THE DAILY COVID-19 EFFECTIVE REPRODUCTIVE NUMBER (R) IN SOUTH AFRICA

NATIONAL INSTITUTE FOR COMMUNICABLE DISEASES
Division of the National Health Laboratory Service

SUMMARY

Overview of report

Disease surveillance is a core function of the National Institute for Communicable Diseases (NICD), a Division of the National Health Laboratory Service (NHLS). This report includes an analysis of data on laboratory-confirmed COVID-19 cases, hospital admissions, and deaths to estimate the effective reproductive number (R) of SARS-CoV-2 over time in South Africa nationally and in selected provinces where sufficient data are available. The basic reproductive number (R0) is the average number of secondary infections produced by a typical case of an infection in a population where everyone is susceptible, which occurs typically in the first few weeks after introduction of a novel infectious agent into the population. The effective reproduction number (R) is the average number of secondary cases per infectious case in a population composed of both susceptible and non-susceptible hosts (once the infectious agent is circulating). If R>1, the number of new cases per time unit will increase, such as at the start of an epidemic. Where R=1, the number of new cases is stable over time, and where R<1, there will be a decline in the number of new cases per time unit.

This report is based on data collected up to 31 Jan 2021 (week 5 of 2021). The data were adjusted for the delays from illness onset to case report, hospital admission, and death and right censored for 2, 7, and 7 days respectively to account for the time lag between each outcome (test result, admission, or death) and the its time of reporting (R estimated up to 30 January). This analysis updates the report released on 5 December 2020, where R was estimated from laboratory-confirmed deaths. In this report, R is estimated from the data on laboratory-confirmed COVID-19 cases, hospital admissions, and hospital-based deaths. There may be non-overlapping sources of bias for the three data sources, which motivates a comparison of R estimates. R estimates are described for each of the lockdown levels implemented by the South African government – for more information regarding the timing and nature of lockdowns see the South African government website [vii]. Note: COVID-19 is the name of the disease and SARS-CoV-2 is the name of the virus.

Highlights

- From August 2020 through February 2021, estimates of R using three different data sources, daily numbers of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths were generally similar.
- Nationally, during the level 2 lockdown, the daily R remained initially constant, then increased slightly, with an average value near 1 at the end of this period. During level 1 lockdown, the daily R increased steadily until the second week of December, when it peaked and then decreased until the end of this period. The average R at the end of level 1 lockdown was between 1 and 1.5. During the adjusted level 3 lockdown, the daily R remained initially steady, then dropped sharply for the remainder of January.
- In the provincial level analysis trends were generally similar to the national picture except for differences in timing related to differences in timing of the first and second COVID-19 waves.
- The increase in R in November and December 2020 may have resulted from a combination of relaxation of implementation of controls to prevent the spread of COVID-19 at the end of the year as well as possible effects of the new lineage SARS-CoV-2 501Y.V2. Reductions in R towards the end of level 1 (but before the move to adjusted level 3) could be as a result of improved implementation of non-pharmaceutical interventions to control COVID-19 as well as increasing population immunity. Further reductions in R in January may be as a result of additional impact of adjusted level 3 recommendations and increasing immunity.
- While the adjusted level 3 lockdown appears to have contributed to reducing transmission, R began to decrease across the country prior to the introduction of the adjusted level 3 lockdowns. This suggests that factors such as voluntary behavioral change in response to growing awareness of second wave's severity, as well as increasing immunity in the population, played important roles in controlling the second wave.
- This analysis has important limitations. Changes in the ascertainment rate of COVID-19 cases and deaths, the proportion of cases admitted to hospital, the delay between symptom onset and reporting, and other factors may change over time, potentially affecting R estimation. In addition, the relatively low numbers of deaths recorded between waves results in high levels of uncertainty and large fluctuation in R estimates based on daily deaths. Furthermore, a number of factors may have altered mortality outcomes over time, including treatment changes, pressure on the hospital system, and potential differences in severity between earlier circulating viruses and the 501Y.V2 variant that dominated the second wave. Combined, these factors may lead to perturbations in the time series data that are unrelated to transmission. No local data are available from which to calculate the serial interval. Therefore, it is important to interpret these findings together with other sources of data on transmission. Caution should be exercised in interpreting comparisons between different timepoints and provinces as these could be affected by differential testing and reporting practices and differences in healthcare provision.

Methods

Daily R estimation

We used data from the first confirmed case in March 2020 until 01 Feb 2021, based on the national DATCOV dataset on hospitalized cases and in-hospital deaths, and the laboratory-confirmed case line list maintained by the National Institute for Communicable Diseases (NICD). The laboratory-confirmed cases data was linked with the national DATCOV dataset to obtain dates of symptom onset. Following data linkage, symptom onset data were available for 5% of laboratory-confirmed cases, while dates of onset were available for 51% of hospitalized cases, and 55% of fatal cases in the DATCOV dataset. 135 cases (0.9%) in the DATCOV database were missing both admission date and date of symptom onset and were excluded from the analyses based on hospital admissions and deaths. The data were adjusted for the delay from symptom onset to reporting of test result / hospital admission and right censored for 2, 7, and 7 days (for cases, hospital admissions, and deaths respectively) to account for reporting delays (last dates of estimation: 31 January 2021, 25 January 2021, and 25 January 2021 respectively). Missing dates of symptom onset were imputed using chained equations multiple imputations (250, 1000, and 1000 respectively) [i,ii]. A negative-binomial model was fitted to confirmed COVID-19 cases for which the date of symptom onset was available and used to impute the dates of symptom onset for cases with missing information. Separate imputations were done for the case and admissions datasets. The hospital-based deaths data set is a subset of admissions, so the same set of imputations were used. The model predictors for the three two imputation procedures were: health sector where sample collection/hospital admission occurred (private or public), age group, month of case report/hospital admission, outcome (for admissions), day of hospital admission (for admissions and deaths), and province. The daily R was estimated using the method of Thompson et al. (EpiEstim v. 2.2-3) [iii,iv] for each imputed dataset. For the serial interval we used a gamma distribution with mean of 5.3 (s.d. 2.1) and standard deviation 1.8 (s.d. 0.6) to account for the variability (and uncertainty) of the selected serial interval values [v]. We report the medians of the central values and the 2.5th-97.5th percentiles of the estimated daily R values obtained from the imputed datasets [i,ii].

Previous versions of this report have included descriptions of trends in daily R values during lockdown levels 5 through 3, and parts of level 2 lockdown. The current report focusses on more recent trends in daily R values in the text, starting from the beginning of level 2 lockdown in August 2020 (for more details regarding the COVID-19 lockdowns in South Africa, please refer to the South African government website [vii]).

Results

The daily number of laboratory-confirmed COVID-19 cases steadily increased until mid-July 2020, following which daily numbers of new cases decreased steadily, flattening around mid-September through to early November, when they began to increase (Figure 1). From December through to early January, the daily number of laboratory-confirmed COVID-19 cases increased rapidly, followed by a rapid decrease through to the end of January 2021.

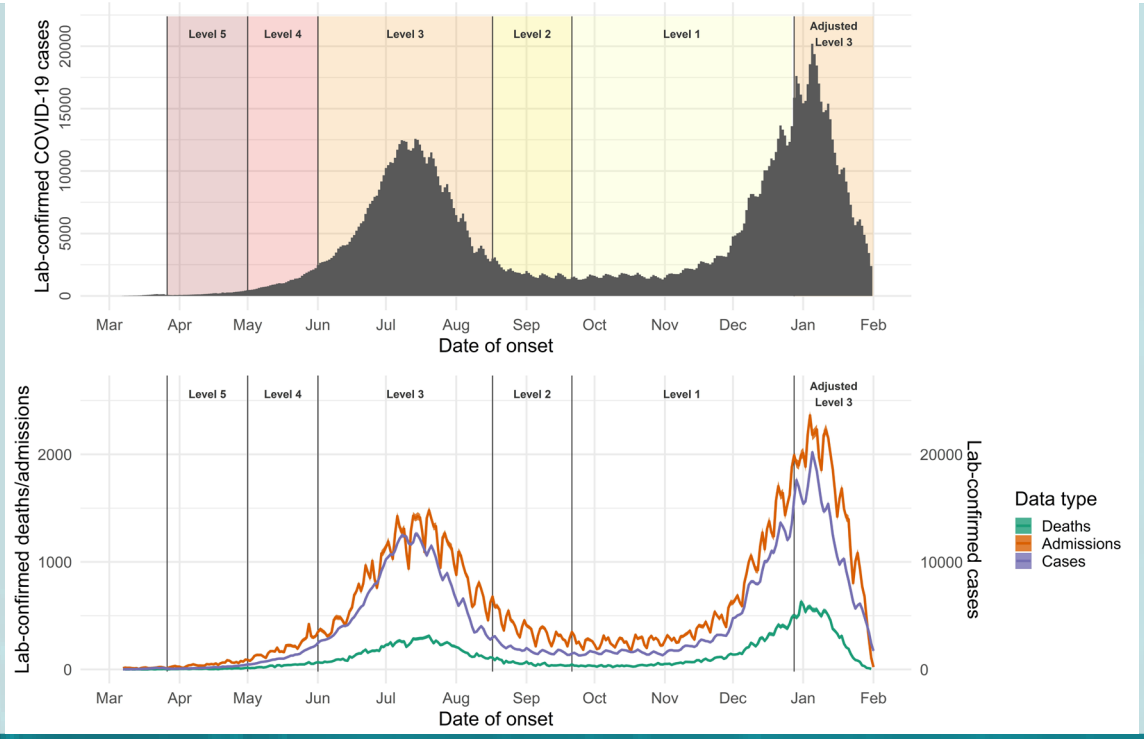

Figure 1. Daily number of laboratory-confirmed COVID-19 cases (above) and daily numbers of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths (below), by date of symptom onset (missing data imputed; medians and 95% quantiles of imputed time series are shown), South Africa (last date included: 1 Feb 2021). Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

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WEEK **7** 2021

From August 2020 through February 2021, estimates of R using three different data sources, daily numbers of laboratory-confirmed COVID-19 deaths, hospital admissions and cases were generally similar (Figure 2, Table 1). Nationally, during the level 2 lockdown, the daily R remained initially constant, then increased slightly, with an average value near 1 at the end of this period. During level 1 lockdown, the daily R increased steadily until the second week of December, when it peaked and then decreased until the end of this period. The average R at the end of level 1 lockdown was between 1 and 1.5. During the adjusted level 3 lockdown, the daily R remained initially steady, then dropped sharply for the remainder of January.

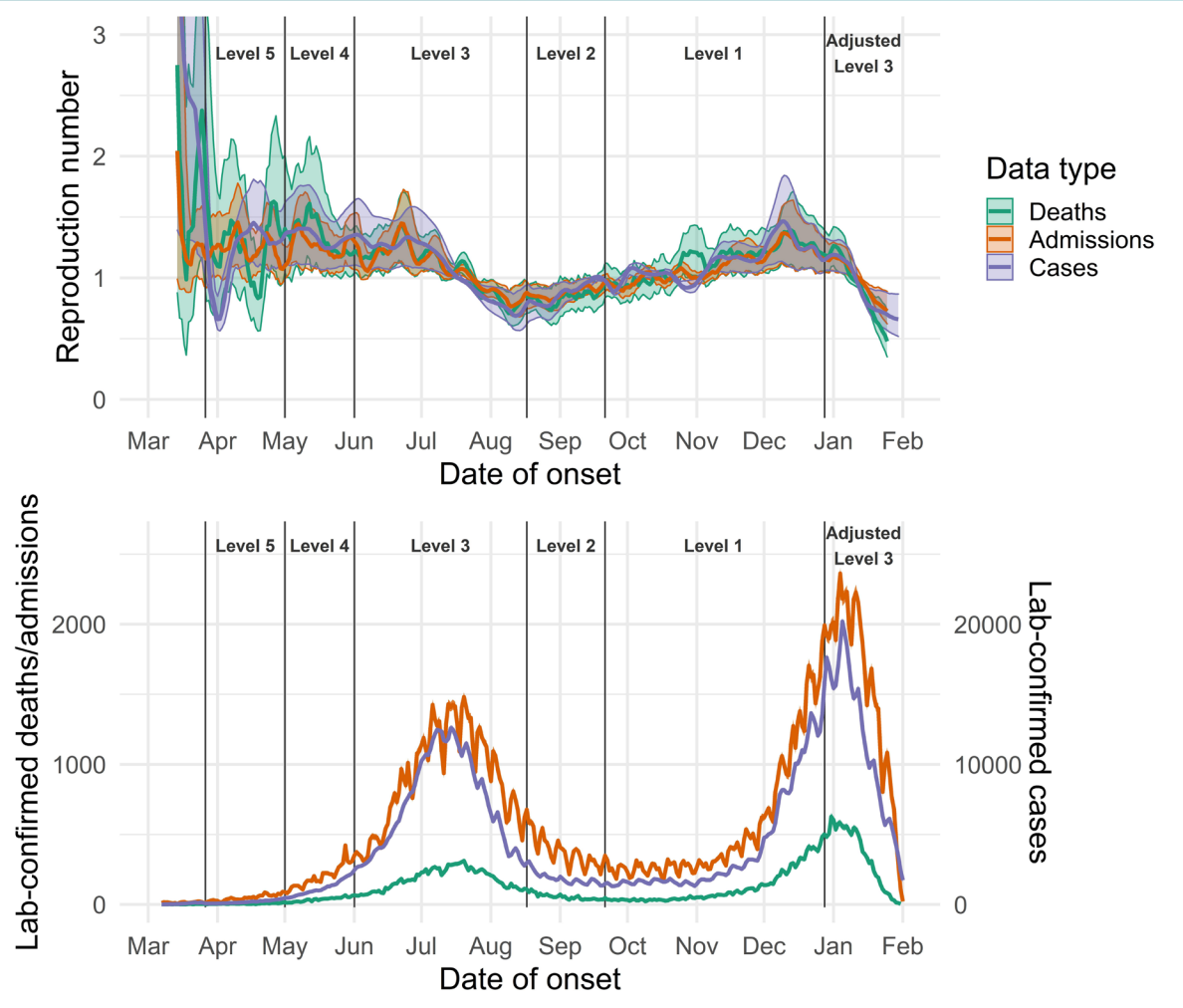

Figure 2. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, South Africa (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 1. National R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.87 (0.78,0.96)	1.18 (1.06,1.33)	0.91 (0.87,0.96)
Admissions	0.88 (0.80,0.96)	1.15 (1.05,1.27)	0.95 (0.94,0.98)
Deaths	0.83 (0.79,0.87)	1.21 (1.19,1.23)	0.89 (0.87,0.91)

In the Western Cape, the average R remained below 1 during the level 2 lockdown, rising to slightly above 1 during the beginning of level 1 lockdown (Figure 3, Table 2). The daily R then rose in early November, peaking at close to 1.5 in mid-December, before dropping steadily. During the adjusted level 3 lockdown, the average daily R dropped steadily, then levelled off, with a value below 1 at the end of January.

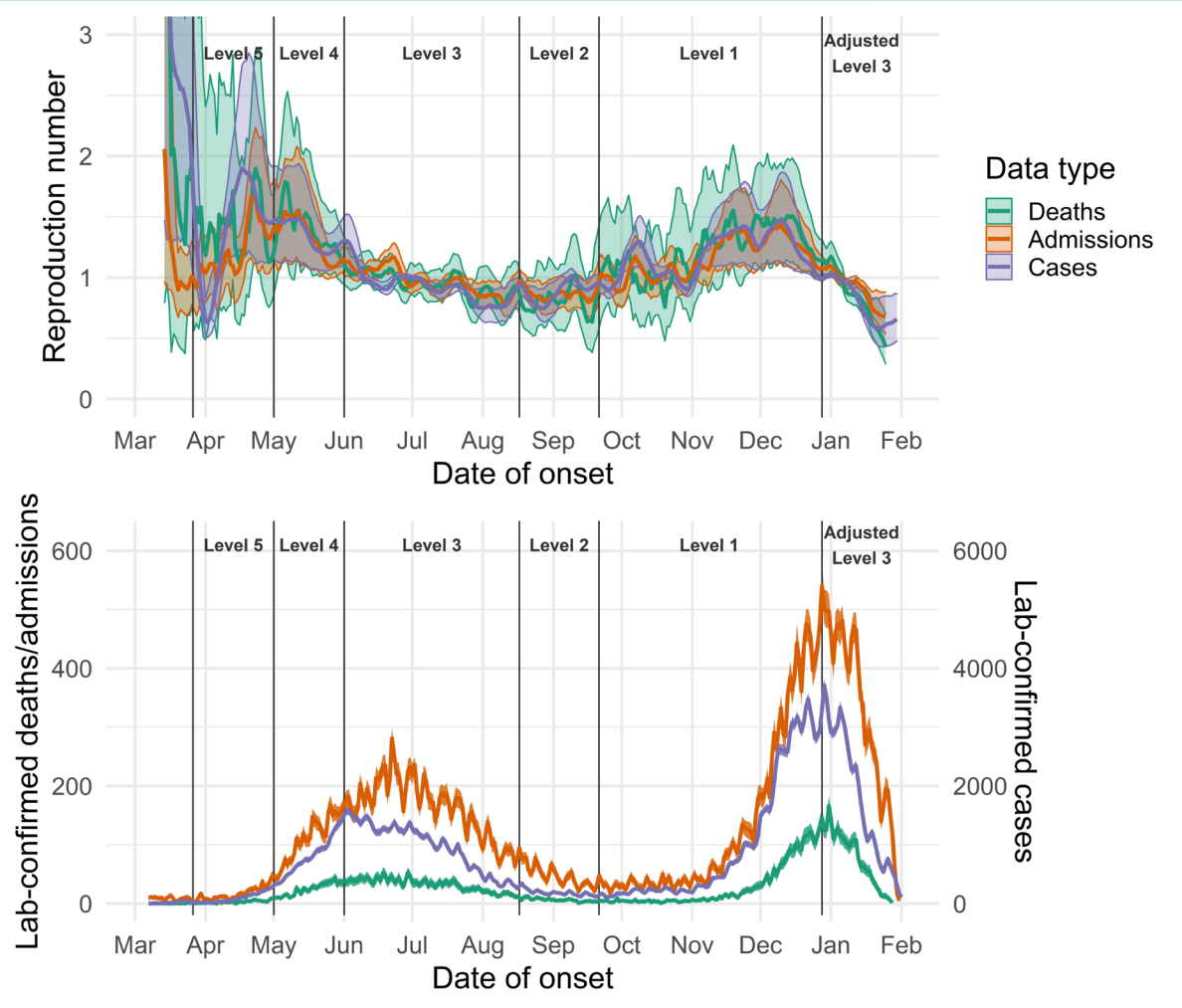

Figure 3. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, Western Cape (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 2. Western Cape R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.87 (0.80,0.96)	1.19 (1.05,1.37)	0.83 (0.75,0.94)
Admissions	0.86 (0.78,0.96)	1.20 (1.06,1.38)	0.90 (0.85,0.96)
Deaths	0.79 (0.70,0.90)	1.27 (1.23,1.32)	0.83 (0.80,0.86)

In Gauteng, the daily R remained below 1 during the level 2 lockdown, fluctuating during this period (Figure 4, Table 3). During the level 1 lockdown, R increased slightly at the end of September, then remained steady near 1 until mid November. R increased from mid November until mid December, then decreased until the end of level 1 lockdown, with a value above 1 at the end of this period. The daily R continued to decrease during the adjusted level 3 lockdown with a value below 1 at the end of January.

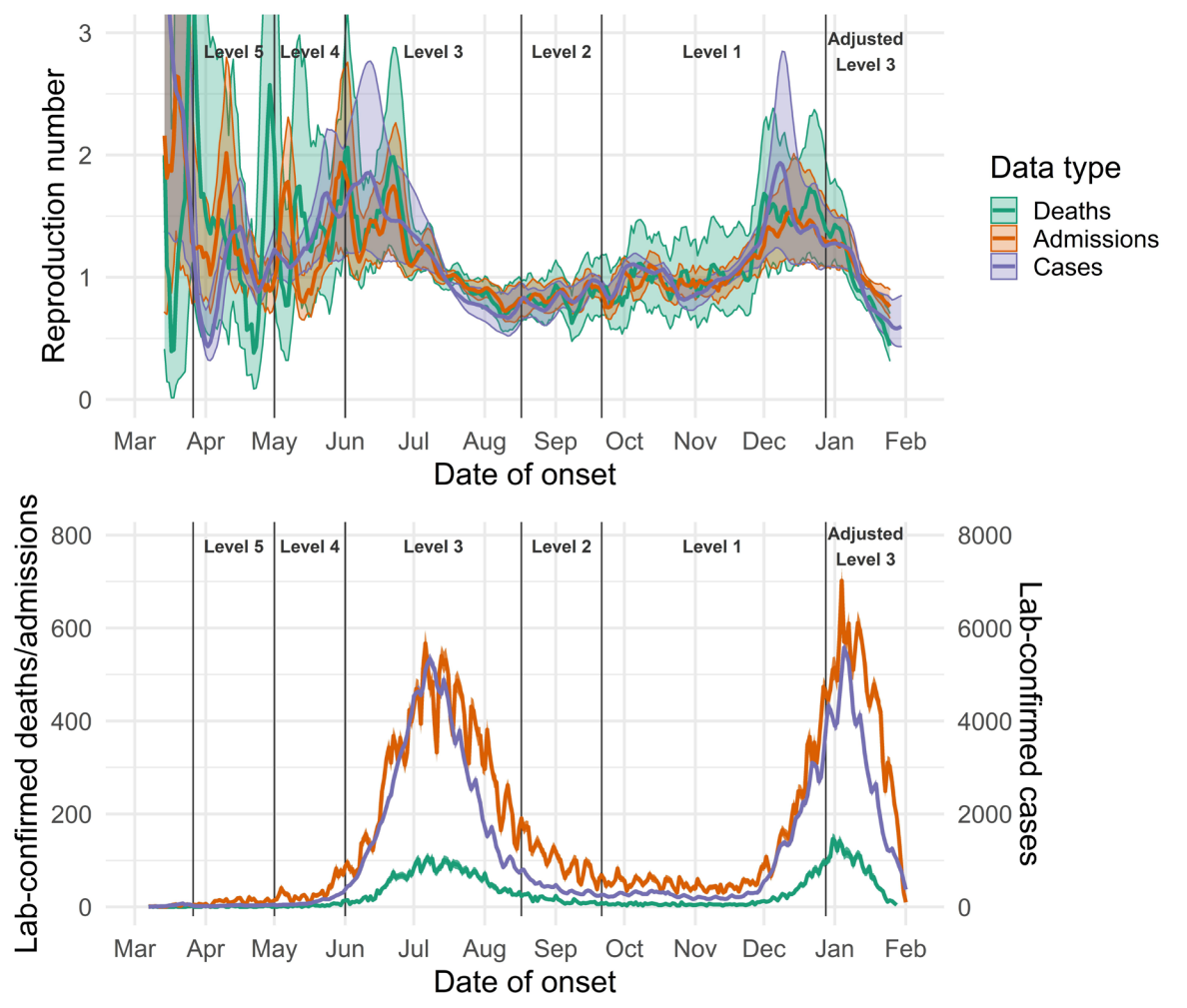

Figure 4. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals Gauteng (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 3. Gauteng R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.82 (0.72,0.94)	1.26 (1.08,1.49)	0.91 (0.88,0.97)
Admissions	0.86 (0.76,0.95)	1.21 (1.07,1.35)	0.99 (0.97,1.02)
Deaths	0.82 (0.75,0.89)	1.33 (1.27,1.40)	0.90 (0.86,0.93)

In the Eastern Cape, the R estimates based on cases differ substantially from those based on hospital admissions and deaths (Figure 5, Table 4). The daily R based on admissions and deaths increased near the end the level 2 lockdown. During level 1 lockdown, the value of R based on admissions and deaths initially increased, peaking in the second half of October, then decreased until mid-December, after which it remained steady at a value close to 1. During the first three weeks of adjusted level 3 lockdown, the value of R remained steady near 1, before dropping sharply to below 1 in the final weeks of January. The daily R estimates based on cases began to increase at the end of adjusted level 3 lockdown.

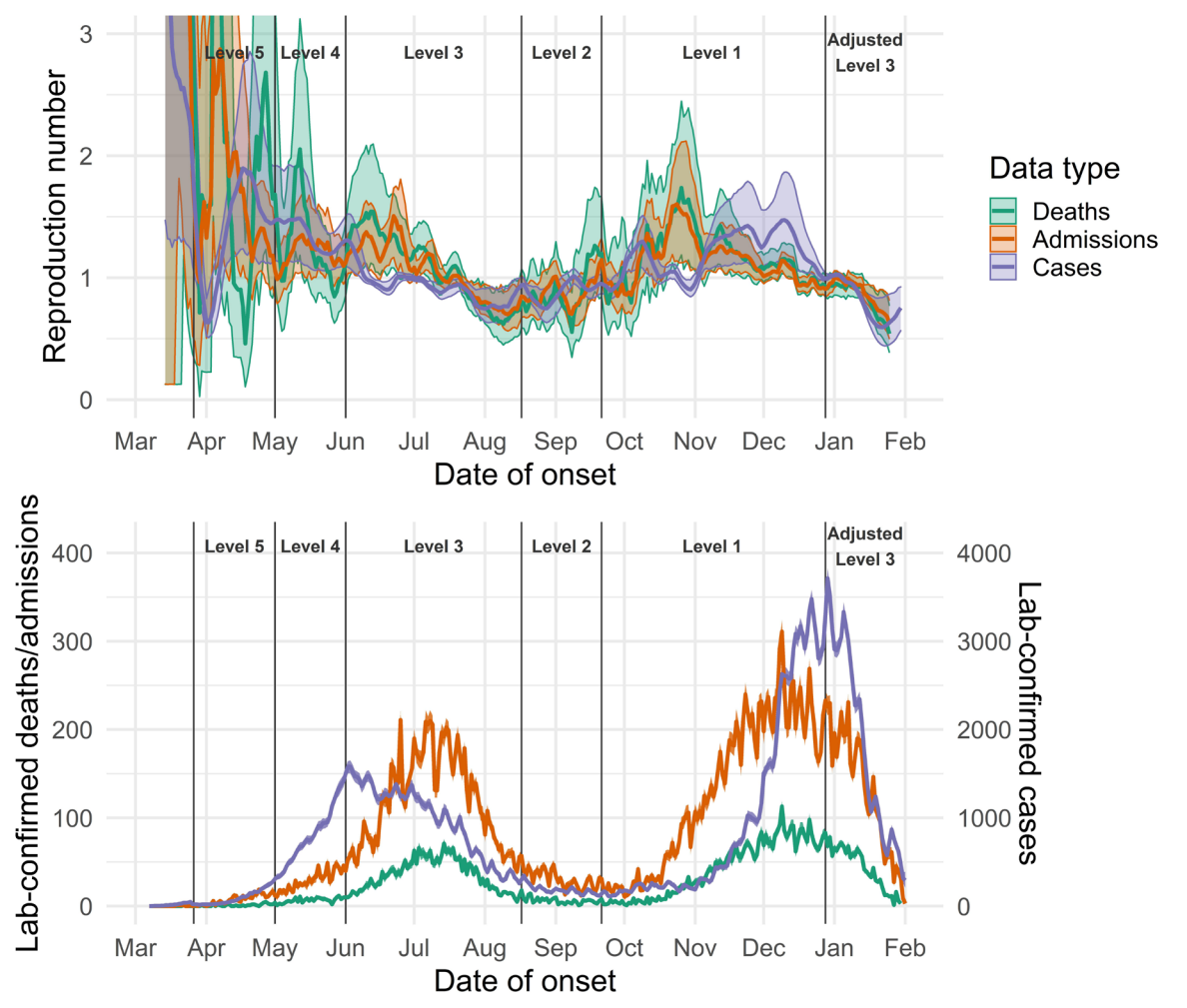

Figure 5. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, Eastern Cape (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 4. Eastern Cape R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.87 (0.8,0.96)	1.19 (1.05,1.37)	0.84 (0.76,0.94)
Admissions	0.88 (0.78,0.98)	1.08 (1.02,1.15)	0.87 (0.81,0.95)
Deaths	0.88 (0.77,1.00)	1.10 (1.06,1.13)	0.83 (0.79,0.88)

In KwaZulu-Natal, the average R increased gradually during the level 2 lockdown, with a value below 1 at the end of this period (Figure 6, Table 5). During the level 1 lockdown, the daily R initially increased slightly, then remained steady until early November. R estimates based on deaths during the first half of the level 1 lockdown fluctuate widely, most likely due to the very low numbers of deaths recorded in this period. The daily R then increased, peaking in early December and decreasing until the end of the level 1 lockdown. The daily R decreased consistently during the adjusted level 3 lockdown, with a value below 1 at the end of January.

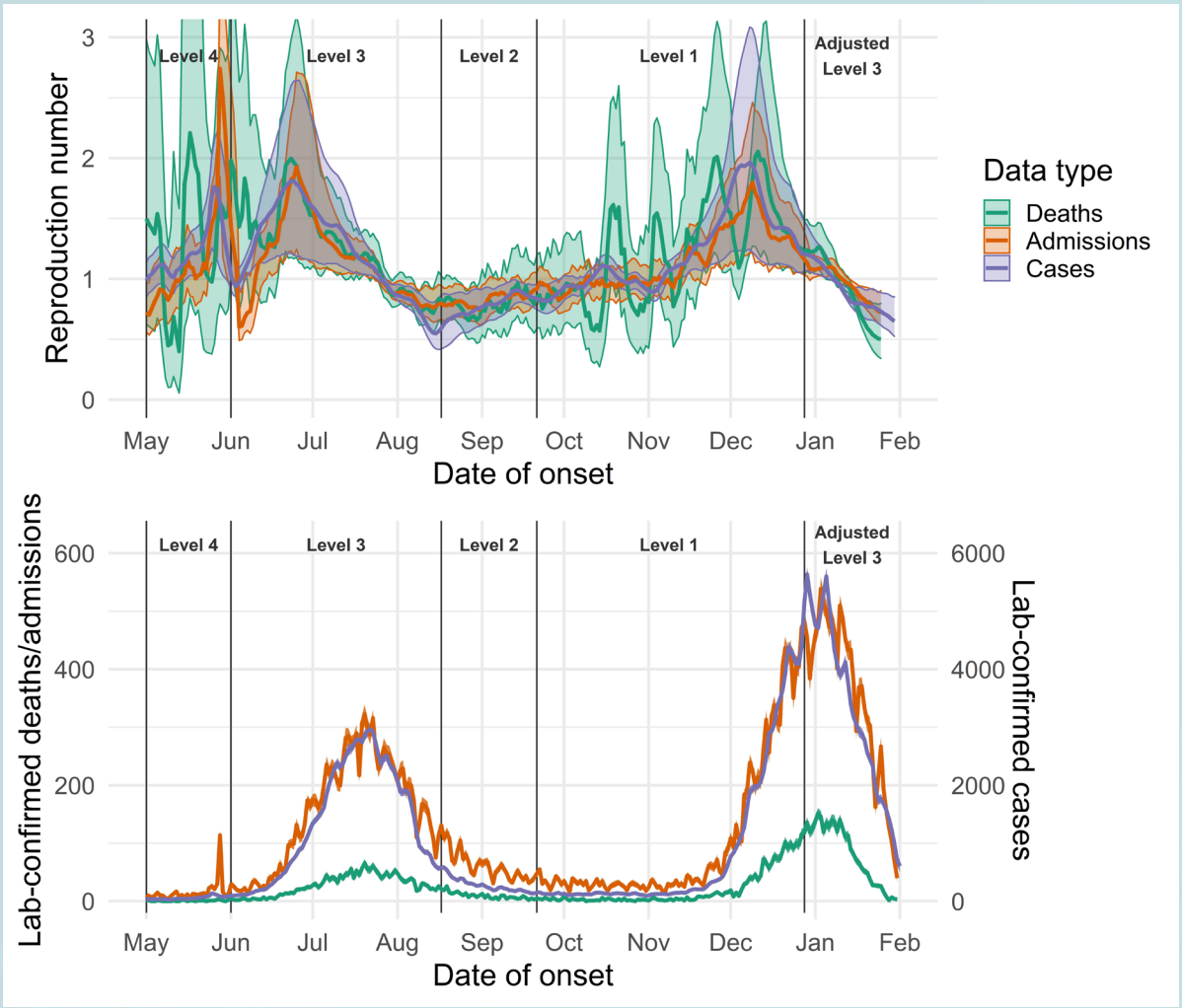

Figure 6. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, KwaZulu-Natal (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 5. Kwa-Zulu Natal R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.77 (0.62,0.92)	1.35 (1.1,1.70)	0.89 (0.85,0.96)
Admissions	0.83 (0.72,0.95)	1.25 (1.08,1.48)	0.93 (0.91,0.98)
Deaths	0.77 (0.69,0.86)	1.36 (1.30,1.42)	0.89 (0.86,0.92)

In Free State, the daily R during the level 2 lockdown fluctuated slightly, with a value close to 1 at the end of this period (Figure 7, Table 6). During the level 1 lockdown, R initially fluctuated near a value of 1, then decreased to below 1 during November. The daily R increased from the last week of November through the end of level 1 lockdown, ending this period with a value above 1. During the adjusted level 3 lockdown, R remained initially steady before dropping rapidly, with a value below 1 at the end of January.

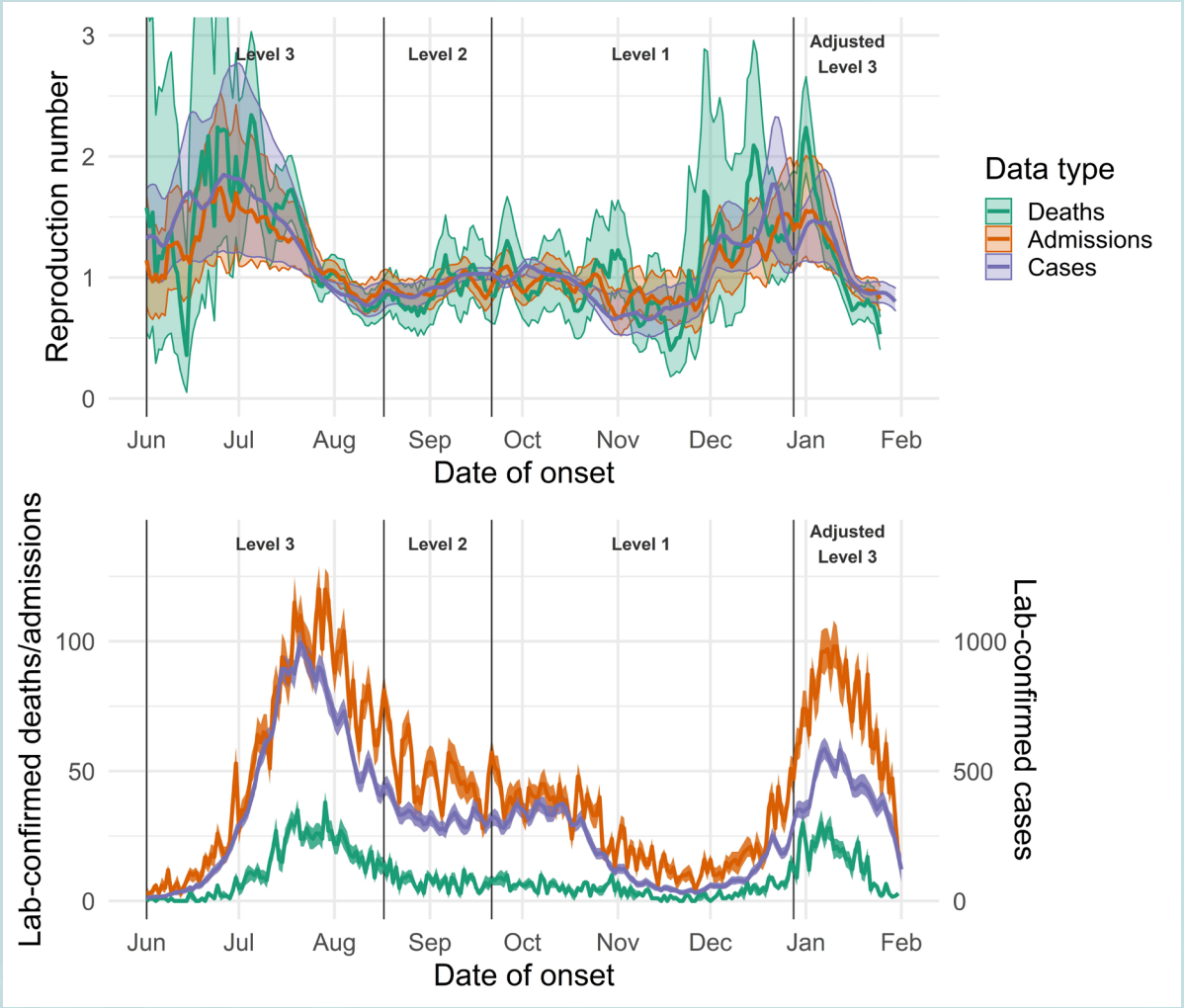

Figure 7. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, Free State (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 6. Free State R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.94 (0.88,0.98)	0.97 (0.94,1.00)	1.04 (1.00,1.09)
Admissions	0.91 (0.85,0.99)	1.00 (0.96,1.04)	1.07 (0.99,1.16)
Deaths	0.86 (0.76,0.96)	1.03 (0.94,1.13)	1.00 (0.91,1.08)

In the Northern Cape, the daily R during the level 2 lockdown remained steady at values close to 1 (Figure 8, Table 7). During the first half of the level 1 lockdown, the daily R remained initially steady, then decreased gradually until around the beginning of November. R increased from the beginning of November through to the last week of December then remained approximately stable until the end of the level 1 lockdown, with a value above 1 at the end of this period. During the adjusted level 3 lockdown, R initially decreased, then levelled around the middle of January, with a value below 1 at the end of January.

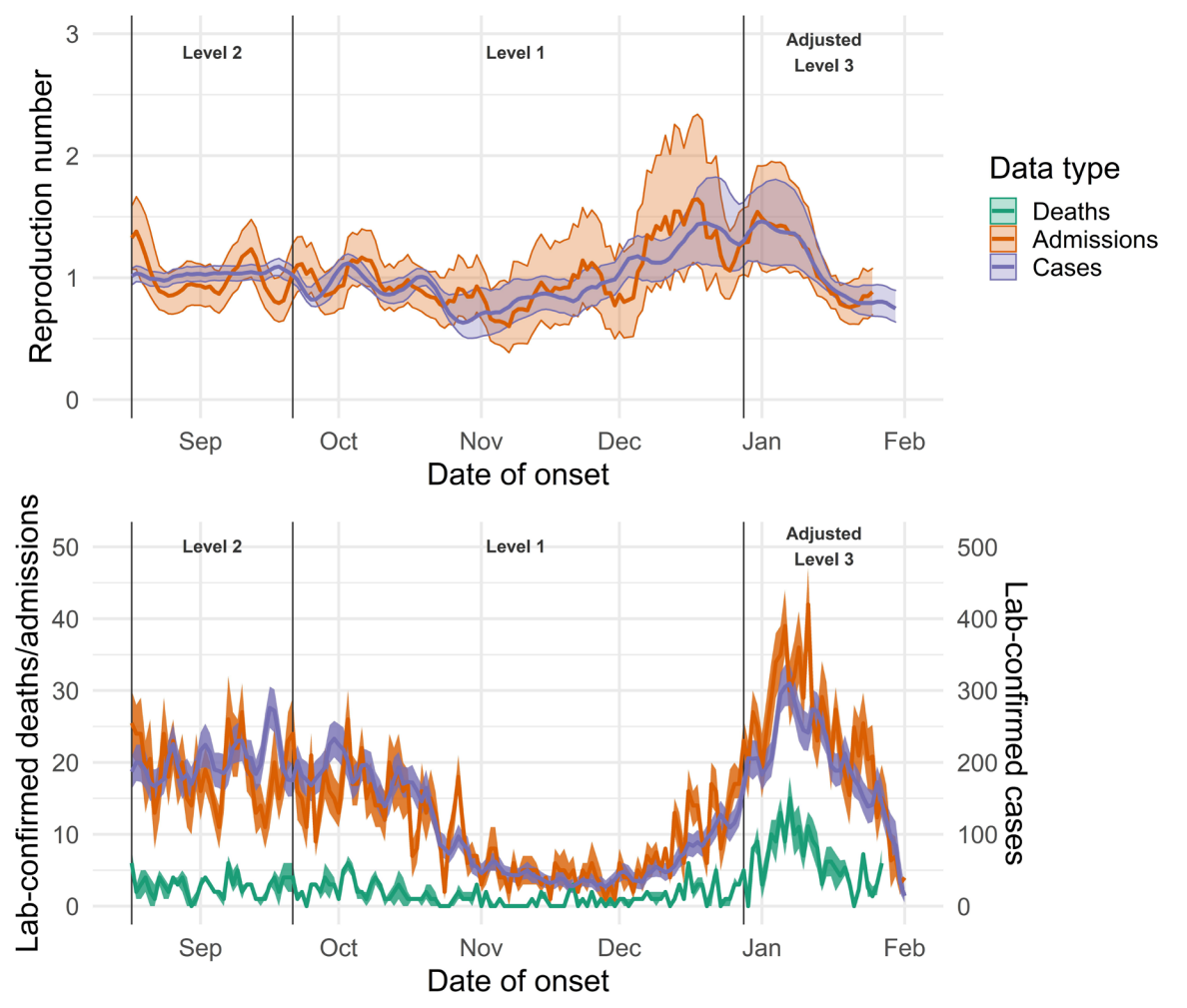

Figure 8. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, Northern Cape (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 7. Northern Cape R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	1.03 (0.99,1.06)	0.95 (0.9,0.99)	1.01 (0.98,1.04)
Admissions	0.96 (0.89,1.04)	0.98 (0.92,1.05)	1.05 (0.97,1.15)
Deaths	0.95 (0.77,1.15)	0.96 (0.81,1.12)	1.04 (0.9,1.19)

In North West province, the daily R during the level 2 lockdown initially increased slightly, then remained stable, with a value close to 1 at the end of this period (Figure 9, Table 8). During the level 1 lockdown, the daily R initially decreased slightly, then remained stable until the last week of November, when it increased sharply for a period of approximately two weeks then remained stable until the end the level 1 lockdown, with a value above 1 at the end of this period. During the adjusted level 3 lockdown, the daily R was stable until the beginning of January, then decreased, with a value below 1 at the end of January.

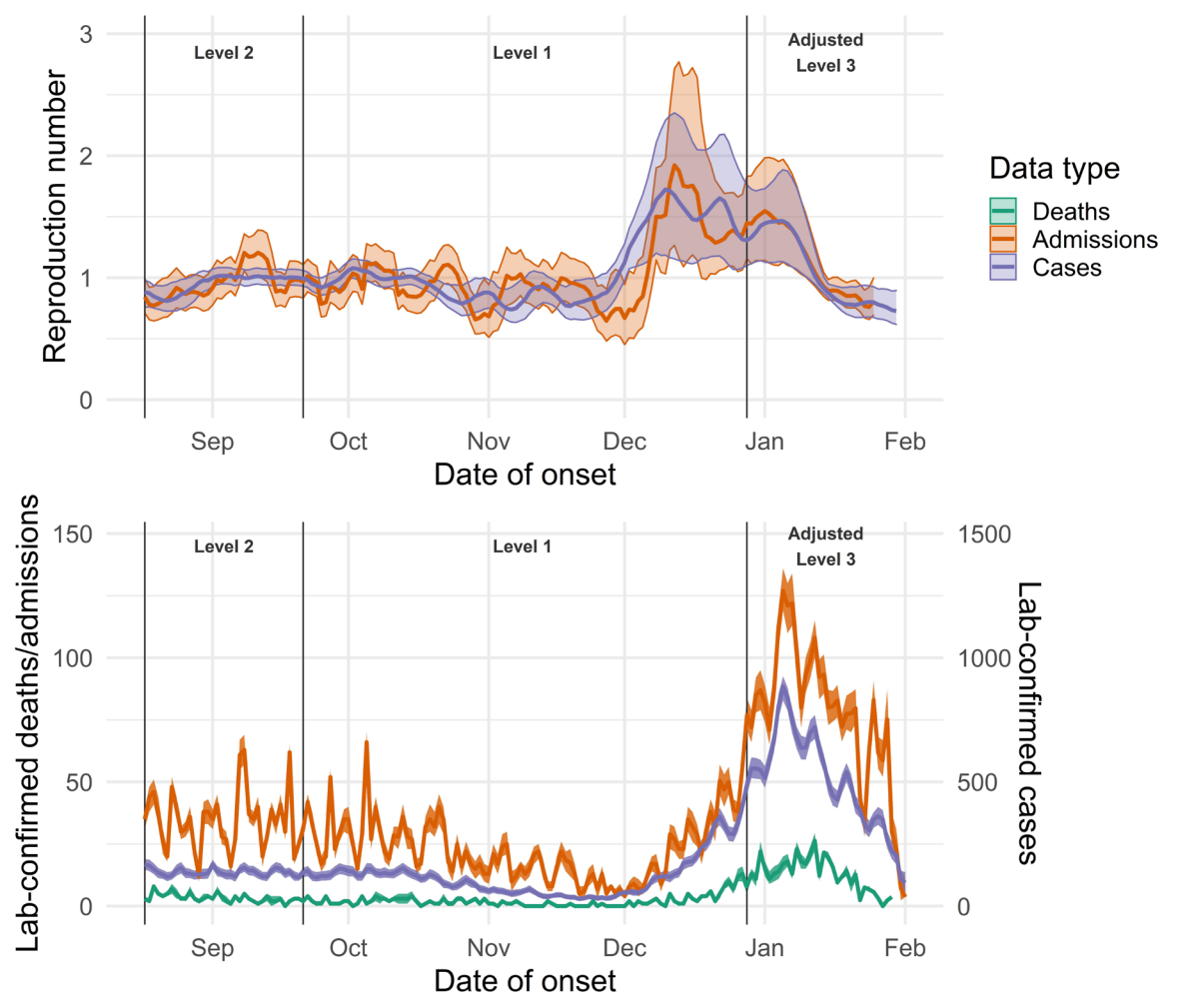

Figure 9. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, North West (last date included in the estimation: 30 Jan 2021). Lower panel: estimated number of laboratory-confirmed COVID-19 cases, hospital admissions, and deaths, by onset date with missing data imputed. The medians and 95% ranges for the imputed datasets are shown. Daily numbers of confirmed laboratory-confirmed COVID-19 cases in the bottom panel are shown on the right-hand y axis.

Table 8. North West R estimates per lockdown level, from 17 August to 30 January for each of laboratory-confirmed COVID-19 cases, hospital admissions and deaths (median values with 95% confidence intervals).

	Level 2	Level 1	Adjusted Level 3
Cases	0.96 (0.91,1)	1.1 (1.04,1.17)	0.99 (0.97,1.01)
Admissions	0.96 (0.89,1.03)	1.03 (0.98,1.07)	1.04 (0.99,1.11)
Deaths	0.85 (0.71,1.02)	1.23 (1.07,1.4)	0.98 (0.89,1.08)

Discussion

In general, the average daily R was similar between provinces. Furthermore, in most cases, the three different endpoints used (cases, hospital admissions, and deaths) led to similar results when the numbers of cases, admissions, and deaths were sufficient. There were however several instances in which different endpoints led to substantially different R estimates (most notably, in the Eastern Cape). Such differences could result from changes in testing practices, admission criteria, and treatment protocols over time, as well as other factors, and should be explored in future analyses.

This report was jointly prepared by the National Institute for Communicable Disease (NICD) and the DSI-NRF Centre of Excellence in Epidemiological Modelling and Analysis (SACEMA). Inquiries should be referred to Prof Cheryl Cohen (cherylc@nicd.ac.za).

The increase in R in November and December 2020 may have resulted from a combination of relaxation of implementation of controls to prevent the spread of COVID-19 at the end of the year as well as possible effects of the new lineage SARS-CoV-2 501Y.V2. Reductions in R towards the end of level 1 (but before the move to adjusted level 3) could be as a result of improved implementation of non-pharmaceutical interventions to control COVID-19 as well as increasing population immunity. Further reductions in R in January may be as a result of additional impact of adjusted level 3 recommendations and increasing immunity.

Limitations

The main limitation of this analysis is that the ascertainment rate of COVID-19 cases and deaths, along with the proportion of cases which are admitted to hospital, may change over time, potentially affecting R estimation. These effects are likely driven in part by changes in the criteria for testing and hospital admission, as well as by shifting care seeking behavior during the epidemic. The increased use of antigen tests through time, which have lower sensitivity than the more-commonly used PCR tests, may result in lower ascertainment rates, particularly during the second wave. Along with the ascertainment rate, the delay between symptom onset and reporting of case/admission/death may change over time, which would affect the accuracy of the adjustment for right-censoring the end of the time series. In addition, the relatively low numbers of deaths recorded between waves results in high levels of uncertainty and large fluctuation in R estimates based on daily deaths. We do not present death-based R estimates in some smaller provinces due to instability of the estimates. Furthermore, a number of factors may have altered mortality outcomes over time, including the introduction of dexamethasone treatment in mid-June, the use of oxygen administration via high flow nasal cannula, changes in quality of healthcare provided if health systems are overwhelmed, and potential differences in severity between earlier circulating viruses and the 501Y.V2 variant that dominated the second wave. Combined, these factors may lead to perturbations in the time series data that are unrelated to transmission. Comparing R estimates from the 3 data sources may help in assessing the severity of some of these biases, as indicated by inconsistent results across analyses of the three data sources. In addition to limitations in the ability of the available time series data to reflect underlying transmission, no local data are available from which to calculate the serial interval. The level of variation in the serial interval estimates used here reflects the range of estimates observed in mainland China [vi]. Lastly, it was not possible to link cases, admissions, or deaths to the importation status of cases, affecting the reliability of initial R0 estimates, which are therefore not reported here.

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