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

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

SOUTH AFRICA | WEEK 49 2020

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 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 26 November 2020 (week 48 of 2020). The data were adjusted for the delay from illness onset to death and right censored for 30 days to account for the time lag between onset and reporting of death (R estimated up to 27 October). This analysis updates the report released on 31 August 2020. As in that report, here R is estimated from the data on laboratory-confirmed COVID-19 deaths. It is felt that laboratory-confirmed COVID-19 deaths are likely a relatively stable indicator of COVID-19 epidemic progression, albeit with a substantial time lag, which is a disadvantage of this approach. Note: COVID-19 is the name of the disease and SARS-CoV-2 is the name of the virus.

Highlights

- Nationally, the average R during the period of the stage 5 lockdown was 1.31 (95%CI: 1.07-1.60), rising to near 1.5 by the end of April.
- The daily R dropped steadily during stage 4 lockdown, with an average over this period of 1.26 (95%CI: 1.06 – 1.50).
- During the stage 3 lockdown, the daily R varied slightly, with an average of 1.02 (95%CI: 1.00 – 1.04) during this period.
- During the stage 2 lockdown, the daily R remained initially constant, then increased slightly, with an average of 0.84 (95%CI: 0.74 – 0.95) during this period.
- During stage 1 lockdown, the daily R remained steady until mid-October, then increased gradually, with an average of 0.99 (95%CI: 0.93 – 1.04) between 21 September and 27 October.
- In the Western Cape Province, the average R was 1.41 (95%CI: 1.08-1.84) during the stage 5 lockdown, dropping steadily throughout stage 4 and 3 lockdown, dropping below 1 during stage 2, and increasing slightly during stage 1. As of 27 October, R was estimated to be 1.06 (95% CI: 0.78-1.41). This indicates substantial slowing of transmission towards the end of June and through July with slightly increasing transmission in October.
- In the Eastern Cape Province, the average R during the stage 5 lockdown was 1.40 (95%CI: 1.01 – 1.93), remaining above 1 during stage 4, decreasing gradually during stage 3, dropping below 1 in the second half of July. During the second half of the stage 2 lockdown R increased, with a value of 1.25 (95% CI: 0.88-1.75) as of 20 September. As of 27 October, R was estimated to be 1.20 (95% CI: 0.96-1.51) indicating ongoing transmission.
- In other provinces where estimation was possible for stages 5, 4, 3, 2 and 1 (Gauteng and KwaZulu-Natal provinces), the value of R dropped during stages 3 and 2, with slight increases during stage 1 (through 27 October).
- Reasons for the increases in R observed during stage 1 in some provinces may include reduced public adherence to non-pharmaceutical interventions (physical distancing, mask use, and other measures), opening of schools, or other factors, including residual biases in the data. It is important that all people adhere to these recommended measures because relaxation of adherence will lead to increased transmission and the potential for increases in case numbers as is seen in some provinces.
- This analysis has important limitations. Changes in the ascertainment rate of COVID-19 deaths, the average risk profile of cases, as well as the delay between symptom onset and reporting of death may change over time, potentially affecting R estimation. The introduction of dexamethasone treatment and use of high flow nasal oxygen since mid-June may lower mortality, while overwhelmed health systems could lead to increased mortality, potentially biasing estimates. 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 death in late March until 26 November 2020, based on the national deaths line list maintained by the National Department of Health (NDoH). The NDoH mortality data was linked with the national DATCOV dataset to obtain dates of symptom onset for 32% of fatal cases. The data were adjusted for the delay from illness onset to death and right censored for 30 days to account for reporting delays (last date of estimation: 27 October 2020). Missing dates of symptom onset were imputed using chained equations multiple (1000) imputations [i,ii]. In addition, 186 cases (0.9%) were missing both death date and date of symptom onset and were excluded from the analysis. The time series is summarized in figures based on the median values for each date. 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. The model predictors for imputation were: health sector where death occurred (private, public, outside hospital, or unclassified), age group, month of death, 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 (1000 time series generated through the multiple imputation process). 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 1000 imputed datasets [i,ii].

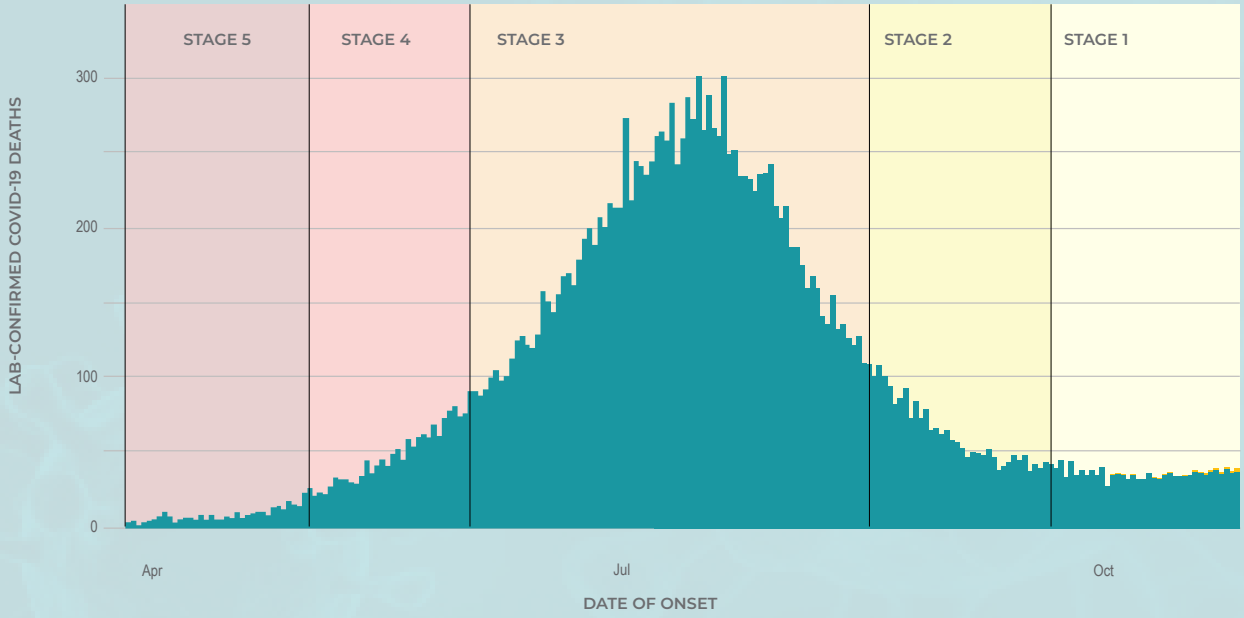
Limitations

The main limitation of this analysis is that the ascertainment rate of COVID-19 deaths may change over time, potentially affecting R estimation. Along with the ascertainment rate, the delay between symptom onset and reporting of death may change over time; cases at the end of the time series will be under-estimated according to the proportion of laboratory-confirmed COVID-19 deaths with delays longer than 30 days between symptom onset and reporting of death. Furthermore, the introduction of dexamethasone treatment in mid-June and use of oxygen administration via high flow nasal cannula as well as changes in quality of healthcare provided if health systems are overwhelmed could alter mortality outcomes, leading to perturbations in the time series data which are unrelated to transmission. In addition, 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 deaths to the importation status of cases, affecting the reliability of initial R0 estimates, which are therefore not reported here.

Results

The daily number of laboratory-confirmed COVID-19 deaths steadily increased until mid-July 2020, following which daily numbers of new deaths decreased steadily, flattening around mid-September through to mid-October, when they began to increase slightly.

Figure 1. Daily number of COVID-19 deaths by date of symptom onset (missing data imputed; median of imputed time series is shown), South Africa (last date included: 27 October 2020). Yellow area shows adjustment for expected future deaths by date of onset.



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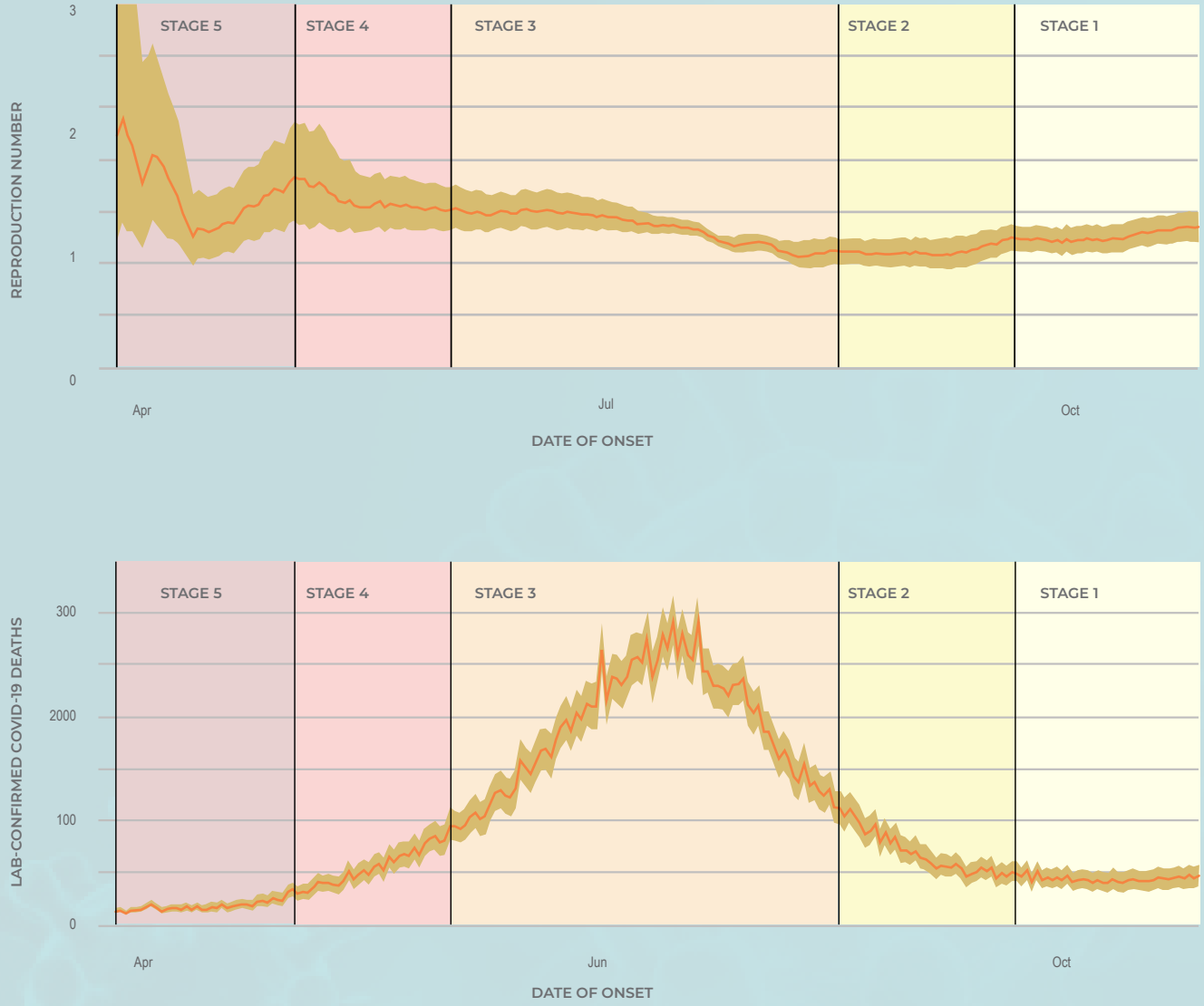
Nationally, the average R during the period of the stage 5 lockdown was 1.31 (95%CI: 1.07 - 1.60), rising to near 1.5 by the end of April (Figure 2). The daily R then dropped steadily throughout stage 4 lockdown, with an average over this period of 1.26 (95%CI: 1.06 – 1.50). During the stage 3 lockdown, the daily R varied slightly, with an average of 1.02 (95%CI: 1.00 – 1.04), between 1 June and 16 August. During the stage 2 lockdown, the daily R remained initially constant, then increased slightly, with an average of 0.84 (95%CI: 0.74 – 0.95) during this period. During stage 1 lockdown, the daily R remained steady until mid-October, then increased steadily, with an average of 0.99 (95%CI: 0.93 – 1.04) between 21 September and 27 October.

Figure 2. Upper panel: Estimated daily reproduction number (R), with 95% confidence intervals, South Africa (last date included in the estimation: 27 October 2020). Lower panel: estimated number of laboratory-confirmed COVID-19 deaths by onset date with missing data imputed. The median and 95% range for the imputed datasets are shown.



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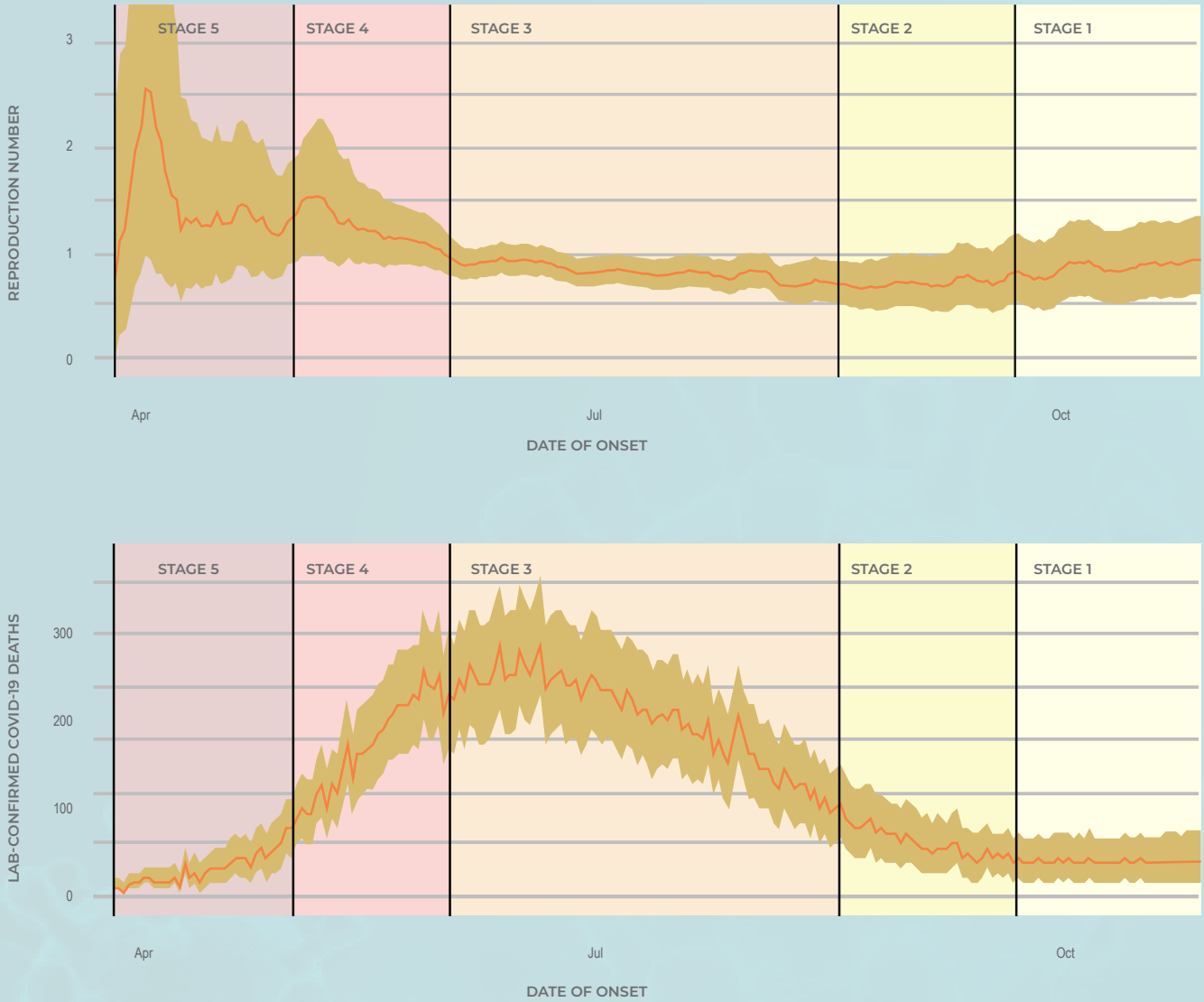
In the Western Cape Province, the average R during the stage 5 lockdown was 1.41 (95%CI: 1.08-1.84), with a value near 1.4 at the end of April (Figure 3). The daily R then dropped steadily throughout stage 4 lockdown, with an average over this period of 1.22 (95%CI: 1.04 – 1.46). During the stage 3 lockdown, the daily R remained close to the threshold value of 1, with an average of 0.96 (95%CI: 0.92 – 1.00) from 1 June to 16 August. During the stage 2 lockdown, R remained below 1, with an average of 0.86 (95% CI: 0.74 – 1.00) during this period. During the stage 1 lockdown, R increased slightly, with an average of 0.99 (95% CI: 0.87 – 1.12) between 21 September and 27 October. As of 27 October, R was estimated to be 1.06 (95% CI: 0.78-1.41).

Figure 3. Western Cape (last date included in the estimation: 27 October 2020). Upper panel: Estimated daily R based on deaths, with 95% confidence intervals. Lower panel: estimated number of laboratory-confirmed COVID-19 deaths by onset date with missing data imputed. The median and 95% range for the imputed datasets are shown.



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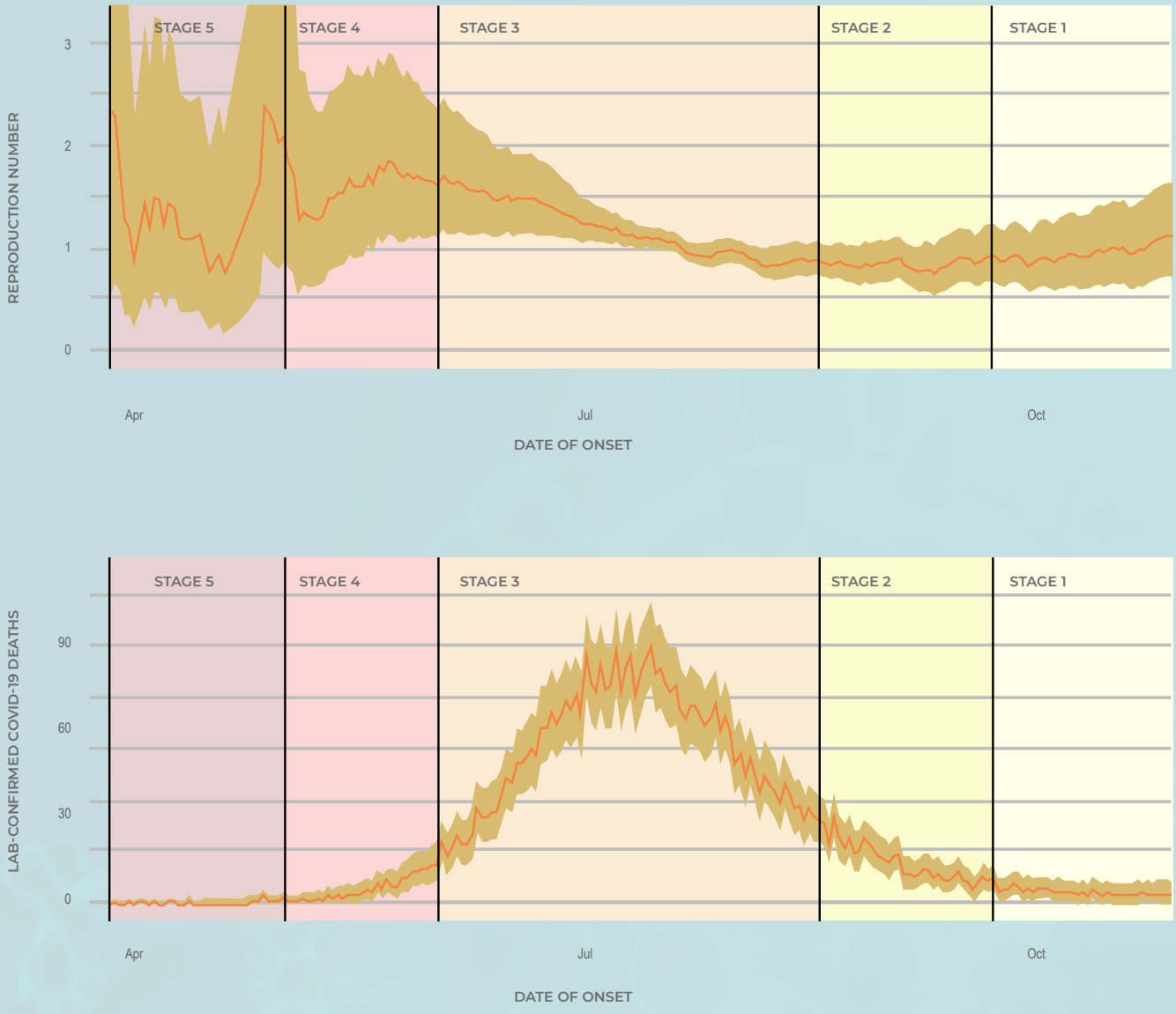
In Gauteng, the average R during the stage 5 lockdown was 1.15 (95%CI: 0.74 – 1.70), with a value near 1.75 at the end of April (Figure 4). The daily R remained relatively steady over the period of the stage 4 lockdown, with an average over this period of 1.53 (95%CI: 1.10 – 2.13). During the stage 3 lockdown, the daily R declined, with an average of 1.03 (95%CI: 0.99 – 1.07) from 1 June to 16 August, dropping below 1 toward the end of July. During the stage 2 lockdown, R remained below 1, with an average of 0.80 (95% CI: 0.67 – 0.95) during this period. During the stage 1 lockdown, R increased gradually, with an average of 0.89 (95% CI: 0.74 – 1.05) between 21 September and 27 October. As of 27 October, R was estimated to be 1.05 (95% CI: 0.69-1.53).

Figure 4. Gauteng (last date included in the estimation: 27 October 2020). Upper panel: Estimated daily R based on deaths, with 95% confidence intervals. Lower panel: estimated number of laboratory-confirmed COVID-19 deaths by onset date with missing data imputed. The median and 95% range for the imputed datasets are shown.



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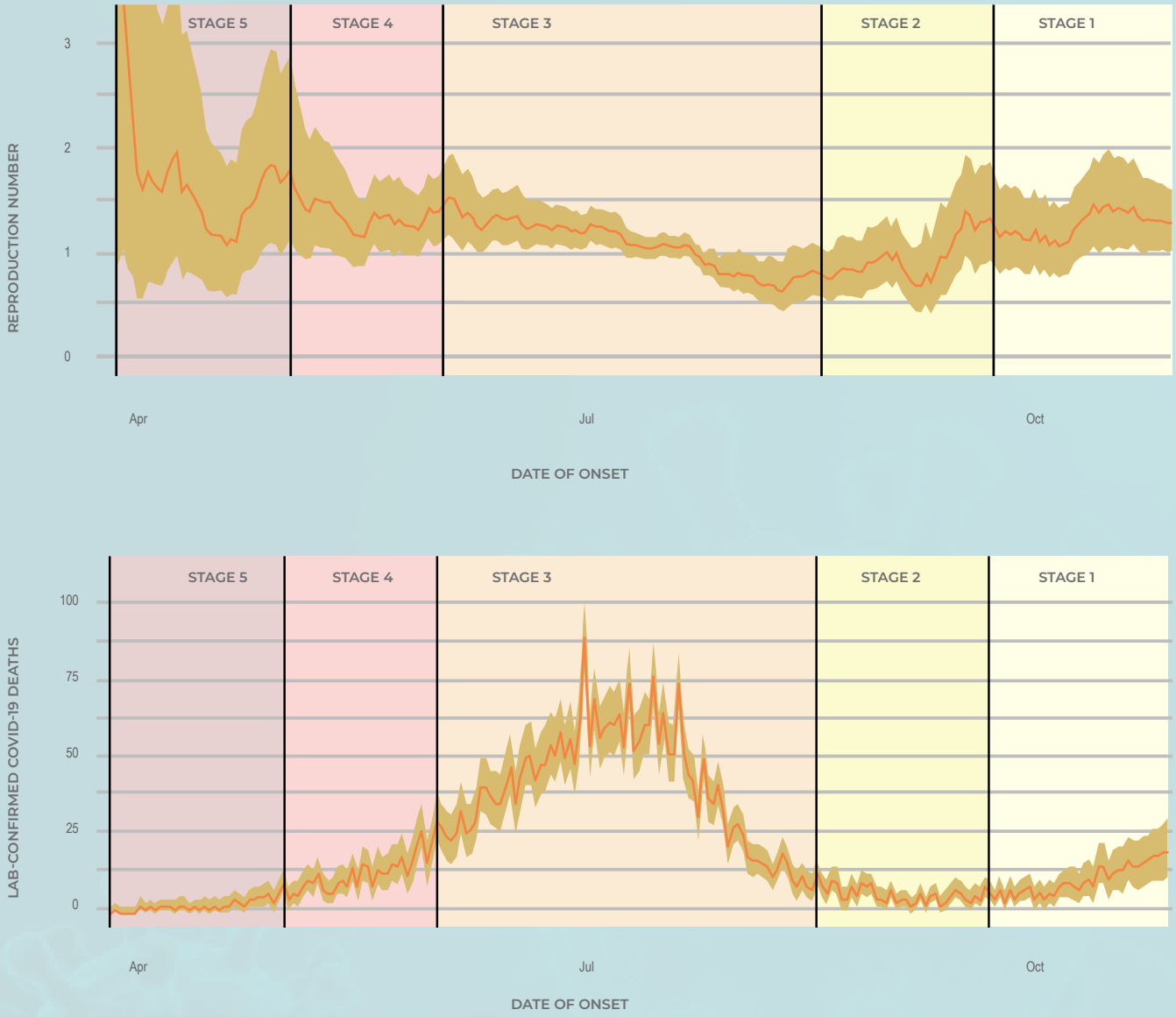
In the Eastern Cape, the average R during the stage 5 lockdown was 1.40 (95%CI: 1.01 – 1.93), with a value near 1.5 at the end of April (Figure 5). The daily R fluctuated during stage 4 lockdown, with an average over this period of 1.25 (95%CI: 1.04 – 1.49). During the stage 3 lockdown, the daily R decreased gradually, with an average of 0.99 (95%CI: 0.95 – 1.02) from 1 June to 16 August, dropping below 1 in the second half of July. During the second half of the stage 2 lockdown the value of R increased, with an average of 0.89 (95% CI: 0.74 – 1.06) during the stage 2 lockdown, and a value of 1.25 (95% CI: 0.88-1.75) as of 20 September. Despite a gradual decline in early stage 1 lockdown, R increased substantially at the beginning of October. The average value of R between 21 September and 27 October was 1.20 (95% CI: 1.02 – 1.40). As of 27 October, R was estimated to be 1.20 (95% CI: 0.96-1.51).

Figure 5. Eastern Cape (last date included in the estimation: 27 October 2020). Upper panel: Estimated daily R based on deaths, with 95% confidence intervals. Lower panel: estimated number of laboratory-confirmed COVID-19 deaths by onset date with missing data imputed. The median and 95% range for the imputed datasets are shown.



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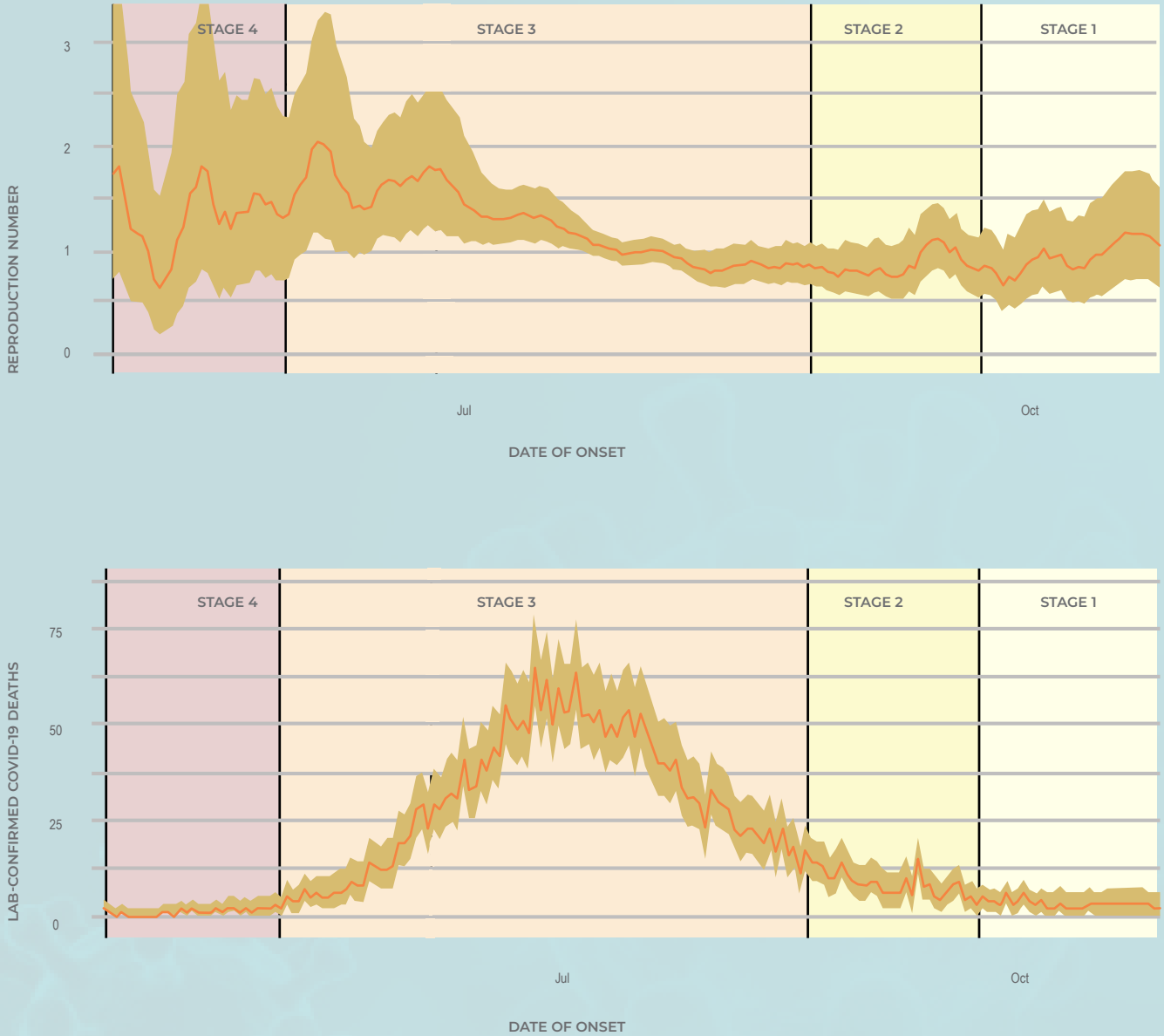
In KwaZulu-Natal, the daily R fluctuated during the stage 4 lockdown, with an average over this period of 1.19 (95%CI: 0.86 – 1.62). During the stage 3 lockdown, the daily R remained initially well above 1, then gradually decreased, with an average of 1.06 (95%CI: 1.00 – 1.12) from 1 June to 16 August. R remained stable for most of the stage 2 lockdown, with an average of 0.80 (95% CI: 0.68-0.95) during this period. During the stage 1 lockdown, R remained close to 1, with an average of 0.86 (95% CI: 0.70-1.05) between 21 September and 27 October. As of 27 October, R was estimated to be 1.00 (95% CI: 0.62-1.52).

Figure 6. KwaZulu-Natal (last date included in the estimation: 27 October 2020). Upper panel: Estimated daily R based on deaths, with 95% confidence intervals. Lower panel: estimated number of laboratory-confirmed COVID-19 deaths by onset date with missing data imputed. The median and 95% range for the imputed datasets are shown. Plots show estimates from 1 May, as daily R estimates are unstable early in the time series due to small numbers of deaths.



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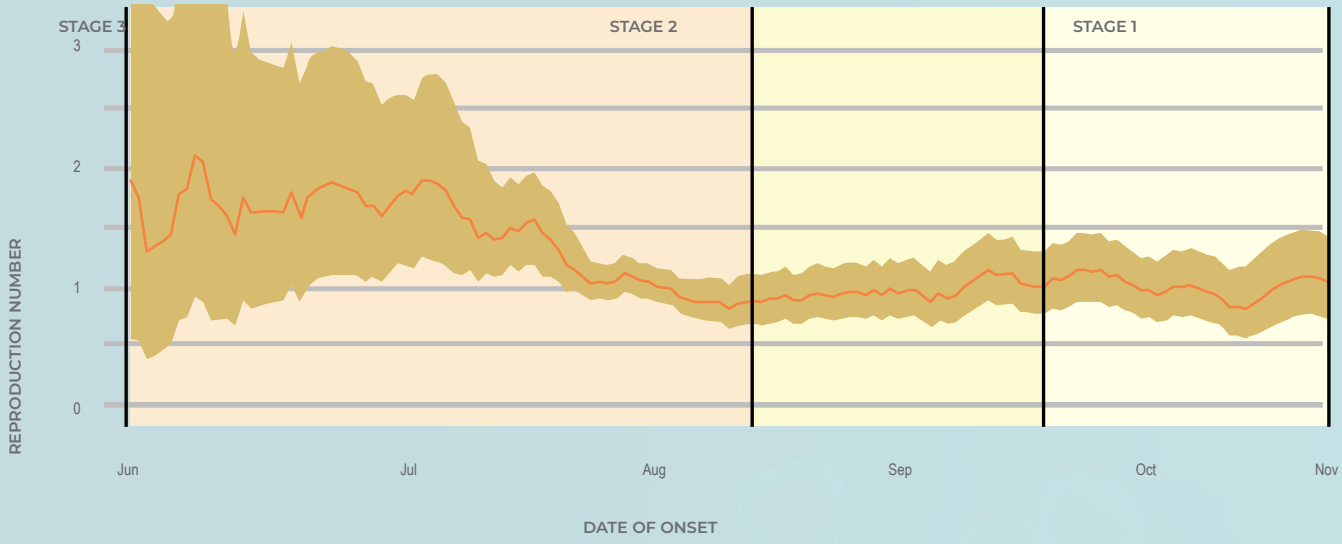
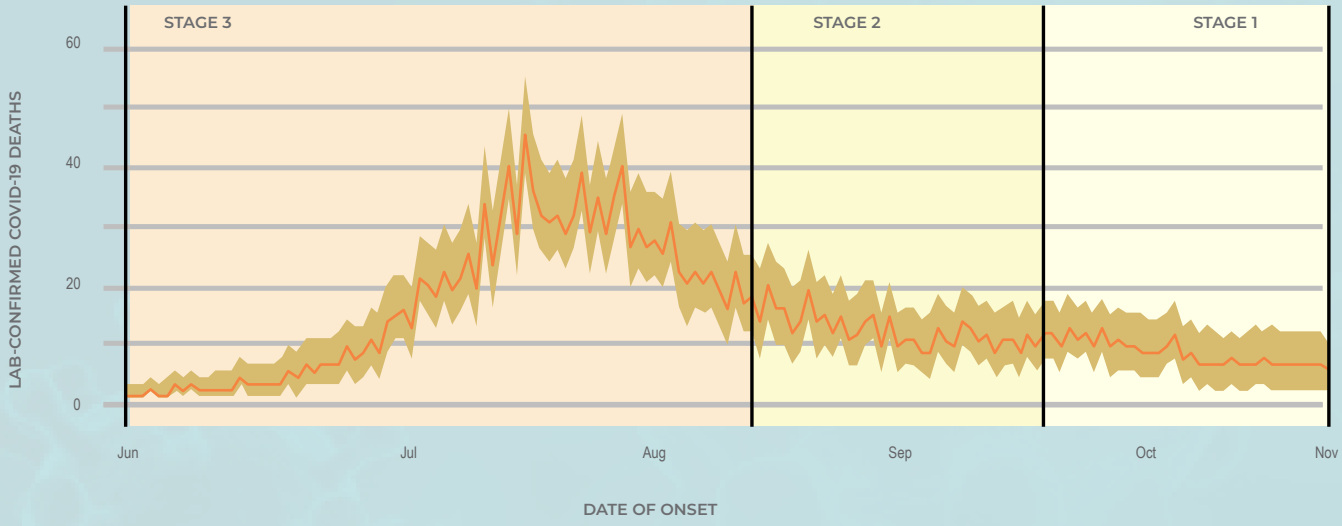
In Free State, the daily R fluctuated during the stage 3 lockdown, with an average of 1.09 (95%CI: 1.00 – 1.18) from 1 June to 16 August. During the stage 2 lockdown, R remained relatively stable, with an average of 0.89 (95% CI: 0.78-1.02) during this period. During the stage 1 lockdown, R remained close to 1, with an average of 0.93 (95% CI: 0.82-1.06) between 21 September and 27 October. As of 27 October, R was estimated to be 0.97 (95% CI: 0.80-1.16).

Figure 7. Free State (last date included in the estimation: 27 October 2020). Upper panel: Estimated daily R based on deaths, with 95% confidence intervals. Lower panel: Estimated number of laboratory-confirmed COVID-19 deaths by onset date with missing data. The median and 95% range for the imputed datasets are shown. Plots show estimates from 1 June, as daily R estimates are unstable early in the time series due to small numbers of deaths.





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

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