs. modelled RWC at different points in time

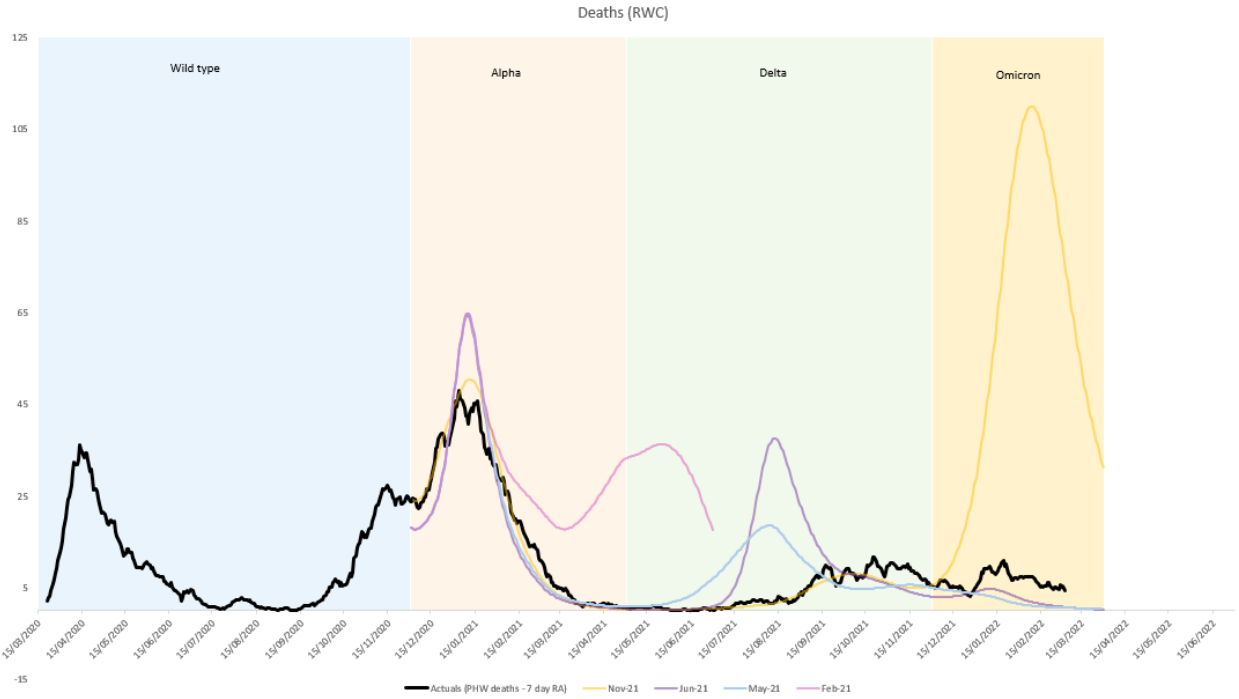
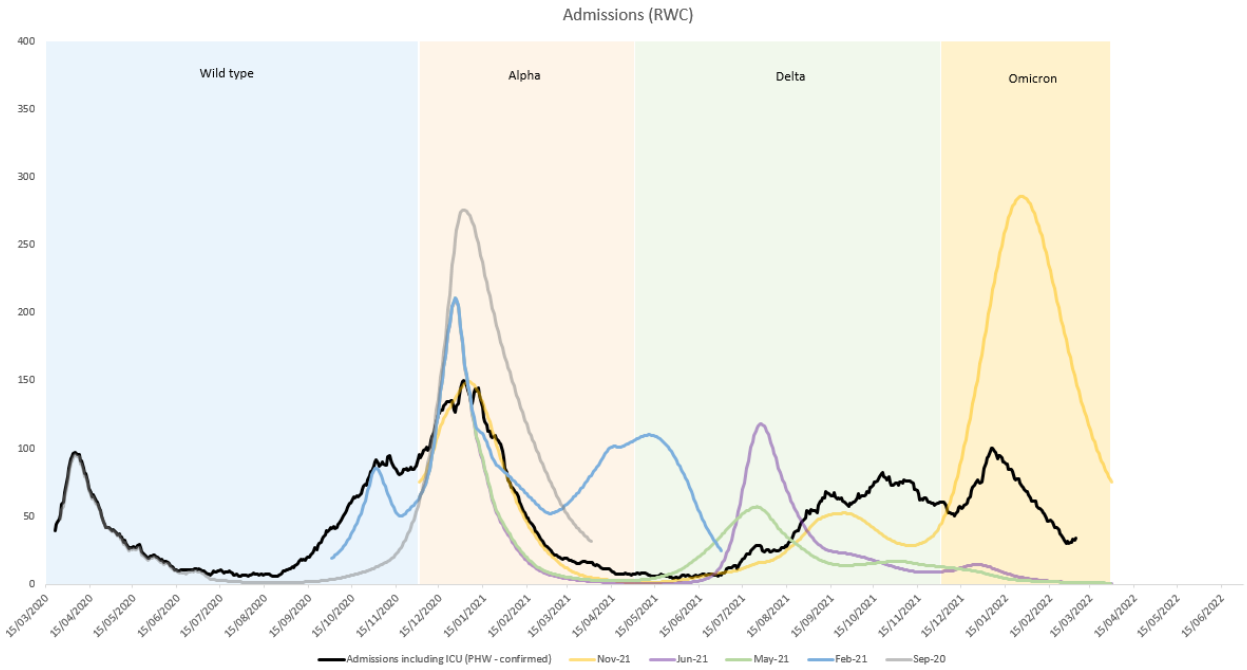


Figure 30: Actual confirmed COVID-19 admissions vs. modelled RWC at different points in time



Probabilistic language

We use a probability yardstick when making an assessment to provide clarity on the associated levels of uncertainty. The terms used correspond to the following ranges: