Estimating cases for COVID-19 in South Africa:

Assessment of alternative scenarios

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FOR PUBLIC RELEASE

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on behalf of the South African COVID-19 Modelling Consortium

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The projections in this report are intended for planning purposes by the South African government.

Key messages

The South African COVID-19 Modelling Consortium was established to project the spread of the disease to support policy and planning in South Africa over the coming months. Due to the rapidly changing nature of the outbreak globally and in South Africa, the projections are updated regularly as new data become available. As such, projections should be interpreted with caution. Changes in testing policy, contact tracing, and hospitalisation criteria will all impact the cases detected as well as the number of hospital admissions and deaths that can be positively identified as associated with COVID-19.

Given the substantial uncertainty regarding overall population susceptibility and changes in population behaviour in reaction to the increase in cases and deaths, in this report we updated a number of our original assumptions. We added the notion of overall behavioural heterogeneity into our main scenario, i.e., the idea that some members of society experience different risks and exhibit different behavioural patterns, introducing substantial variation in the number of people that different people infect, with highly connected individuals becoming infected earlier in the epidemic and infecting more contacts.

We also added a number of additional outputs in this report. Firstly, we now produce estimates not only of the number of needed general hospital and ICU beds, but also of the number of beds that were in fact used- as in all provinces only a subset of the beds needed for patients with severe and critical disease were in fact used, due to lack of capacity or lack of treatment seeking, or both. Secondly, we acknowledge that the officially reported COVID-19 related deaths are only a subset of all excess natural deaths summarised from the death registry statistics over the last months, and that many of these excess deaths might have occurred at home- also in keeping with the fact that fewer severe COVID-19 cases were hospitalised than previously projected. We thus now estimate both the deaths in hospital and all deaths, regardless of whether the patient has been hospitalised at the time of death.

Our updated projections show the following:

- The COVID-19 pandemic peaked in mid-July, earlier and at a lower total number of active cases than in our optimistic scenario published in May.
- The model estimates that there have been 15.20 million infections to date, equating to 25.5% (uncertainty range: 22.0%-28.6%) of the population.
- Since testing guidelines and practices change, we estimate cumulative detected cases under two scenarios i) moderate testing coverage as implemented in May and June, and ii) a more limited testing coverage policy that prioritises testing in hospitalised cases and in healthcare workers. Under the moderate testing scenario, cumulative detected cases will continue to grow until 1.2 million in early November, and only marginally so thereafter. Whereas only about 567,500 cases (447,800-707,100) were estimated to be detected under limited testing, the actual number of detected cases has already surpassed the median of the limited testing scenario and will likely end up lying somewhere between these two scenarios.
- The peak number of general hospital (i.e., non-ICU) beds *in use* was estimated to be reached in early-August, at around 8,000 beds (when around 12,500 beds would have been *needed*). The peak number of ICU beds in use was estimated to be reached

around the same time, with around 1,100 beds (when more than 2,000 beds would have been needed). Total deaths are estimated to continue to increase until early November when the cumulative number of all deaths will reach 37,000 (of which 16,000 will have been in hospital); thereafter the growth rate will be very low.

While the number of COVID-19 cases in South Africa appears to have peaked, there is much uncertainty in the remaining course of the epidemic, its duration and consequences. The future of the spread of SARS-CoV-2 and the impact of COVID-19 on health and health resources depends on many unknowns. We do not yet know whether those already infected will have long-lasting immunity or short-term immunity, and whether this immunity will offer complete or partial protection. In the absence of a vaccine, SARS-CoV-2 transmission remains largely dependent on the proportion of population still susceptible, individual behaviour and the ability of the population to adopt preventative measures like mask-wearing and practise social distancing whilst going about their daily lives. Depending on the nature of immunity and/or the development of a vaccine, the future of SARS-CoV-2 could become regular annual epidemics, seasonal epidemics, epidemics occurring every few years or even sporadic, unpredictable epidemics. It is therefore important to continue to monitor the epidemic and remain vigilant to detect localised outbreaks as and when they occur. Additional work on modelling the impact of the above-mentioned factors on the timing, frequency and amplitude of a future resurgence in COVID-19 cases is currently under way.

About the South African COVID-19 Modelling Consortium

The South African COVID-19 Modelling Consortium is a group of researchers from academic, non-profit, and government institutions across South Africa. The group is coordinated by the National Institute for Communicable Diseases, on behalf of the National Department of Health. The mandate of the group is to provide, assess and validate model projections to be used for planning purposes by the Government of South Africa. For more information, please contact Dr Harry Moultrie (harrym@nicd.ac.za).

Structure of this report

This report starts by summarising the changes made since the last set of long-term projections and gives some context for interpreting the findings. We then report how well the model fits developments in deaths and admissions over the last four months, and discuss the implications of a number of scenario analyses on the projections for a sub-set of the provinces with more advanced epidemics (Western Cape, Eastern Cape, Gauteng and KwaZulu-Natal), We report on our most recent projections of cases, deaths and hospital and ICU beds (needed and used) nationally and per province. We end with an assessment that summarises our findings.

Changes since last set of long-term projections

In this section, we summarise changes that have been made to the modelling approach and parameterization since the previously released version of the long-term projections. The main changes are as follows:

The spatial scale of the model is now at the district level (as opposed to the province level, in the previous release), reflecting the population size and connectivity of each district. Model calibration to hospital admissions and deaths is still done at the provincial level, due to limited district-level data. While all provinces were individually calibrated, provinces with smaller numbers of confirmed cases, hospitalisations and deaths (Free State, Limpopo, Mpumalanga, North West, and Northern Cape) were less easily calibrated due to sparse data at this stage. These calibrations will improve with additional data.

Movement between districts is estimated based on aggregate cell phone mobility data provided by Vodacom. District-to-district connectivity matrices were constructed based on the proportion of mobile phone pings that occur in each district outside the home district. The home district is defined as the location where a mobile device is normally located between 10pm and 4am. Separate matrices were constructed for each lockdown phase (pre-lockdown, Level 5, Level 4, Level 3 (disaggregated) and Level 2) to reflect the average levels of movement within each period.

Inputs regarding the reproductive number have been updated based on analyses by the National Institute for Communicable Diseases (NICD) for lockdown levels 5 and 4[1,2]. Thereafter changes in contact rates at the provincial level are updated based on reductions in google mobility trends for places of residence[3]. (details see Table A1 in the Appendix).

Instead of relying on data from international studies, local data are now used to define the parameters on care pathways in hospital. Data-based estimates were derived from DATCOV, the NICD's sentinel hospital surveillance dataset, which records the details of COVID-19 associated hospitalisations[4]. As only 53% of public hospitals are participating in DATCOV, admissions would be underrepresented in the public sector. To adjust for this, we calculated a province-specific inflation factor for general and ICU admissions based on the total number of hospital beds available in both sectors versus the number of beds in hospitals represented in the DATCOV dataset. This inflation factor was applied to the admissions data and used for calibration. Both sets of admissions data are presented in the figures below, with the inflated data referred to as "adjusted DATCOV data". This includes the length of hospital stay and the proportion of patients in general vs. ICU wards (see Table A1 for details).

Mortality assumptions continue to incorporate local hospital fatality data. The infection fatality rates used in the May projections included an allowance for asymptomatic cases that was misspecified. This was corrected in the June publication and all updates onwards where hospital and publicly reported fatality data were used to estimate fatality due to COVID-19. Mortality in hospital is now estimated from the DATCOV dataset with province-specific estimates for Eastern Cape, Gauteng, KwaZulu-Natal and Western Cape, and national estimates for the remaining provinces. Additionally, we calculate the potential mortality impact of not receiving necessary care, either because of patients not seeking care or because care capacity has been breached, and the required hospital beds are no longer available. We parameterised these additional deaths, which do not occur in hospital, by using

the excess mortality from natural causes estimated by the South African Medical Research Council (MRC) on a weekly basis that compares current deaths reported to the vital registry by way of death certificates to projections based on mortality in the same calendar week in previous years[5]. While not all excess deaths will be COVID-19 deaths, the spatio-temporal patterns of excess deaths, confirmed COVID-19 cases and officially reported COVID-19 deaths suggest that the bulk of excess deaths are from COVID-19 rather than from collateral causes. For example, in the Western Cape Province, which has a provincial health data centre that integrates patient level health data across facilities and services in the province[6], confirmed COVID-19 deaths are approximately two thirds of the excess deaths[7]. Based on these and other data, we assume that 80% of the estimated excess deaths are due to Covid-19, with treatment seeking for inpatient care overall reducing during periods of peak hospital admission as a result of overwhelmed inpatient capacity.

The model now incorporates behavioural heterogeneity as a mechanism to explain the lower- and earlier-than-expected peak in cases, deaths and admissions in the Western and Eastern Cape in particular. This acknowledges the fact that some members of society experience different risks and exhibit different behavioural patterns, with highly connected individuals becoming infected earlier in the epidemic and infecting more contacts. It is modelled through altering the transmission function (force of infection) to decrease as immunity builds up in the most connected individuals early on.

The following parameters were updated: While the original paper estimated that >90% of presymptomatic infections occurred within 2 days before the onset of symptoms, a correction to the analysis revealed that >90% of presymptomatic infections were estimated to occur within 4 days before symptom onset[8]. Additionally, the relative infectiousness of asymptomatic infections was updated from 75% to 80%.

The model now incorporates both the need for hospitalisations, including for critical care, and the actual use of hospital care, informed by the fact that only a subset of those beds predicted to be needed in most provinces were in fact used, in particular at the ICU level, due to constraints in capacity leading to less admissions and shorter lengths of stay, lower than expected presentation of patients for hospital care, or both**.**

The model code for the provincial model has been made available under https://sacovid19mc.github.io/.

Context for interpreting projections

The results presented below must be interpreted considering the following points of context:

Not all COVID-19 infections will be detected. Many infected individuals will be asymptomatic or mildly symptomatic and are not likely to seek out a diagnostic test. Additionally, owing to the severe laboratory capacity constraints in South Africa, not all individuals can be tested even if they present for a test. Previous projections from the NCEM have assumed that while all hospitalised cases will receive a laboratory-confirmed diagnosis, only 1 of 4 mildly symptomatic cases will be detected. This fraction was based on inflation factors determined by reviewing the number of confirmed COVID-19 cases, evolution of 'person under investigation' (PUI) criteria for COVID-19 testing, the number of contacts identified and proportion traced, and publications/reports on under-detection rates in other countries. However, a change in policy to prioritise testing of hospitalised patients, health care workers, elderly individuals and individuals with co-morbidities with respiratory symptoms, has been implemented in the Western Cape, and a similar policy that also includes staff and inhabitants of nursing homes, entrants into quarantine facilities and a fraction of essential workers has been implemented to varying extents in other provinces. It can be assumed that this prioritised strategy led to a decreased detection of mild cases from mid-June onwards, with approximately 1 in 10 mild cases now being detected. The Cumulative Detected Cases panels below show detected cases under two policy scenarios: a) assuming the current testing policy (blue) and b) detected cases projected under a limited policy of detecting only hospitalised cases from mid-June (orange). Projections of detected cases may deviate from observed detected cases if testing practices change, and actual detected cases are likely to fall between the two scenarios.

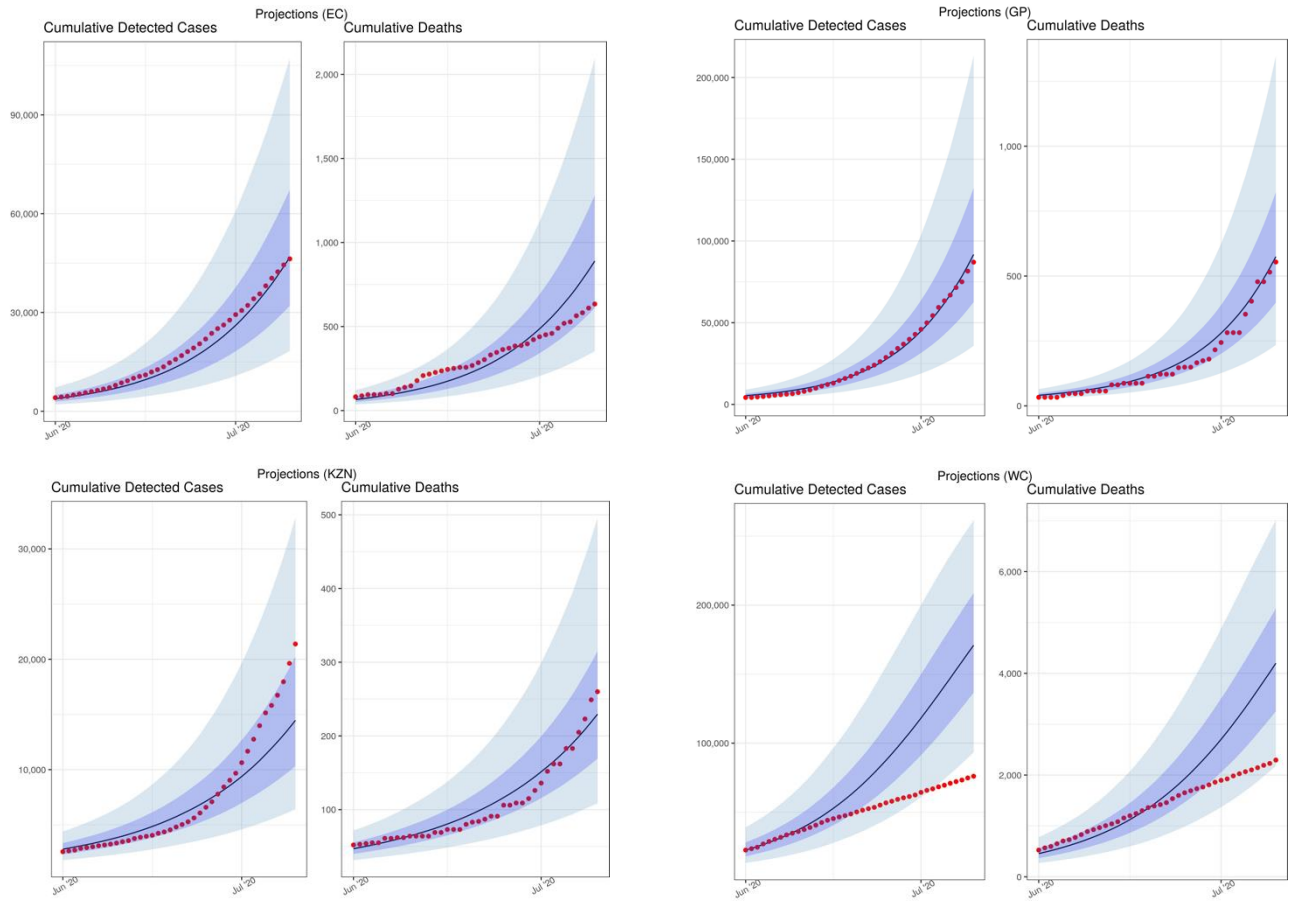
Projections at the population level do not capture local clustering of cases. The methods used in this report make simplifying assumptions regarding how contacts between infectious and uninfected people occur. The models therefore cannot capture the specific differences in risk experienced by some members of society – e.g. health care workers or those living in close, confined quarters such as informal settlements. They also cannot capture the effects of specific events – e.g. religious gatherings or re-opening of individual schools – on local transmission. While we have incorporated some level of contact heterogeneity, as described above, this is captured at a population level and does not account for specific contexts, such as those leading to superspreading events.

Understanding of the virus's epidemiology is continually evolving, both locally and globally. Important parameters about which there remains substantial uncertainty in the scientific literature include the proportion of infections that are truly asymptomatic, the relative infectiousness of these asymptomatic individuals, the relative duration of infectiousness for these individuals, as well as the severity profile of cases in different contexts. In the absence of reliable serology data, there also remains significant uncertainty with regards to population susceptibility to the virus and the overall attack rate (i.e. what proportion of the population needs to have been infected for transmission to stagnate). Whether existing T-cell derived-immunity after prior exposure to other coronaviruses exists is also unclear (and if so, how much of a role it plays). We have included a reduction in the proportion of the population that is susceptible as an alternative scenario below.

Findings: Model performance

On 12 June, we published a set of short-term projections to estimate cases and deaths for June/July. Figure 1 shows the projected (black line) and observed (red dots) cumulative detected cases (left) and cumulative deaths (right) from 21 March to 15 July for select provinces. These projections were made on 12 June and show that the NCEM model closely estimated the actual cumulative detected cases observed for the projection period. It was during this period that daily deaths and admissions began to flatten in the Western Cape, for reasons that are not yet well understood. Given that infectious disease models such as the NCEM are mechanistic models driven by the underlying biology of the virus and the care pathways, without knowledge of the reason behind the deceleration in daily deaths, it was not possible to predict this change in trajectory. We however performed a number of scenario analyses to interrogate the impact that four distinct factors could have had in explaining the difference between our projections from June and real case and death development.

Figure 1: Model performance: Previously projected (12 June) vs observed cumulative detected cases and cumulative deaths (select provinces)



The factors that we took into account as offering potential plausible explanations for the earlier-than-expected plateauing of admissions and deaths in the Western Cape included the following:

a) A **lower than assumed population attack rate**, possibly due to different levels of susceptibility in different population groups (including children) or the presence of existing T-

cell derived-immunity after prior exposure to other coronaviruses. This is modelled by allowing a proportion of individuals to be immune throughout the course of the epidemic.

b) **Behaviour change in response to an increased local death rate**. This scenario takes into account a potential impact of public awareness of the increasing deaths and the looming threat of overwhelmed healthcare facilities in the Western Cape, which, combined with communication campaigns, may have resulted in better adherence to non-pharmaceutical interventions (NPIs) (e.g. masks, hand washing and physical distancing) and in those most at risk for severe COVID-19 disease taking additional precautions to isolate themselves. This is modelled by allowing the population in each district to reduce interactions when district death rates are high and increase interactions when death rates are low.

c) **Better adherence to NPIs regardless of death rate** is incorporated to reflect the population's will to adhere to NPIs regardless of a national directive to do so, or at a time when restrictions are being relaxed. This is modelled by assuming that the level of adherance to NPIs in Level 4 (measured by population contact rate) does not increase when restrictions were relaxed to Level 3 and beyond.

d) **Behavioural heterogeneity** acknowledges that some members of society experience different risks and exhibit heterogeneous/ different behavioural patterns, introducing substantial variation in the number of people that different people infect, with highly connected individuals becoming infected earlier in the epidemic and infecting more contacts. This is modelled through altering the transmission function (force of infection) to be inflated at the start of the epidemic, but decrease as immunity builds up in the most connected individuals early on.

Table 1 summarises how we implemented each of these scenarios by changing model parameters; Figure 2 shows the results for projected Covid-19 deaths in the Western Cape. It is probable that the explanation for the earlier-than-projected plateauing of admissions and deaths in the Western Cape is a combination of these factors, and there is not as enough evidence in the international literature or local data for any of these factors. Nonetheless, we ran a number of scenario analyses to see how well these factors would explain the early plateau in the Western Cape, and what the impact of similar phenomena in the three provinces with the most progressed epidemics over the next months would be.

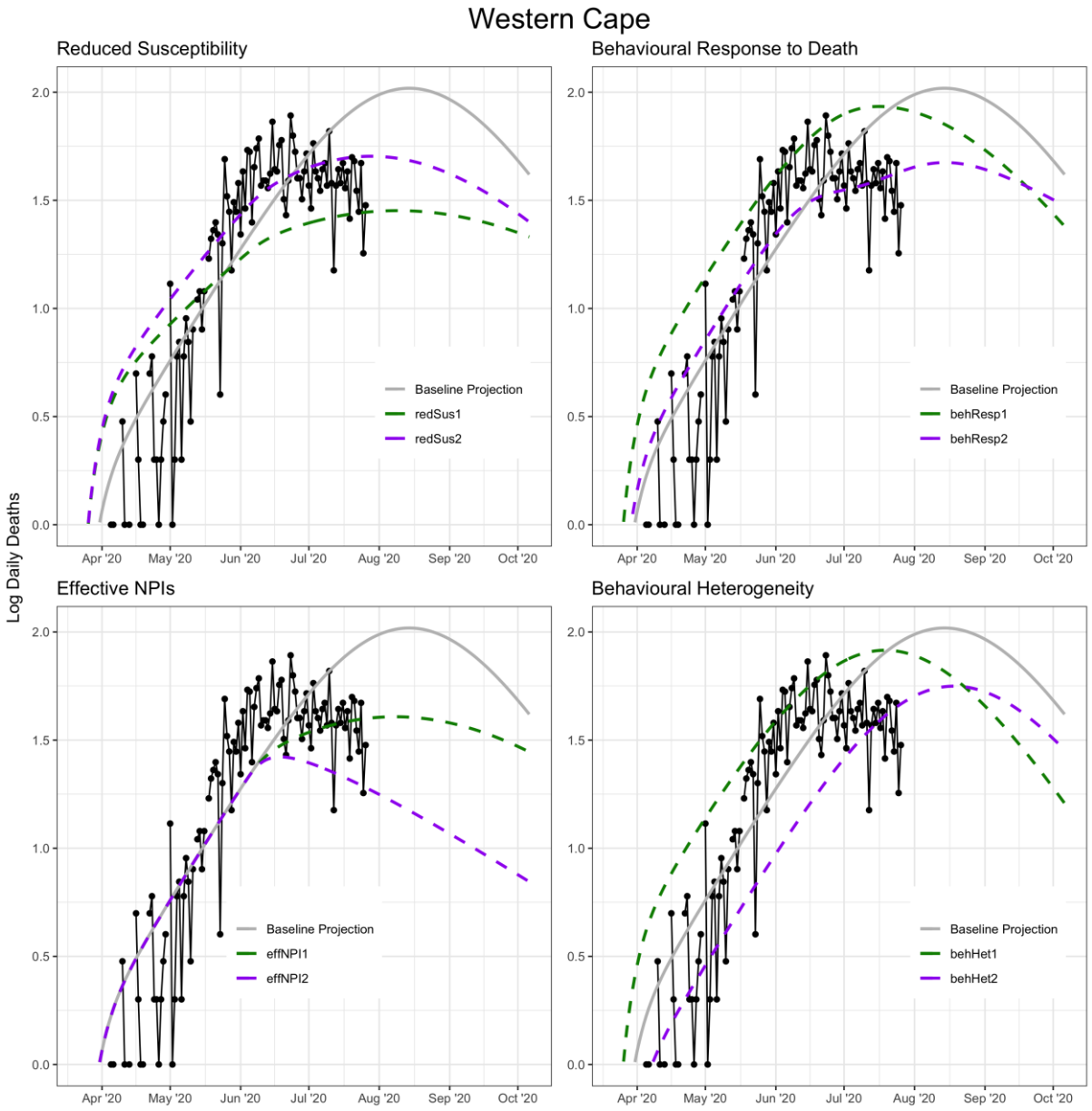
Note that the purpose of the analysis is to demonstrate how each one of these phenomena may be a possible explanation for the observed trends in the Western Cape, rather than attempting to find a best fitting parameter set for each phenomenon.

Table 1: Scenario parameters

Scenario	Description
Reduced susceptibility	
redSus1	12.5% of the population assumed to be completely immune to infection. Additional curvature achieved by assuming a further 20% reduction in contacts from Level 3 restrictions. (Asymptomatic proportion: 0.75)
redSus2	6% of the population assumed to be completely immune to infection. (Asymptomatic proportion: 0.75)

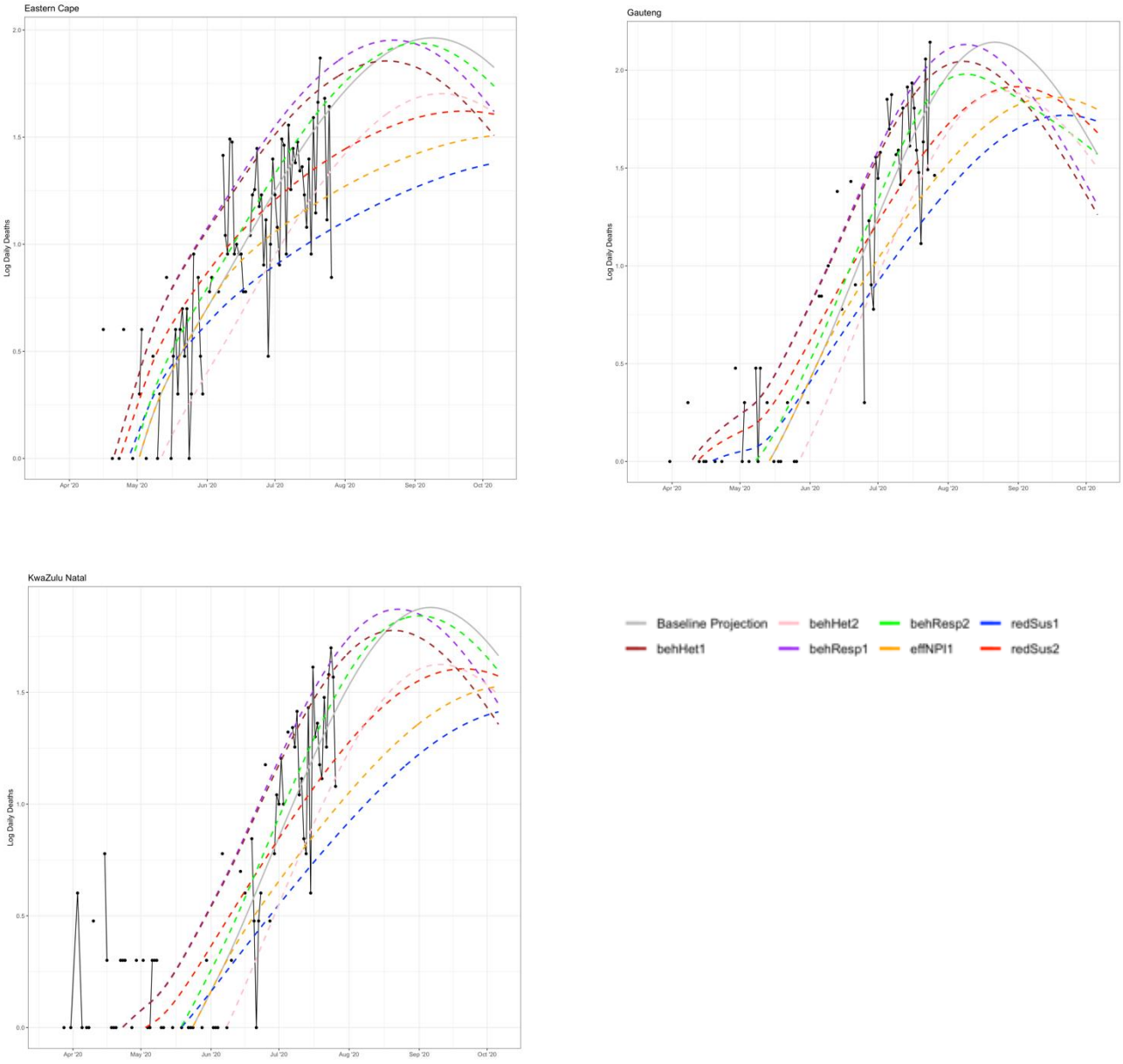
	Note that different combinations of asymptomatic proportion and immune proportion can yield similar results.
Behaviour response to high mortality	
behResp1	Half-saturation point / response threshold is assumed to be 110 deaths per day
behResp2	Half-saturation point / response threshold is assumed to be 30 deaths per day with a reduced seed
Better adherence to NPIs	
effNPI1	Average contacts during level 4 decreased to 80% during level 3 and beyond
effNP!2	Average contacts during level 4 decreased to 65% during level 3 and beyond
Behavioural heterogeneity	
behHet1	Concavity parameter k = 0.3, with increased seed
behHet2	Concavity parameter k=1, with reduced seed

Figure 2: Impact of alternative scenarios on current and projected deaths in the Western Cape



When applying each scenario to the three provinces with the next most advanced epidemics, Eastern Cape, Gauteng and KwaZulu-Natal, we noticed that each in turn led to either later or lower peaking of cases than our original projections, with the exception of the behResp1 scenario, the behaviour response to high mortality scenario in which the behavioural response threshold is assumed to be 110 deaths per day, which peaked at roughly the same level but shifted the peak forward slightly in all three provinces (Figure 3).

Figure 3: Impact of alternative scenarios on current and projected deaths in the Eastern Cape, Gauteng and KwaZulu-Natal



Based on these analyses, we chose to include the notion of behavioural heterogeneity as the most plausible explanation as it is a known infectious disease phenomenon that is broadly true of all social contact networks.

Findings: Projected national cases and resource needs (May 2020 – Jan 2021)

Figure 4 summarises our projected cumulative detected cases at the national level assuming the current testing policy (blue) and a limited policy of detecting only hospitalised cases from mid-June (orange), required ICU and non-ICU beds, as well as total COVID-19 deaths. Importantly, a change in the testing policy only affects the number of detected cases, not any of the other projections.

Table 2 gives an overview of our projections at select dates.

The total number of projected cases has been reduced in comparison to the projections from May, owing in part to our update of the reproductive numbers by province and in part to the inclusion of behavioural heterogeneity. Active symptomatic cases are now projected to have peaked in mid-July, i.e., at a time point that is earlier and at a level that is lower than our previously-projected optimistic trend. The model estimates that while continued mass testing across the country would have resulted in approximately 1.2 million detected cases by November, the limited testing scenario of targeting diagnoses in inpatient settings would have resulted in approximately 550,000 detected cases (median 567,500 cases (range, 447,800-707,100) in early November).

The current number of detected Covid-19 cases is at the upper bound of the projected limited testing scenario. For the estimation of hospital bed requirements, scenarios of both the estimated *need* and the actual *use* of ICU and non-ICU beds are depicted. The peak number of hospital beds *in use* was estimated to be reached in early-August, at around 8,000 general hospital and 1,100 ICU beds (when around 12,500 general and around 2,000 ICU beds would have been *needed*). While hospital-based deaths are projected to be approximately 16,000 by November, total COVID-19 deaths occurring both in and out of hospital assuming that 80% of estimate excess deaths are due to COVID-19, are projected to be approximately 37,000 by November.

Figure 4: Projected cases and inpatient bed need and use at the national level. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

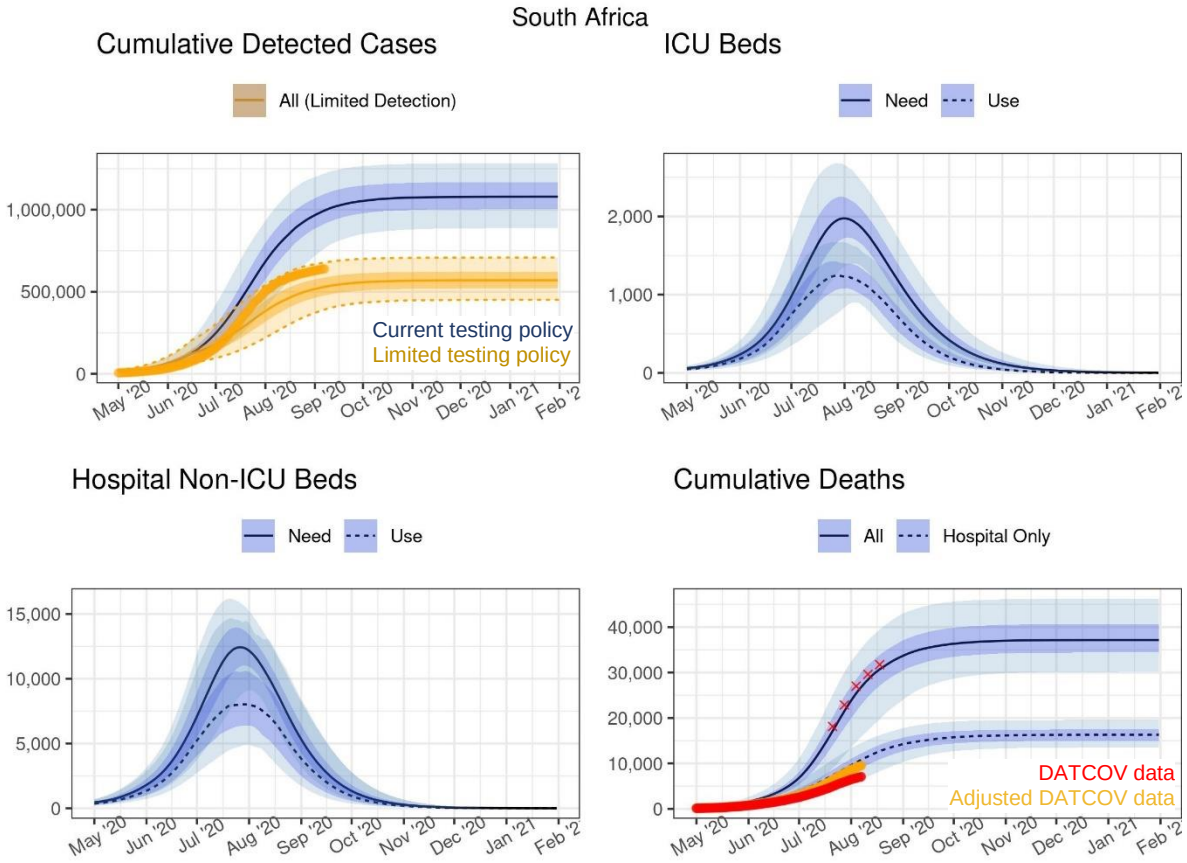


Table 2: Projections of national cases, deaths and resources needed at select dates (Main scenario)

Table for SA

2020-09-01 to 2021-02-02

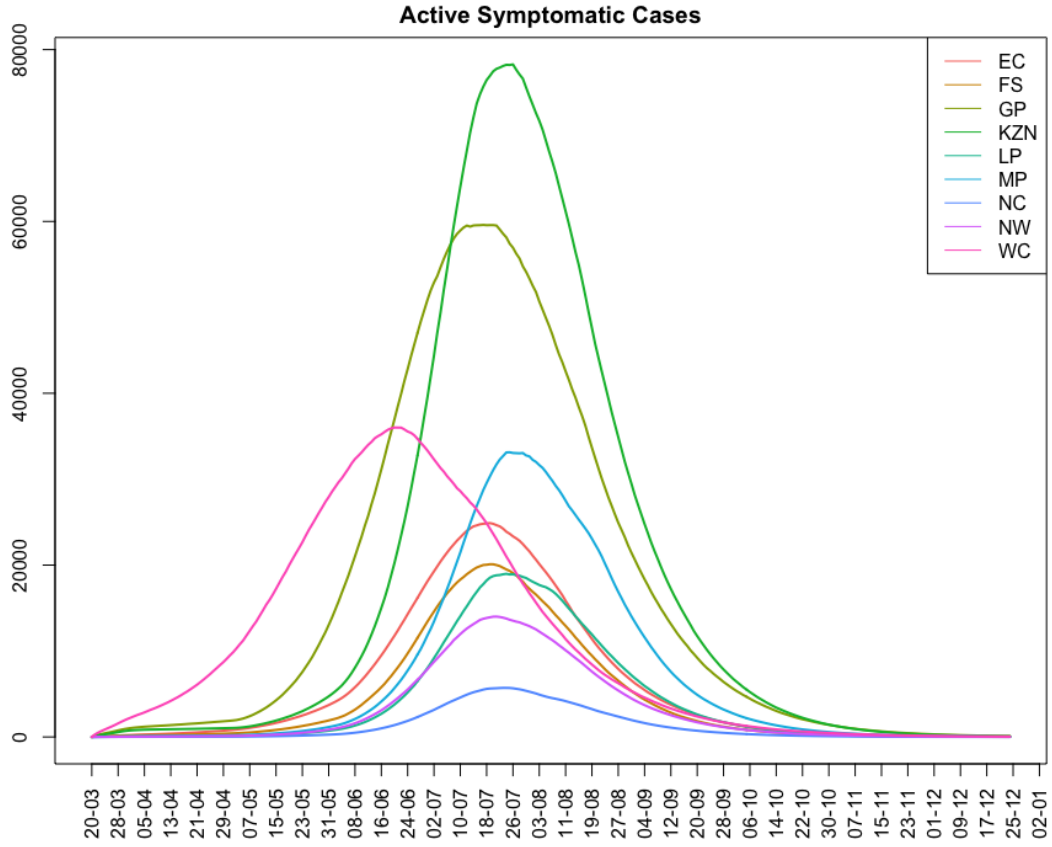
Date	Cumulative Incidence		Active Cases		Cumulative Detected Cases
	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	15,201,000 (13,138,000 - 17,023,000)	3,697,800 (2,835,700 - 4,521,500)	462,600 (267,000 - 817,800)	85,260 (46,810 - 151,500)	517,000 (372,000 - 668,300)
2020-10-01	15,840,000 (14,112,000 - 17,488,000)	3,914,700 (3,172,100 - 4,688,100)	102,300 (54,020 - 238,000)	19,320 (9,730 - 47,560)	557,800 (433,500 - 700,400)
2020-11-01	15,977,000 (14,415,000 - 17,581,000)	3,961,300 (3,246,400 - 4,720,300)	20,840 (10,210 - 52,710)	3,950 (1,840 - 10,690)	567,500 (447,800 - 707,100)
2020-12-01	16,004,000 (14,480,000 - 17,596,000)	3,970,400 (3,260,300 - 4,727,800)	4,510 (2,050 - 11,990)	860 (370 - 2,500)	569,300 (450,400 - 708,600)
2021-01-01	16,010,000 (14,499,000 - 17,599,000)	3,972,000 (3,263,400 - 4,729,700)	950 (390 - 2,700)	180 (70 - 570)	569,800 (451,000 - 708,900)
2021-02-01	16,011,000 (14,501,000 - 17,600,000)	3,972,400 (3,264,000 - 4,730,000)	210 (70 - 650)	40 (10 - 140)	569,900 (451,200 - 709,000)

Date	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	97,500 (73,290 - 121,400)	11,940 (9,010 - 15,060)	3,830 (1,720 - 8,410)	720 (400 - 1,090)	14,250 (10,300 - 17,760)	33,710 (24,020 - 43,010)
2020-10-01	105,700 (85,730 - 127,400)	12,950 (10,550 - 15,860)	950 (360 - 2,810)	200 (90 - 430)	15,740 (12,680 - 19,210)	36,330 (28,640 - 45,600)
2020-11-01	107,800 (88,740 - 128,900)	13,190 (10,900 - 16,110)	190 (70 - 680)	40 (10 - 130)	16,170 (13,320 - 19,510)	37,000 (29,850 - 46,140)
2020-12-01	108,200 (89,310 - 129,300)	13,240 (10,970 - 16,150)	40 (10 - 160)	<10 (<10 - 40)	16,260 (13,460 - 19,570)	37,140 (30,120 - 46,230)
2021-01-01	108,300 (89,420 - 129,400)	13,250 (10,980 - 16,160)	<10 (<10 - 40)	<10 (<10 - <10)	16,290 (13,490 - 19,580)	37,160 (30,170 - 46,260)
2021-02-01	108,300 (89,450 - 129,400)	13,260 (10,980 - 16,160)	<10 (<10 - <10)	<10 (<10 - <10)	16,300 (13,500 - 19,580)	37,170 (30,180 - 46,260)

Findings: Provincial variability

Owing to our updates of the reproductive number, and the fact that we had enough data to allow it to vary in each province, we now see considerable increased variation in the projected timing and height of peak infection between the provinces (Figure 5). This means that the strain on healthcare resources is more spread out, potentially allowing for more healthcare capacity if resources such as beds, oxygen, test kits and reagents and staff can be shifted between provinces (and within provinces, patients needing hospitalisation can be moved between under- and better resourced districts).

Figure 5: Development of active symptomatic cases by province



Findings: Projected provincial cases and resource needs in the next six months (May 2020 – Jan 2021)

Across provinces, projections of deaths and cases requiring hospitalisation are lower than our previous sets of estimates (Figures 6-14 and Tables 3-11). Across provinces, estimates of all Covid-19 related deaths are almost double those of the reported Covid-19 related deaths occurring in hospital which the DATCOV dataset aims to capture, and the number of hospital beds that we estimated would have been needed are more than those estimated to have been used over the last weeks, with the largest difference in the Eastern Cape where more than twice as many ICU beds would have been required.

Figure 6: Projections of cases, deaths and resources needed: Eastern Cape. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

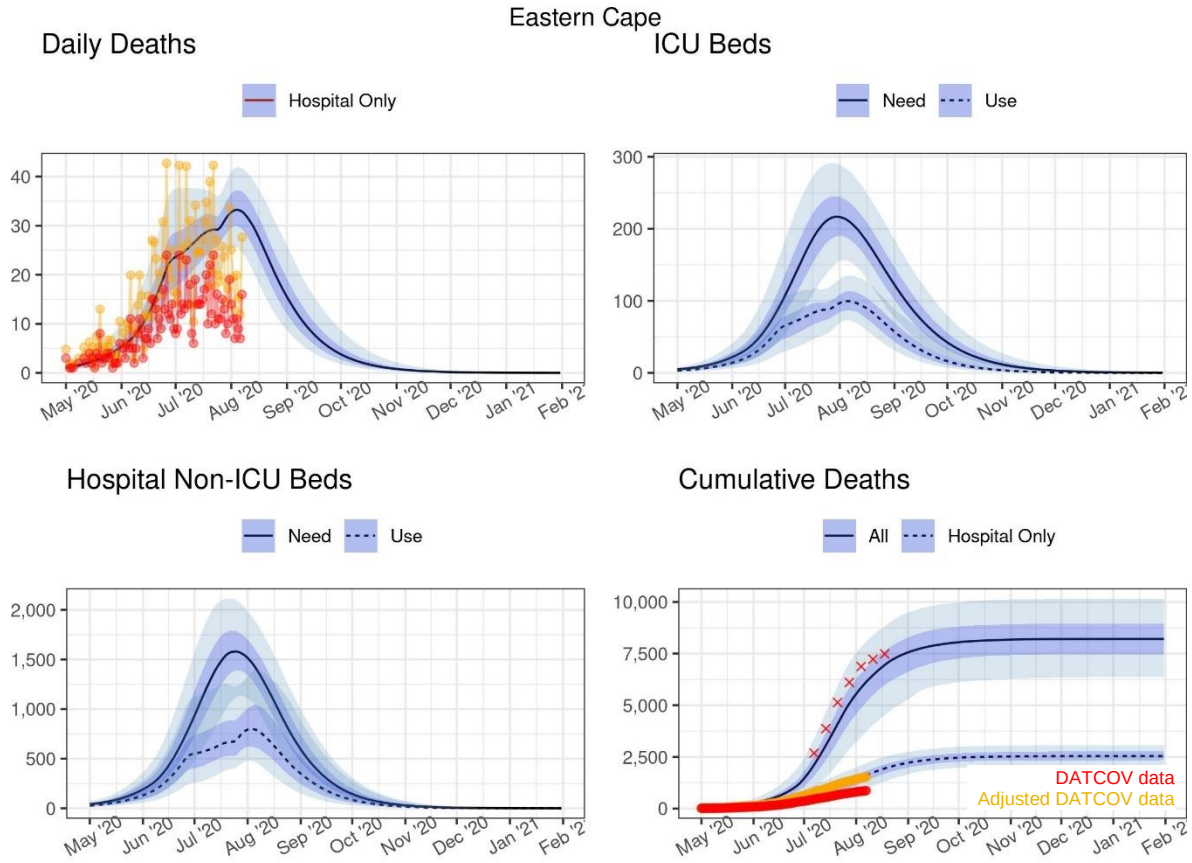


Table 3: Projections of cases, deaths and resources needed at select dates: Eastern Cape

Table for EC

2020-09-01 to 2021-02-02

Date	Cumulative Incidence		Active Cases		Cumulative Detected Cases
	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	1,227,300 (1,040,500 - 1,363,400)	300,500 (228,900 - 358,100)	33,190 (18,620 - 58,770)	6,350 (3,420 - 11,480)	42,290 (30,830 - 53,260)
2020-10-01	1,267,200 (1,141,700 - 1,392,700)	314,200 (252,000 - 371,300)	7,560 (3,700 - 16,700)	1,460 (680 - 3,350)	45,060 (34,750 - 55,950)
2020-11-01	1,276,300 (1,166,600 - 1,399,200)	317,600 (257,500 - 374,800)	1,550 (680 - 3,960)	300 (120 - 780)	45,800 (35,790 - 56,610)
2020-12-01	1,278,000 (1,171,900 - 1,400,900)	318,200 (258,900 - 375,500)	340 (130 - 960)	70 (20 - 190)	45,940 (36,050 - 56,770)
2021-01-01	1,278,500 (1,173,100 - 1,401,100)	318,400 (259,400 - 375,700)	70 (20 - 220)	10 (<10 - 50)	45,970 (36,120 - 56,800)
2021-02-01	1,278,600 (1,173,400 - 1,401,200)	318,400 (259,400 - 375,700)	20 (<10 - 60)	<10 (<10 - 20)	45,980 (36,130 - 56,810)

Date	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	9,410 (7,320 - 11,470)	840 (640 - 1,020)	350 (150 - 890)	60 (30 - 90)	2,220 (1,660 - 2,740)	7,570 (5,290 - 9,490)
2020-10-01	10,130 (8,230 - 12,150)	910 (730 - 1,090)	90 (30 - 280)	20 (<10 - 40)	2,460 (1,980 - 2,990)	8,050 (6,120 - 9,990)
2020-11-01	10,310 (8,440 - 12,300)	930 (740 - 1,110)	20 (<10 - 70)	<10 (<10 - <10)	2,520 (2,050 - 3,050)	8,180 (6,270 - 10,130)
2020-12-01	10,350 (8,480 - 12,340)	930 (750 - 1,110)	<10 (<10 - 20)	<10 (<10 - <10)	2,540 (2,060 - 3,060)	8,200 (6,340 - 10,160)
2021-01-01	10,350 (8,490 - 12,340)	930 (750 - 1,110)	<10 (<10 - <10)	<10 (<10 - <10)	2,540 (2,060 - 3,060)	8,210 (6,360 - 10,160)
2021-02-01	10,350 (8,490 - 12,350)	930 (750 - 1,110)	<10 (<10 - <10)	<10 (<10 - <10)	2,540 (2,060 - 3,060)	8,210 (6,370 - 10,160)

Figure 7: Projections of cases, deaths and resources needed: Free State. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

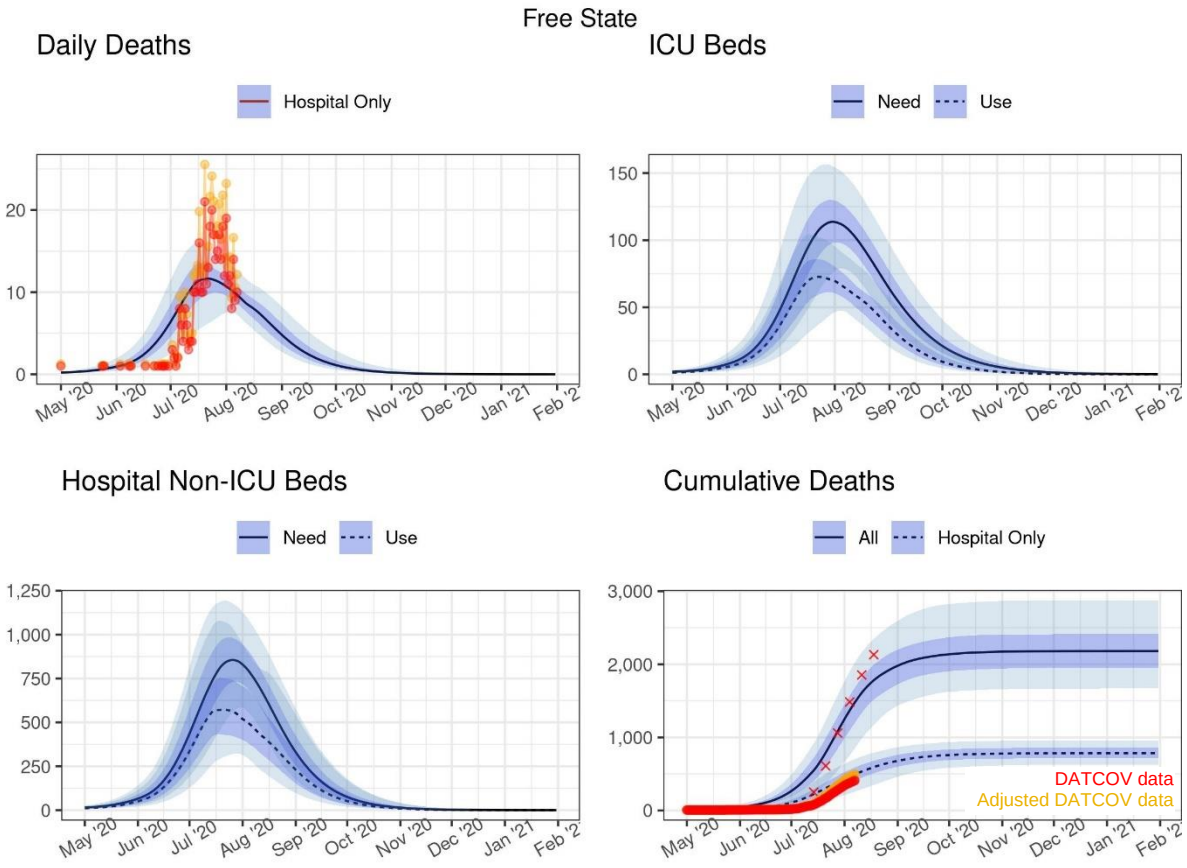


Table 4: Projections of cases, deaths and resources needed at select dates: Free State

Table for FS

2020-09-01 to 2021-02-02

Date	Cumulative Incidence		Active Cases		Cumulative Detected Cases
	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	932,500 (779,700 - 1,057,100)	229,500 (170,800 - 277,700)	27,310 (15,350 - 53,870)	5,160 (2,740 - 9,860)	30,520 (21,400 - 38,990)
2020-10-01	969,400 (861,500 - 1,075,800)	241,100 (189,400 - 288,000)	5,760 (2,670 - 14,970)	1,080 (490 - 2,980)	32,660 (24,760 - 40,880)
2020-11-01	977,800 (878,900 - 1,079,900)	243,800 (194,100 - 290,300)	1,100 (430 - 3,360)	200 (80 - 670)	33,190 (25,680 - 41,350)
2020-12-01	979,300 (882,400 - 1,080,600)	244,400 (195,000 - 290,700)	220 (70 - 790)	40 (10 - 160)	33,270 (25,840 - 41,440)
2021-01-01	979,600 (883,300 - 1,080,700)	244,500 (195,300 - 290,800)	40 (10 - 180)	<10 (<10 - 40)	33,290 (25,870 - 41,450)
2021-02-01	979,700 (883,500 - 1,080,800)	244,600 (195,300 - 290,800)	<10 (<10 - 40)	<10 (<10 - <10)	33,300 (25,880 - 41,460)

Date	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	6,150 (4,510 - 7,630)	620 (440 - 800)	230 (90 - 550)	40 (20 - 60)	680 (460 - 870)	1,980 (1,430 - 2,600)
2020-10-01	6,600 (5,190 - 7,970)	670 (520 - 840)	50 (10 - 180)	<10 (<10 - 30)	760 (580 - 940)	2,140 (1,620 - 2,830)
2020-11-01	6,700 (5,360 - 8,040)	680 (540 - 850)	<10 (<10 - 50)	<10 (<10 - <10)	780 (610 - 960)	2,170 (1,650 - 2,870)
2020-12-01	6,720 (5,380 - 8,060)	680 (540 - 850)	<10 (<10 - <10)	<10 (<10 - <10)	780 (620 - 960)	2,180 (1,660 - 2,880)
2021-01-01	6,730 (5,390 - 8,060)	680 (540 - 850)	<10 (<10 - <10)	<10 (<10 - <10)	780 (620 - 960)	2,180 (1,660 - 2,880)
2021-02-01	6,730 (5,390 - 8,060)	680 (540 - 850)	<10 (<10 - <10)	<10 (<10 - <10)	780 (620 - 960)	2,180 (1,660 - 2,880)

Figure 8: Projections of cases, deaths and resources needed: Gauteng. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

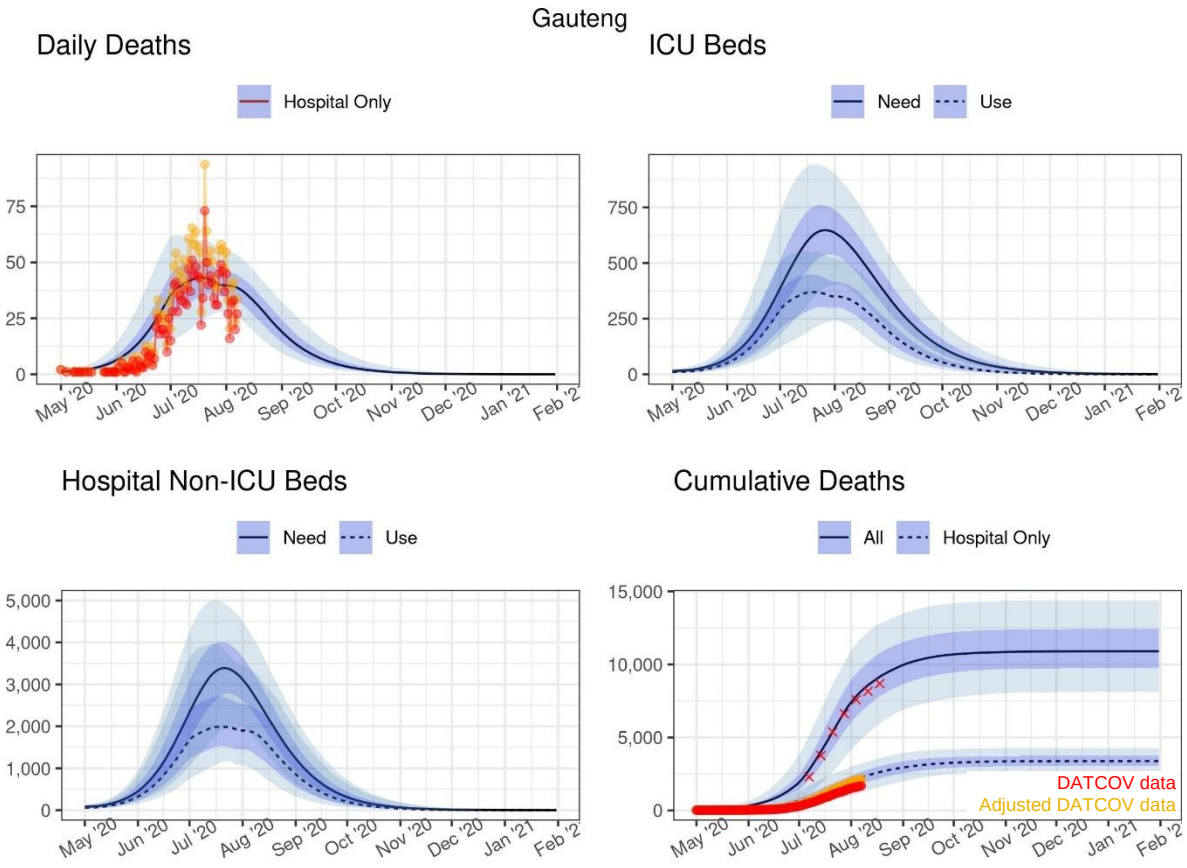


Table 5: Projections of cases, deaths and resources needed at select dates: Gauteng

Table for GP

2020-09-01 to 2021-02-02

	Cumulative Incidence		Active Cases		Cumulative Detected Cases
Date	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	3,736,400 (2,950,000 - 4,340,800)	898,300 (661,100 - 1,154,000)	96,890 (48,840 - 183,400)	18,470 (8,920 - 34,710)	125,600 (87,450 - 174,200)
2020-10-01	3,878,400 (3,199,900 - 4,413,800)	948,000 (746,600 - 1,184,700)	22,150 (9,420 - 58,440)	4,200 (1,770 - 11,320)	134,400 (100,700 - 181,200)
2020-11-01	3,905,100 (3,267,700 - 4,429,100)	960,700 (762,600 - 1,192,400)	4,450 (1,700 - 15,180)	860 (310 - 3,050)	136,900 (104,400 - 182,600)
2020-12-01	3,911,900 (3,281,900 - 4,433,000)	964,000 (766,800 - 1,193,900)	950 (300 - 3,900)	180 (50 - 790)	137,500 (105,100 - 182,900)
2021-01-01	3,913,400 (3,285,800 - 4,433,500)	964,800 (767,400 - 1,194,100)	190 (50 - 950)	40 (10 - 200)	137,600 (105,300 - 183,000)
2021-02-01	3,913,700 (3,286,900 - 4,433,600)	965,000 (767,500 - 1,194,200)	40 (<10 - 230)	<10 (<10 - 50)	137,700 (105,300 - 183,000)

	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
Date	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	24,670 (17,930 - 32,230)	3,790 (2,680 - 5,040)	860 (330 - 1,920)	190 (90 - 330)	2,940 (1,990 - 3,940)	9,970 (6,890 - 13,490)
2020-10-01	26,450 (20,650 - 33,830)	4,110 (3,150 - 5,260)	200 (70 - 640)	50 (20 - 130)	3,270 (2,500 - 4,210)	10,690 (7,710 - 14,180)
2020-11-01	26,980 (21,340 - 34,170)	4,180 (3,250 - 5,300)	40 (10 - 180)	10 (<10 - 40)	3,360 (2,640 - 4,260)	10,850 (8,030 - 14,350)
2020-12-01	27,120 (21,480 - 34,240)	4,200 (3,270 - 5,310)	<10 (<10 - 50)	<10 (<10 - <10)	3,380 (2,670 - 4,270)	10,890 (8,100 - 14,390)
2021-01-01	27,160 (21,520 - 34,250)	4,210 (3,270 - 5,310)	<10 (<10 - 20)	<10 (<10 - <10)	3,380 (2,670 - 4,280)	10,900 (8,120 - 14,390)
2021-02-01	27,170 (21,540 - 34,250)	4,210 (3,280 - 5,310)	<10 (<10 - <10)	<10 (<10 - <10)	3,380 (2,680 - 4,280)	10,900 (8,130 - 14,390)

Figure 9: Projections of cases, deaths and resources needed: KwaZulu-Natal. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

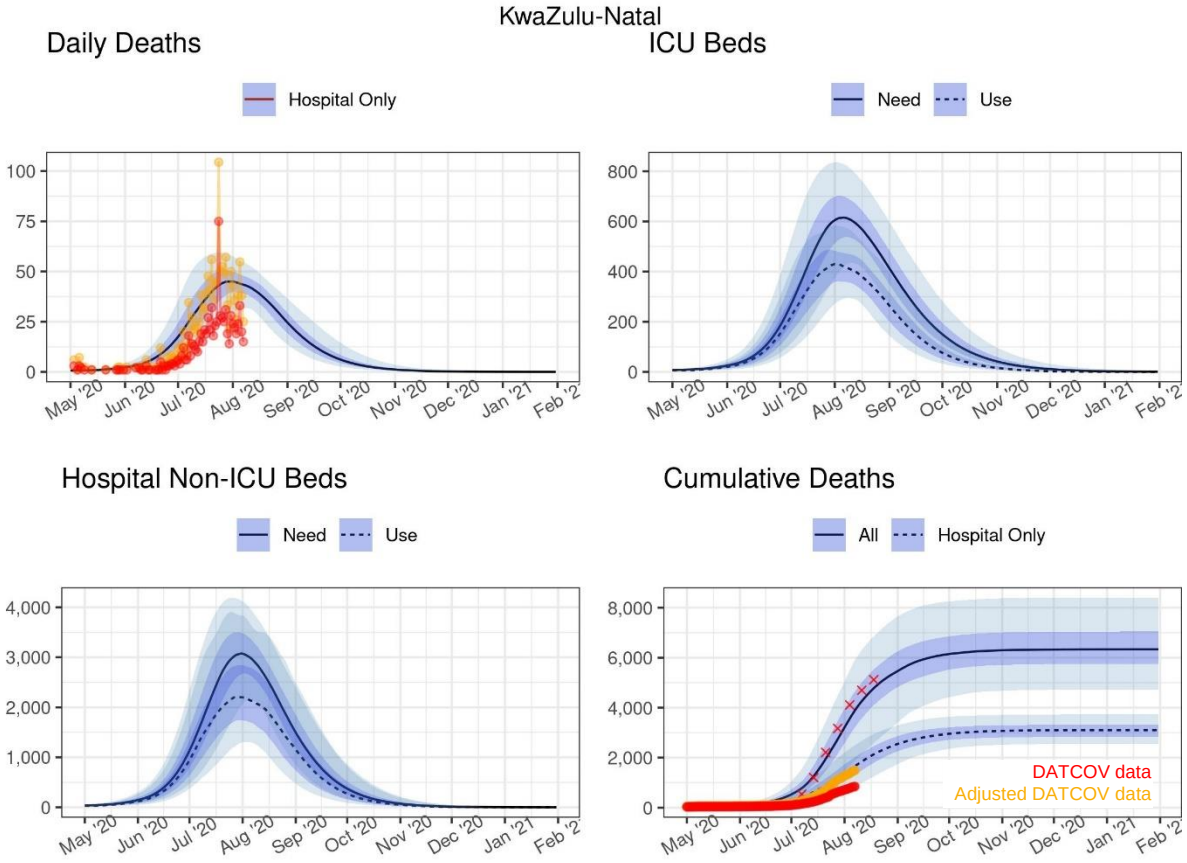


Table 6: Projections of cases, deaths and resources needed at select dates: KwaZulu-Natal

Table for KZN

2020-09-01 to 2021-02-02

	Cumulative Incidence		Active Cases		Cumulative Detected Cases
Date	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	3,690,700 (3,071,500 - 4,114,900)	893,500 (671,100 - 1,104,500)	141,300 (76,480 - 254,000)	26,670 (13,600 - 47,190)	114,700 (81,580 - 147,100)
2020-10-01	3,865,400 (3,493,000 - 4,238,800)	954,600 (767,600 - 1,152,800)	29,740 (13,860 - 76,590)	5,770 (2,500 - 14,610)	126,300 (98,450 - 156,800)
2020-11-01	3,898,400 (3,557,100 - 4,265,200)	968,500 (794,400 - 1,162,400)	5,490 (2,270 - 17,030)	1,060 (410 - 3,270)	129,100 (103,300 - 158,800)
2020-12-01	3,904,800 (3,569,600 - 4,270,100)	971,000 (798,500 - 1,164,100)	1,070 (370 - 3,700)	210 (70 - 740)	129,600 (104,100 - 159,200)
2021-01-01	3,906,300 (3,573,200 - 4,271,300)	971,500 (799,400 - 1,164,500)	200 (50 - 760)	40 (10 - 160)	129,700 (104,300 - 159,300)
2021-02-01	3,906,500 (3,574,000 - 4,271,500)	971,500 (799,600 - 1,164,600)	40 (<10 - 160)	<10 (<10 - 40)	129,700 (104,300 - 159,300)

	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
Date	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	22,680 (16,820 - 27,920)	3,410 (2,540 - 4,330)	1,160 (470 - 2,500)	260 (140 - 400)	2,550 (1,740 - 3,290)	5,470 (3,410 - 7,660)
2020-10-01	25,030 (20,080 - 29,900)	3,750 (3,060 - 4,620)	270 (90 - 870)	80 (30 - 160)	2,960 (2,350 - 3,640)	6,150 (4,410 - 8,260)
2020-11-01	25,610 (20,980 - 30,250)	3,850 (3,210 - 4,690)	50 (10 - 220)	20 (<10 - 50)	3,070 (2,510 - 3,720)	6,300 (4,670 - 8,380)
2020-12-01	25,730 (21,160 - 30,300)	3,870 (3,220 - 4,710)	<10 (<10 - 50)	<10 (<10 - 20)	3,090 (2,550 - 3,730)	6,330 (4,710 - 8,400)
2021-01-01	25,750 (21,200 - 30,320)	3,870 (3,230 - 4,710)	<10 (<10 - <10)	<10 (<10 - <10)	3,100 (2,550 - 3,740)	6,330 (4,720 - 8,410)
2021-02-01	25,750 (21,210 - 30,320)	3,870 (3,230 - 4,710)	<10 (<10 - <10)	<10 (<10 - <10)	3,100 (2,560 - 3,740)	6,340 (4,720 - 8,410)

Figure 10: Projections of cases, deaths and resources needed: Limpopo. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

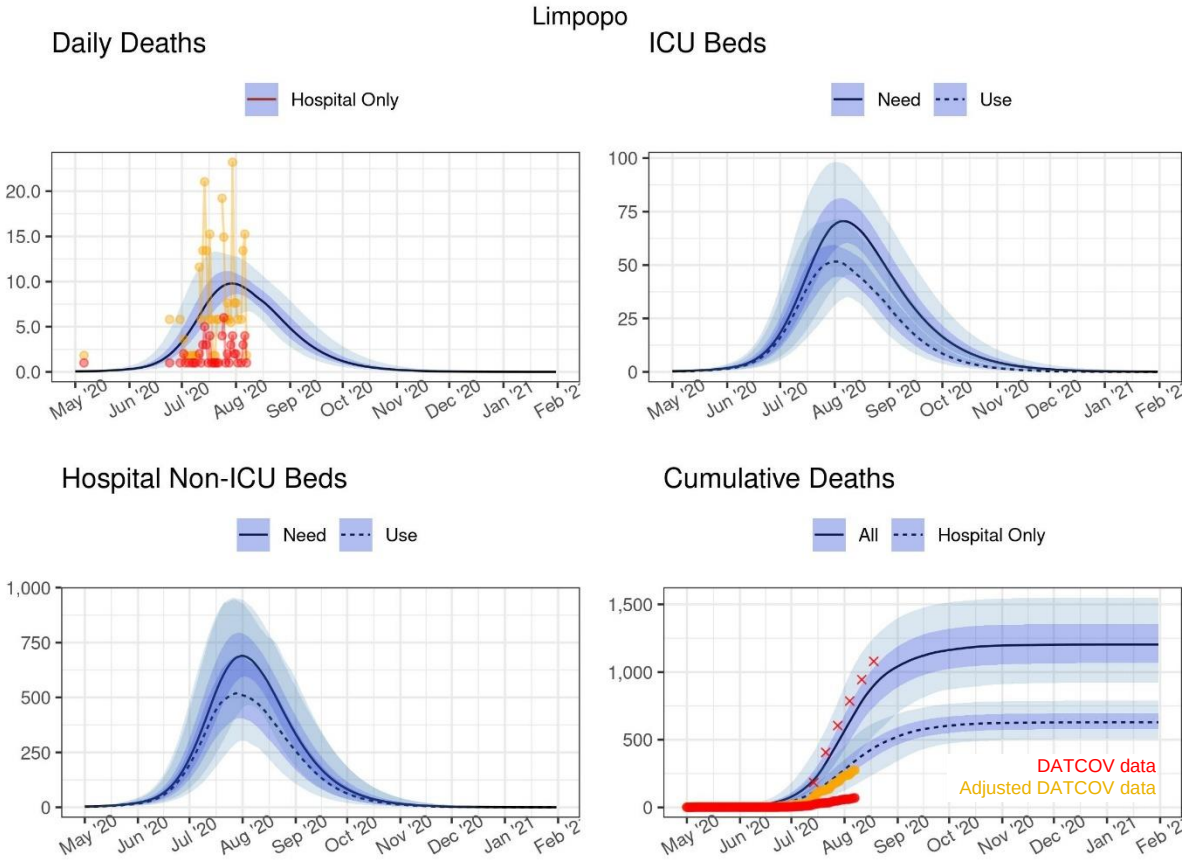


Table 7: Projections of cases, deaths and resources needed at select dates: Limpopo

Table for LP

2020-09-01 to 2021-02-02

	Cumulative Incidence		Active Cases		Cumulative Detected Cases
Date	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	844,000 (695,100 - 960,700)	204,200 (154,500 - 252,700)	32,560 (18,000 - 61,860)	6,190 (3,290 - 11,130)	25,400 (17,840 - 32,930)
2020-10-01	888,800 (781,500 - 987,800)	218,500 (177,900 - 265,100)	7,090 (3,210 - 18,380)	1,340 (600 - 3,470)	28,040 (22,270 - 35,110)
2020-11-01	899,600 (803,500 - 994,500)	221,800 (183,400 - 268,200)	1,350 (520 - 3,910)	260 (90 - 760)	28,670 (23,230 - 35,710)
2020-12-01	901,800 (806,800 - 995,700)	222,600 (184,500 - 268,900)	270 (90 - 860)	50 (10 - 170)	28,830 (23,410 - 35,830)
2021-01-01	902,400 (807,600 - 995,900)	222,800 (184,700 - 269,000)	50 (10 - 190)	10 (<10 - 40)	28,860 (23,440 - 35,850)
2021-02-01	902,500 (807,700 - 996,000)	222,800 (184,700 - 269,000)	10 (<10 - 50)	<10 (<10 - <10)	28,860 (23,450 - 35,850)

	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
Date	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	5,160 (3,690 - 6,630)	410 (280 - 530)	260 (100 - 590)	30 (10 - 50)	520 (340 - 700)	1,040 (690 - 1,400)
2020-10-01	5,660 (4,500 - 7,040)	450 (340 - 560)	60 (20 - 190)	<10 (<10 - 20)	600 (470 - 770)	1,160 (870 - 1,520)
2020-11-01	5,810 (4,680 - 7,130)	460 (360 - 570)	10 (<10 - 50)	<10 (<10 - <10)	620 (490 - 790)	1,200 (910 - 1,550)
2020-12-01	5,840 (4,720 - 7,150)	460 (370 - 570)	<10 (<10 - <10)	<10 (<10 - <10)	630 (500 - 790)	1,200 (920 - 1,550)
2021-01-01	5,840 (4,730 - 7,150)	460 (370 - 570)	<10 (<10 - <10)	<10 (<10 - <10)	630 (500 - 790)	1,200 (920 - 1,550)
2021-02-01	5,840 (4,730 - 7,150)	460 (370 - 570)	<10 (<10 - <10)	<10 (<10 - <10)	630 (500 - 790)	1,200 (920 - 1,550)

Figure 11: Projections of cases, deaths and resources needed: Mpumalanga. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

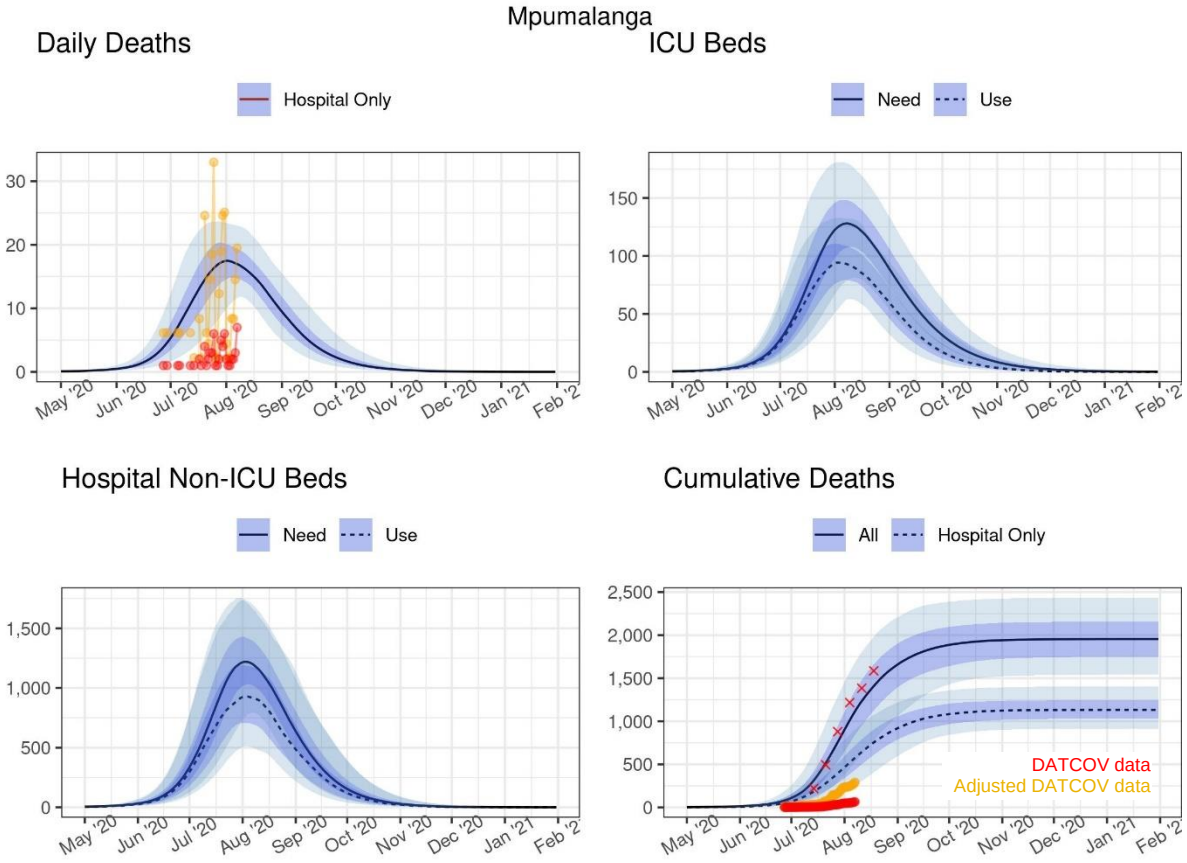


Table 8: Projections of cases, deaths and resources needed at select dates: Mpumalanga

Table for MP

2020-09-01 to 2021-02-02

	Cumulative Incidence		Active Cases		Cumulative Detected Cases
Date	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	1,521,100 (1,213,800 - 1,727,900)	366,400 (264,500 - 455,400)	64,180 (30,740 - 123,400)	12,370 (5,510 - 22,250)	45,050 (30,230 - 58,520)
2020-10-01	1,598,000 (1,399,700 - 1,774,400)	394,400 (321,900 - 474,900)	13,770 (5,240 - 39,700)	2,640 (980 - 7,370)	50,180 (39,850 - 62,280)
2020-11-01	1,614,900 (1,439,400 - 1,782,800)	400,600 (332,500 - 479,000)	2,530 (800 - 8,300)	480 (150 - 1,550)	51,380 (41,840 - 63,170)
2020-12-01	1,618,200 (1,447,100 - 1,784,400)	402,000 (334,200 - 479,700)	500 (120 - 1,720)	100 (20 - 340)	51,630 (42,190 - 63,320)
2021-01-01	1,618,800 (1,448,500 - 1,784,800)	402,400 (334,700 - 479,800)	90 (10 - 360)	20 (<10 - 70)	51,700 (42,270 - 63,350)
2021-02-01	1,619,000 (1,448,900 - 1,784,800)	402,400 (334,800 - 479,800)	20 (<10 - 80)	<10 (<10 - 20)	51,710 (42,290 - 63,360)

	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
Date	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	9,090 (6,330 - 11,560)	730 (510 - 940)	490 (210 - 1,140)	60 (30 - 100)	920 (590 - 1,220)	1,660 (1,060 - 2,210)
2020-10-01	10,050 (8,110 - 12,340)	820 (640 - 1,020)	120 (30 - 400)	20 (<10 - 40)	1,080 (840 - 1,360)	1,890 (1,420 - 2,390)
2020-11-01	10,320 (8,480 - 12,500)	840 (680 - 1,040)	20 (<10 - 90)	<10 (<10 - 20)	1,120 (900 - 1,400)	1,940 (1,520 - 2,430)
2020-12-01	10,360 (8,540 - 12,540)	840 (680 - 1,050)	<10 (<10 - 20)	<10 (<10 - <10)	1,130 (910 - 1,410)	1,950 (1,530 - 2,440)
2021-01-01	10,370 (8,550 - 12,540)	840 (690 - 1,050)	<10 (<10 - <10)	<10 (<10 - <10)	1,130 (910 - 1,410)	1,960 (1,540 - 2,440)
2021-02-01	10,380 (8,550 - 12,550)	840 (690 - 1,050)	<10 (<10 - <10)	<10 (<10 - <10)	1,130 (910 - 1,410)	1,960 (1,540 - 2,440)

Figure 12: Projections of cases, deaths and resources needed: Northern Cape. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

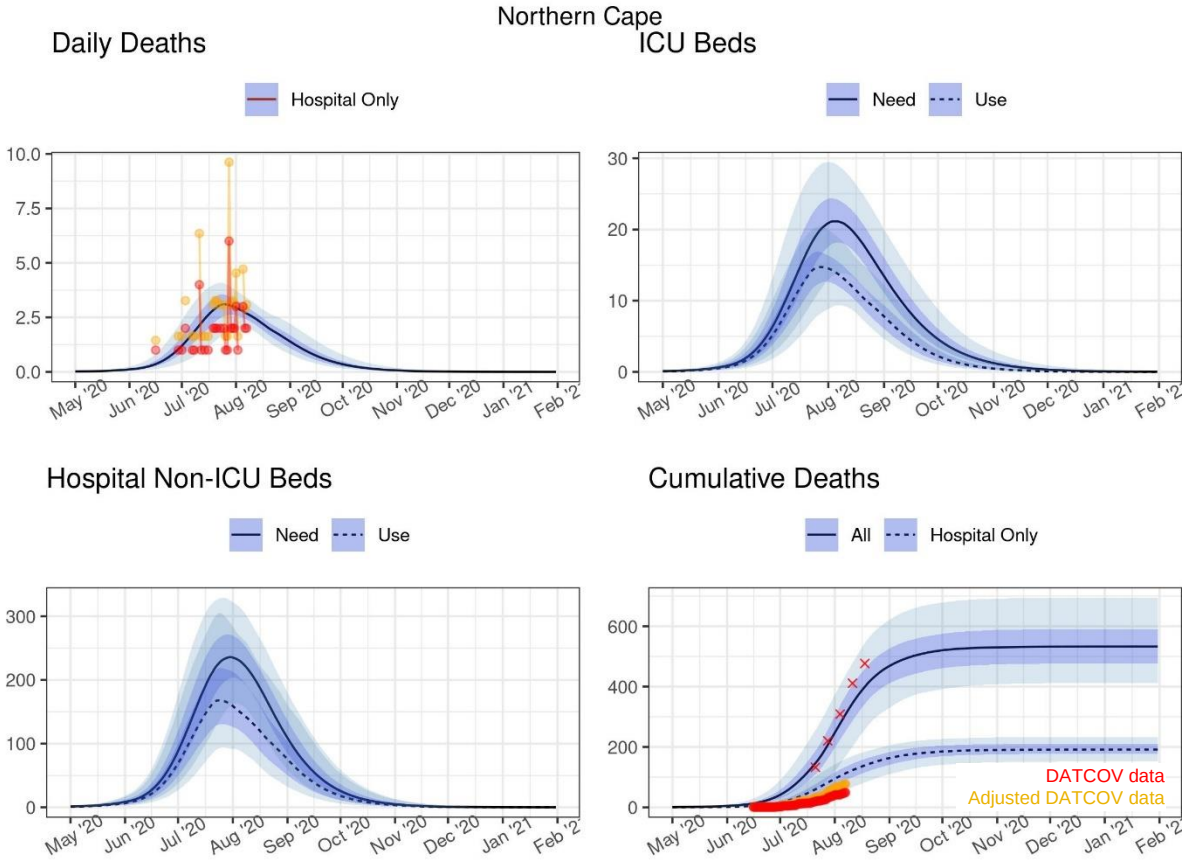


Table 9: Projections of cases, deaths and resources needed at select dates: Northern Cape

Table for NC

2020-09-01 to 2021-02-02

Date	Cumulative Incidence		Active Cases		Cumulative Detected Cases
	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	256,600 (213,000 - 289,100)	62,340 (45,950 - 76,010)	9,510 (5,210 - 17,580)	1,790 (960 - 3,180)	7,930 (5,560 - 10,030)
2020-10-01	269,600 (238,700 - 296,500)	66,370 (53,180 - 79,320)	1,970 (940 - 4,830)	380 (170 - 950)	8,650 (6,680 - 10,700)
2020-11-01	272,300 (242,900 - 298,100)	67,310 (54,960 - 80,040)	370 (150 - 1,060)	70 (20 - 210)	8,820 (7,010 - 10,850)
2020-12-01	272,800 (243,600 - 298,400)	67,490 (55,260 - 80,230)	70 (20 - 240)	10 (<10 - 50)	8,860 (7,060 - 10,880)
2021-01-01	272,900 (243,800 - 298,500)	67,520 (55,320 - 80,270)	10 (<10 - 50)	<10 (<10 - <10)	8,860 (7,070 - 10,880)
2021-02-01	273,000 (243,800 - 298,500)	67,530 (55,330 - 80,270)	<10 (<10 - 20)	<10 (<10 - <10)	8,860 (7,080 - 10,880)

Date	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	1,670 (1,170 - 2,050)	120 (70 - 150)	80 (30 - 170)	<10 (<10 - 20)	160 (110 - 210)	470 (330 - 630)
2020-10-01	1,810 (1,380 - 2,180)	130 (90 - 160)	20 (<10 - 60)	<10 (<10 - <10)	190 (140 - 230)	520 (390 - 680)
2020-11-01	1,840 (1,440 - 2,210)	130 (90 - 160)	<10 (<10 - 20)	<10 (<10 - <10)	190 (140 - 240)	530 (400 - 700)
2020-12-01	1,850 (1,450 - 2,220)	130 (100 - 160)	<10 (<10 - <10)	<10 (<10 - <10)	190 (150 - 240)	530 (410 - 700)
2021-01-01	1,850 (1,450 - 2,220)	130 (100 - 160)	<10 (<10 - <10)	<10 (<10 - <10)	190 (150 - 240)	530 (410 - 700)
2021-02-01	1,850 (1,450 - 2,220)	130 (100 - 160)	<10 (<10 - <10)	<10 (<10 - <10)	190 (150 - 240)	530 (410 - 700)

Figure 13: Projections of cases, deaths and resources needed: North West. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

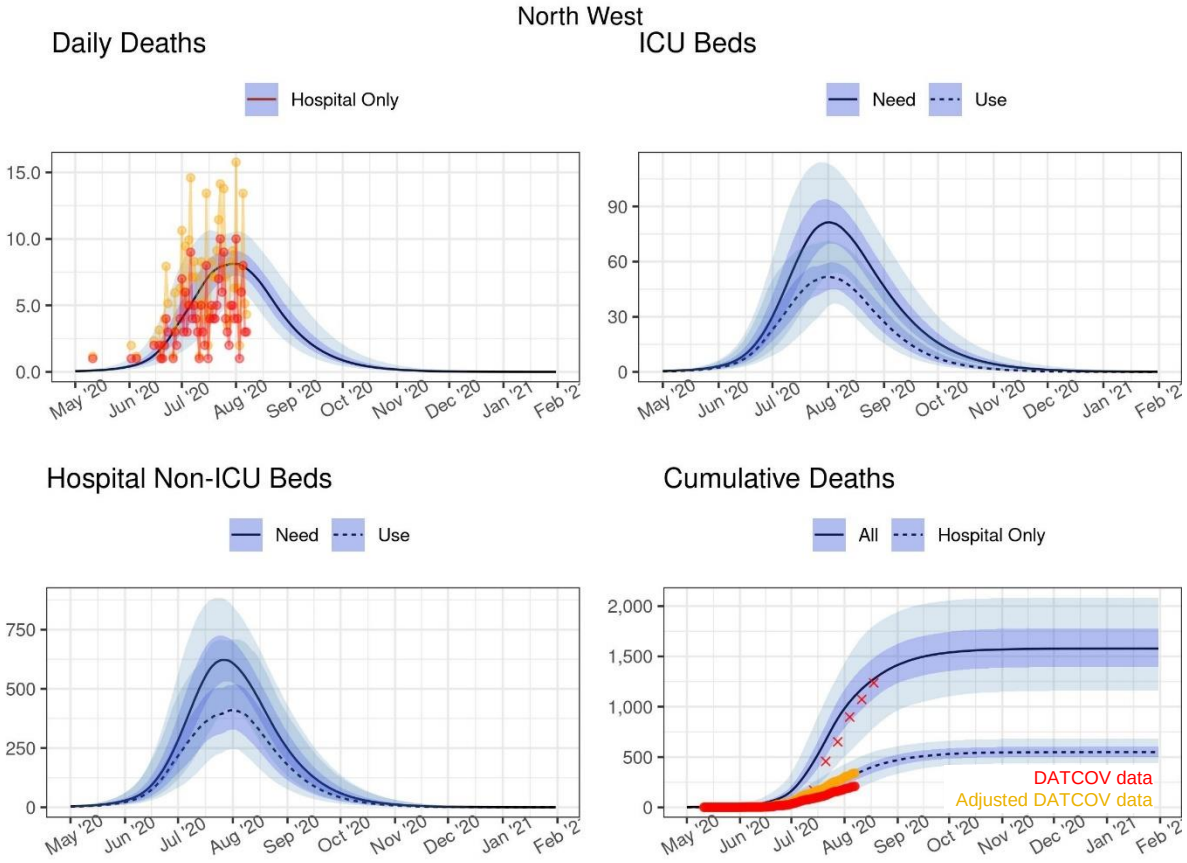


Table 10: Projections of cases, deaths and resources needed at select dates: North West

Table for NW

2020-09-01 to 2021-02-02

Date	Cumulative Incidence		Active Cases		Cumulative Detected Cases
	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	658,200 (555,300 - 740,600)	159,700 (122,100 - 198,400)	20,570 (11,240 - 38,810)	3,900 (2,070 - 7,330)	20,620 (15,030 - 27,020)
2020-10-01	686,700 (610,600 - 764,400)	169,000 (137,100 - 206,600)	4,430 (2,170 - 11,060)	850 (410 - 2,090)	22,230 (17,560 - 28,590)
2020-11-01	693,000 (621,400 - 769,500)	171,500 (141,100 - 208,000)	870 (370 - 2,480)	170 (70 - 490)	22,680 (18,240 - 28,900)
2020-12-01	694,200 (624,200 - 770,200)	171,900 (141,900 - 208,300)	180 (60 - 580)	30 (10 - 120)	22,770 (18,380 - 28,970)
2021-01-01	694,400 (624,800 - 770,400)	172,000 (142,000 - 208,400)	40 (10 - 130)	<10 (<10 - 30)	22,790 (18,410 - 28,980)
2021-02-01	694,500 (624,900 - 770,500)	172,100 (142,100 - 208,400)	<10 (<10 - 30)	<10 (<10 - <10)	22,790 (18,410 - 28,990)

Date	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	4,240 (3,280 - 5,370)	420 (310 - 550)	180 (70 - 400)	30 (10 - 50)	470 (330 - 610)	1,420 (960 - 1,950)
2020-10-01	4,570 (3,690 - 5,680)	460 (370 - 590)	40 (10 - 130)	<10 (<10 - 20)	530 (410 - 670)	1,540 (1,100 - 2,060)
2020-11-01	4,660 (3,790 - 5,760)	470 (380 - 600)	<10 (<10 - 40)	<10 (<10 - <10)	550 (430 - 680)	1,570 (1,140 - 2,080)
2020-12-01	4,680 (3,810 - 5,770)	470 (380 - 600)	<10 (<10 - <10)	<10 (<10 - <10)	550 (430 - 690)	1,580 (1,150 - 2,090)
2021-01-01	4,680 (3,820 - 5,770)	470 (380 - 600)	<10 (<10 - <10)	<10 (<10 - <10)	550 (440 - 690)	1,580 (1,160 - 2,090)
2021-02-01	4,690 (3,820 - 5,770)	470 (380 - 600)	<10 (<10 - <10)	<10 (<10 - <10)	550 (440 - 690)	1,580 (1,160 - 2,090)

Figure 14: Projections of cases, deaths and resources needed: Western Cape. The red crosses in the bottom right-hand panel represents 80% of the excess deaths found in the SAMRC analysis

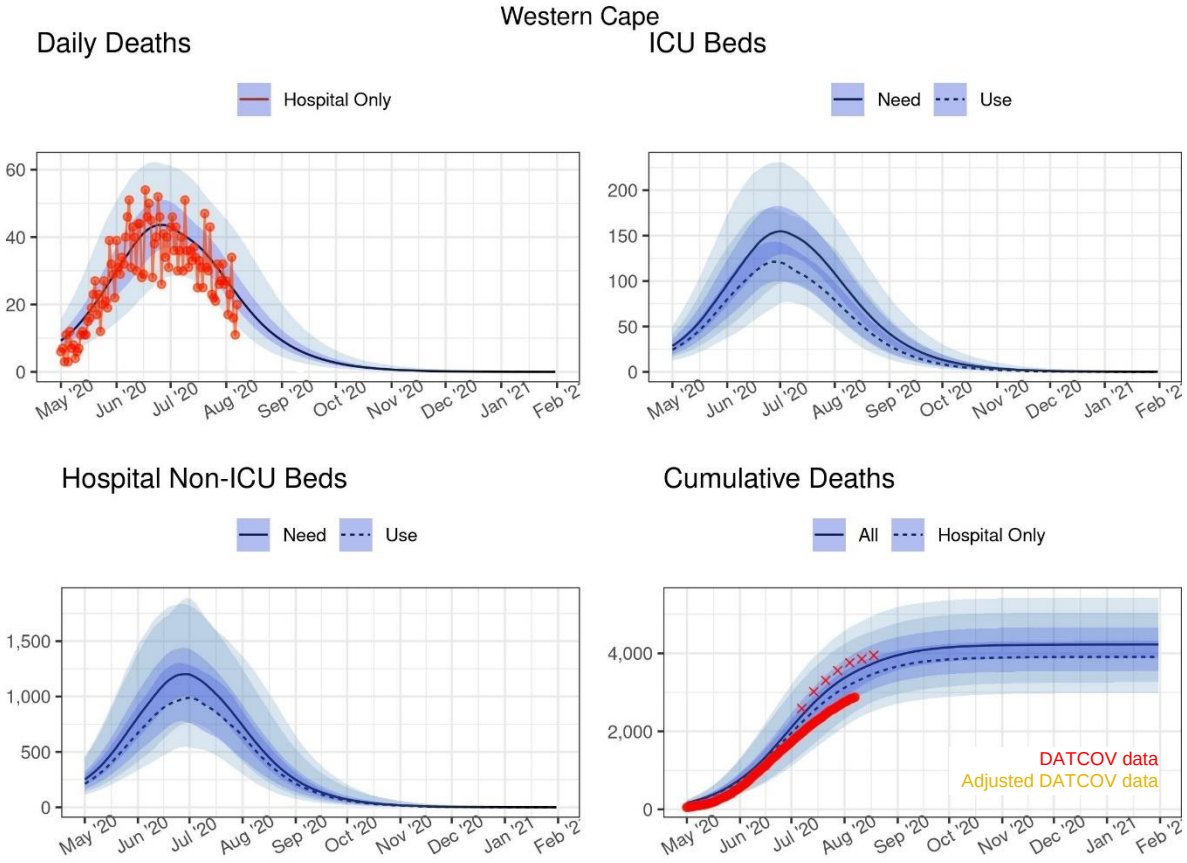


Table 11: Projections of cases, deaths and resources needed at select dates: Western Cape

Table for WC

2020-09-01 to 2021-02-02

Date	Cumulative Incidence		Active Cases		Cumulative Detected Cases
	Total	Symptomatic	All	Symptomatic	Limited Detection
2020-09-01	2,363,400 (2,025,700 - 2,668,500)	580,200 (453,200 - 715,200)	29,760 (13,340 - 58,000)	5,430 (2,410 - 11,330)	104,400 (73,310 - 139,800)
2020-10-01	2,409,300 (2,105,400 - 2,696,300)	596,500 (473,700 - 728,300)	8,240 (3,110 - 19,440)	1,520 (570 - 3,530)	107,300 (76,620 - 142,300)
2020-11-01	2,422,900 (2,133,800 - 2,703,000)	600,900 (481,100 - 731,200)	2,070 (690 - 6,150)	390 (120 - 1,140)	108,000 (77,890 - 142,900)
2020-12-01	2,426,500 (2,143,700 - 2,705,100)	602,100 (483,300 - 732,000)	540 (150 - 2,020)	100 (20 - 380)	108,200 (78,290 - 143,100)
2021-01-01	2,427,700 (2,145,800 - 2,705,700)	602,400 (484,100 - 732,200)	130 (30 - 670)	20 (<10 - 120)	108,300 (78,410 - 143,100)
2021-02-01	2,428,000 (2,146,300 - 2,706,200)	602,500 (484,300 - 732,300)	30 (<10 - 230)	<10 (<10 - 40)	108,300 (78,450 - 143,100)

Date	Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths	
	General	ICU	Non-ICU	ICU	Hospital	All
2020-09-01	14,570 (11,080 - 18,450)	1,630 (1,210 - 2,130)	210 (70 - 650)	30 (10 - 60)	3,670 (2,710 - 4,780)	3,950 (2,950 - 5,190)
2020-10-01	15,110 (11,700 - 18,870)	1,690 (1,290 - 2,190)	60 (10 - 210)	<10 (<10 - 20)	3,840 (2,880 - 4,990)	4,150 (3,150 - 5,370)
2020-11-01	15,250 (11,920 - 19,010)	1,710 (1,310 - 2,210)	20 (<10 - 60)	<10 (<10 - <10)	3,890 (2,950 - 5,030)	4,210 (3,220 - 5,410)
2020-12-01	15,290 (11,990 - 19,050)	1,710 (1,320 - 2,210)	<10 (<10 - 20)	<10 (<10 - <10)	3,900 (2,970 - 5,050)	4,220 (3,240 - 5,430)
2021-01-01	15,300 (12,010 - 19,050)	1,710 (1,320 - 2,210)	<10 (<10 - <10)	<10 (<10 - <10)	3,910 (2,980 - 5,050)	4,220 (3,250 - 5,430)
2021-02-01	15,310 (12,020 - 19,060)	1,710 (1,320 - 2,210)	<10 (<10 - <10)	<10 (<10 - <10)	3,910 (2,980 - 5,050)	4,230 (3,250 - 5,430)

Assessment

Our assessment of the Covid-19 situation in South Africa based on our scenario analyses is as follows:

1. **Covid-19 cases, admissions and deaths in all provinces plateaued and declined earlier, and at a lower level, than our original model projections predicted,** despite the easing of lockdown. The reasons for this remain unclear but likely include a combination of the following:

a) A **lower than assumed population attack rate**, possibly due to different levels of susceptibility in different population groups (e.g. in children) or the presence of existing T-cell derived-immunity after prior exposure to other coronaviruses.

b) **Behaviour change in response to an increased local death rate** through a potential impact of public awareness of the increasing deaths and the looming threat of overwhelmed healthcare facilities resulting in better adherence to non-pharmaceutical interventions.

c) **Better adherence to NPIs regardless of death rate**, i.e. the population's will to adhere to NPIs regardless of a national directive to do so, or at a time when restrictions are being relaxed.

d) **Behavioural heterogeneity** meaning that some members of society experience different risks and exhibit heterogeneous / different behavioural patterns, introducing substantial variation in the number of people that different people infect, with highly connected individuals becoming infected earlier in the epidemic and infecting more contacts.

We have incorporated the last aspect into the model projections presented in this report.

2. **Though hospital capacity was breached in parts of the Eastern Cape, it was not breached to the extent originally expected in Western Cape and Gauteng.** Possible reasons for this include the lower-than-expected case load as well as lower levels of presentation for inpatient care. Our analysis of excess mortality suggests that many people may have been unable to be accommodated in Eastern Cape hospitals during June and early July.

3. **While the number of COVID-19 cases in South Africa appears to have peaked, there is much uncertainty in the remaining course of the epidemic, its duration and consequences**. The future of the spread of SARS-CoV-2 and the impact of COVID-19 on health and health resources depends on many unknowns. We do not yet know whether those already infected will have long-lasting immunity or short-term immunity, and whether this immunity will offer complete or partial protection. In the absence of a vaccine, SARS-CoV-2 transmission remains largely dependent on the proportion of population still susceptible, individual behaviour and the ability of the population to adopt preventative measures like mask-wearing and practise social distancing whilst going about their daily lives. Depending on the nature of immunity and/or the development of a vaccine, the future of SARS-CoV-2 could become regular annual epidemics, seasonal epidemics, epidemics occurring every few years or even sporadic, unpredictable epidemics. It is therefore important to continue to monitor the epidemic and remain vigilant to detect localised outbreaks as and when they occur. Additional work on modelling the impact of the above-mentioned factors on the timing, frequency and amplitude of a future resurgence in COVID-109 cases is currently under way.

Recommendations

In order to increase preparedness for a potential resurgence of Covid-19 cases and / or future novel pathogens, our recommendations following from the above are two-fold:

- Invest in equipment and infrastructure which will have long-term benefit to public health care system.

This includes investment in a continuous supply of protective equipment for health care workers for the months to come, general hospital bed capacity (while most stand-alone field hospitals could be demoted or used for other purposes), oxygen delivery and reticulation systems in general hospital wards, and additional ICU capacity, as well as emergency medical services (vehicles such as ambulances as well as training of EMS staff).

- Invest in additional data required to improve model estimates and surveillance

The country's ability to detect and react swiftly to a resurgence of Covid-19 cases or other novel pathogens depends on an improved surveillance data infrastructure. This could include a complete hospitalisation database, the generation of SARS CoV-2 seroprevalence data from routine care (e.g., antenatal care clinics and primary healthcare for chronic conditions) and testing of residual samples routinely submitted for other tests (HIV viral load, etc), and robust case and mortality data at district level.

Appendix

Key parameter values

Tables A1 and A2 below show the values of key parameters used to inform the model. Parameter values have been selected for use by an expert panel of clinicians on the SA Covid-19 Modelling Consortium and updated with inputs from recent South African data where indicated. Parameter values that are provided as ranges only differ by province.

Table A1. Results of NICD analysis of estimated national and provincial reproductive numbers [1,3]*

Restriction level	**National**	**Eastern Cape**	**Gauteng**	**KwaZulu Natal**	**Western Cape**
None (R_0)	2.5 (2, 3)	2.5 (2, 3)	2.5 (2, 3)	2.5 (2, 3)	2.5 (2, 3)
Level 5 R_t[2]	1.3 (1.0, 1.6)	1.4 (1.1, 1.7)	1.2 (1.0, 1.4)	1.1 (0.9, 1.43	1.5 (1.2, 1.8)
Level 4 R_t: NICD R_t estimates calibrated to fit hospital-based provincial deaths[2]	1.6 (1.3, 1.9)	1.6 (1.2, 1.8)	1.8 (1.4, 2.2)	1.6 (1.3, 1.9)	1.6 (1.3, 1.9)
	Other Provinces	**Eastern Cape**	**Gauteng**	**KwaZulu Natal**	**Western Cape**
Level 3 (1–30 June): increase in contacts (relative to previous period) estimated from a decrease in residential mobility[3]	(21.1%, 26.0%)	21.0% (16.8, 25.2)	4.3% (3.4, 5.2)	20.5% (16.4, 24.6)	8.1% (6.5, 9.7)
Level 3 (1 July – 17 August): increase in contacts (relative to previous period) estimated from a decrease in residential mobility[3]	(0.5%, 2.5%)	3.0% (2.4, 3.6)	1.8% (1.4, 2.2)	0.8% (0.6, 1.0)	6.6% (5.3, 7.9)
Level 2 (18 August ->): increase in contacts (relative to previous period) estimated from a decrease in residential mobility[3]	(3.3%, 5.8%)	5.4% (4.3, 6.5)	1.7% (1.4, 2.0)	4.8% (3.8, 5.8)	3.1% (2.5, 3.7)

* We utilised national estimates where provincial data was too sparse. R_0, and R_t for Level 5 and Level 4 from symptom onset date adjusted for testing volumes

Table A2. Key model parameters

	Parameter	**Value (range)**	**Sources**
Infection severity	Proportion of cases that are asymptomatic	75% (70% - 80%)	[9-12]
	Relative infectiousness of asymptomatic cases	80% (77.5%, 82.5%)	[13-15] Estimated through calibration to admissions and fatalities count data (DATCOV) [4]

	Mild to moderate cases among the symptomatic	(94.55% - 97.13%)	Estimated through calibration to admissions and fatalities count data (DATCOV) [4]
	Severe cases among the symptomatic	(2.58% - 5.00%)	
	Critical cases among the symptomatic	(0.18% - 0.55%)	
	Fatal cases among the admitted (general)	(6.82% - 20.28%)	Estimated from NICD COVID-19 Hospital Sentinel Surveillance database (DATCOV) [4] & Western Cape Line List Data (SPV) [16]
	Fatal cases among the admitted (ICU ventilated)	(43.01% - 85.03%)	
	Fatal cases among the admitted (ICU non-ventilated)	(22.73% - 43.35%)	
	Proportion of cases in ICU requiring ventilation	(19.44% - 51.47%)	
	Fatal cases among the critically infected requiring ventilation, *in the absence of appropriate care*	100%	Expert opinion of clinicians convened by the National COVID-19 Modelling Consortium
	Fatal cases among the critically infected not requiring ventilation, *in the absence of appropriate care*	Unchanged: Fatal cases among the admitted (ICU non-ventilated)	
	Fatal cases among the critically infected requiring oxygen, *in the absence of appropriate care*	100%	
	Fatal cases among the severely infected requiring oxygen, *in the absence of appropriate care*	90%	
	Probability of seeking hospital-level care for severely and critically ill	(50.00% - 97.00%)	Estimated through calibration to 80% of excess mortality [5]
Timeframes & treatment durations	Time from infection to onset of infectiousness	2 days (1.0 - 3.0)	[8, 17-26] with input from the National COVID-19 Modelling Consortium
	Time from onset of infectiousness to onset of symptoms	4 days (3.0 - 5.0)	
	Duration of infectiousness from onset of symptoms	5 days (4.0 - 6.0)	[26, 27]
	Time from onset of symptoms to testing	4 days (3.0 - 5.0)	[17,18, 28-32]
	Time from onset of symptoms to hospitalisation	5 days (4.0 - 6.0)	
	Time in non-ICU (never ICU) to death/recovery	8 days (4.0 - 12·0)	Lengths of stay: values and ranges sourced from NICD COVID-19 Hospital Sentinel Surveillance database (DATCOV) [4]
	Time in non-ICU for those destined for ICU	0 days (0.0 - 2.0)	
	Time in ICU for those ventilated and destined to die	14 days (7.0 - 27.0)	
	Time in ICU for those never ventilated and destined to die	11 days (7.0 - 18.0)	
	Time in ICU for those ventilated and recovered	19 days (15.0 - 37.0)	
	Time in ICU for those never ventilated and recovered	5 days (1.0 - 10.0)	
	Time in non-ICUs for those who were in ICU and recovered	0 days (0.0 - 6.0)	

* A full list of parameters are available in the code.

Summary of data sources

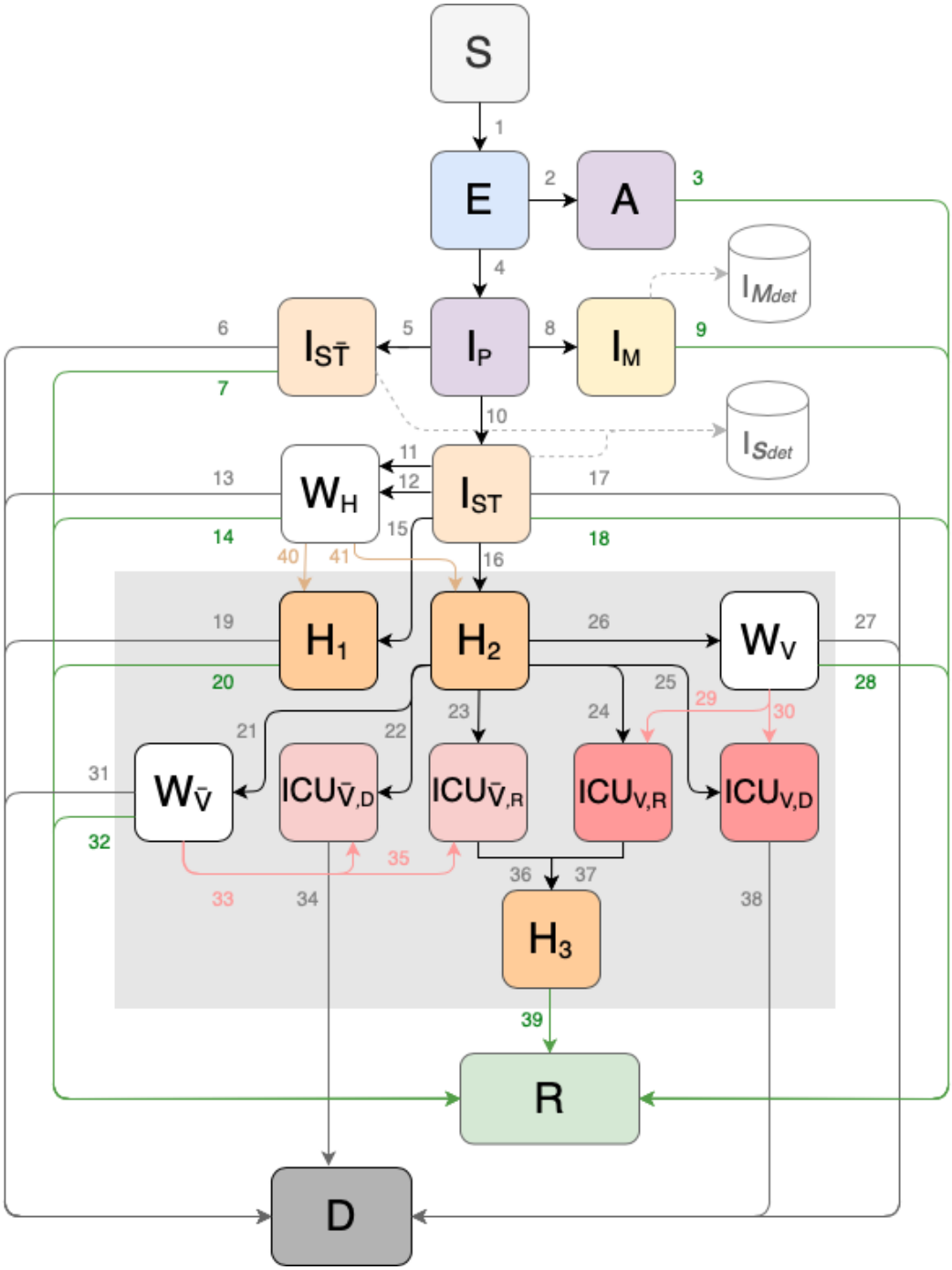
- National case and hospitalisation data from the South African National Institute for Communicable Diseases
- Statistics South Africa projected 2020 district population projections[33]
- Coronavirus COVID-19 (2019-nCoV) Data Repository for South Africa, Data Science for Social Impact Research Group @ University of Pretoria[34]
- Vodacom Mobile Event Database
- Google COVID-19 Community Mobility Reports
- Published and pre-print academic literature (cited in Table A2)
- Expert input from members of the SA COVID-19 Modelling Consortium, and https://sacoronavirus.co.za/category/press-releases-and-notices/

About the National COVID-19 Epi Model

The National COVID-19 Epi Model (NCEM) is a stochastic compartmental transmission model to estimate the total and reported incidence of COVID-19 in the nine provinces of South Africa. The outputs of the model may be used to inform resource requirements and predict where gaps could arise based on the available resources within the South African health system. The model follows a generalised Susceptible-Exposed-Infectious-Recovered (SEIR) structure accounting for disease severity (asymptomatic, mild, severe and critical cases) and the treatment pathway (outpatients, non-ICU and ICU beds) as shown in Figure A1. Contributors to the NCEM include Sheetal Silal, Rachel Hounsell, Jared Norman, Saadiyah Mayet, Frank Kagoro, Juliet Pulliam, Roxanne Beauclair, Jeremy Bingham, Jonathan Dushoff, Reshma Kassanjee, Michael Li, Cari van Schalkwyk, Alex Welte, Lise Jamieson, Brooke Nichols and Gesine Meyer-Rath. For more information please contact Dr Sheetal Silal (sheetal.silal@uct.ac.za).

Figure A1: Updated NCEM model structure (generalised SEIR model)

Note that a series of 'waiting' compartments have been added to represent individuals who are in need of a hospital or ICU bed but unable to occupy one due to capacity constraints (i.e., beds are full).



Model States

S	Susceptible
E	Exposed (not infectious)
A	Infected, asymptomatic (A)
I_P	Infected, pre-symptomatic (Ip)
I_M	Infected, mild
I_{ST}	Infected, severe, untreated
I_{ST}	Infected, severe, seeking treatment
W_H	Infected, severe, waiting for hospital bed
Hospitalised	Infected, severe, general ward (H_1)
	Infected, severe, general ward pre-ICU (H_2)
	Infected, critical, waiting for ICU, no ventilation ($W_{\bar{V}}$)
	Infected, critical, in ICU, not ventilated, non-survivor ($ICU_{\bar{V},D}$)
	Infected, critical, in ICU, not ventilated, survivor ($ICU_{\bar{V},R}$)
	Infected, critical, waiting for ICU & ventilation (W_V)
	Infected, critical, in ICU, ventilated, survivor ($ICU_{V,R}$)
	Infected, critical, in ICU, ventilated, non-survivor ($ICU_{V,D}$)
	Infected, severe, general ward post-ICU (H_3)
R	Removed (recovered)
D	Died
I_{Mdet}	Detection of mild cases (laboratory confirmed)
I_{Sdet}	Detection of severe cases (laboratory confirmed)

Model Flows

1. Force of infection
2. Latent period (until asymptomatic infectiousness)
3. Recovery: duration of asymptomatic infectiousness)
4. Latent period (until symptomatic infectiousness)
5. Development of severe symptoms, does not seek treatment
6. Death of severe, untreated case
7. Recovery: duration of severe case's infectiousness
8. Development of mild symptoms
9. Recovery: duration of mild case's infectiousness
10. Development of severe symptoms, seeks treatment
11. Severe case waiting for a hospital bed (if bed capacity reached)
12. Critical case waiting for a hospital bed (if bed capacity reached)
13. Death while waiting for hospital bed (excess mortality)
14. Recovery while waiting for hospital bed
15. Severe case admitted to hospital
16. Critical case admitted to hospital (pre-ICU progression)
17. Death of severe case while seeking treatment
18. Recovery of severe case while seeking treatment
19. Death of severe case in general hospital bed
20. Recovery of severe case in general hospital bed
21. Critical case in hospital, waiting for ICU admission (no ventilation)
22. Progression to ICU admission (no ventilation), non-survivor
23. Progression to ICU admission (no ventilation), survivor
24. Progression to ICU admission (with ventilation), survivor
25. Progression to ICU admission (with ventilation), non-survivor
26. Critical case in hospital, waiting for ICU admission (ventilation)
27. Death of critical case while awaiting ICU & ventilation
28. Recovery of critical case while awaiting ICU & ventilation
29. Waiting critical case needing ventilation (survivor) admitted to ICU
30. Waiting critical case needing ventilation (non-survivor) admitted to ICU
31. Death of critical case while awaiting ICU, non-ventilation
32. Recovery of critical case while awaiting ICU, non-ventilation
33. Waiting critical case not needing ventilation (survivor) admitted to ICU
34. Death of critical case from ICU (not ventilated)
35. Waiting critical case not needing ventilation (non-survivor) admitted to ICU
36. Critical case discharged from ICU (non-ventilated) to general ward
37. Critical case discharged from ICU (ventilated) to general ward
38. Death of critical case from ICU (ventilated)
39. Recovery of critical case (discharged from hospital)
40. Waiting severe case admitted to general ward
41. Waiting critical case admitted to general ward

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