Estimating cases for COVID-19 in South Africa

Short term Projections: June 2020

Report Update: 12 June 2020

FOR PUBLIC RELEASE

Prepared by MASHA, HE²RO, and SACEMA

on behalf of the South African COVID-19 Modelling Consortium

Please address all queries and comments to: Harry Moultrie at HarryM@nicd.ac.za

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

Summary

The purpose of this report is to project estimated COVID-19 cases at national and provincial levels for the next 4 weeks. A mathematical model was used to simulate the transmission of local and imported COVID-19 cases based on data regarding laboratory confirmed infections until 5 June 2020 using parameter estimates jointly agreed upon by the SA COVID-19 Modelling Consortium.

The model projects that if testing patterns remain unchanged there may be more than 408,000 detected cases by mid-July. However, prioritization of testing may result in a reduction in detected cases to approximately 133,000. The cumulative number of deaths by mid-July is expected to be 7,440 (3,610 - 14,000). ICU and hospital bed numbers are to be interpreted with caution as use of hospital beds are influenced by treatment practices, and admission to ICU is likely to be subject to criteria that change through time and as a function of resources available. The model projections indicate that the demand for ICU beds is likely to exceed available ICU beds in the Western Cape and Eastern Cape during the month of June (including expanded capacity that has been made available in the Western Cape).

The models have been recalibrated based on updated data. This is an ongoing process as new testing and hospital data become available.

Due to the rapidly changing nature of the outbreak globally and in South Africa, the projections will need to be updated regularly and should be interpreted with caution. The models have been developed using data that is subject to a high degree of uncertainty. Transmission has been modelled at national and provincial levels resulting in model predictions providing broad-stroke national/provincial guidance rather than informing strategy at a more granular level. All models are simplifications of reality that are designed to describe and predict system behaviour and are justified by the assumptions and data with which they are developed.

Findings: Projected cases in the next four weeks

The model was calibrated to reported cumulative admissions and death data from 21 March to 5 June. Given that, in the early stages of the epidemic, the disease had seeded differently in the provinces and in communities with varying contact behaviour, the growth of the epidemic is different in each of the provinces. Thus, to provide short term projections reflective of the admissions and deaths reported, the basic reproductive number and the estimated decrease during lockdown were incorporated into the model. The basic reproductive number (R_0) and impact of the hard lockdown were informed by an analysis of laboratory testing and confirmed cases conducted by the National Institute for Communicable Diseases[1]. The reproductive numbers under Level four restrictions were varied in the model to reproduce trends in reported deaths between provinces. As detection is a function of the number of tests conducted and testing strategy (e.g. mass vs focal), inflation factors were adjusted to reproduce detected cases per province. As in previous reports, severe and critical cases were assumed to receive a test, with only a proportion of mild cases being tested.

Table 1. Level description and estimated parameters

Scenario	Description	Estimated Impact on Reproductive Number
Level five: National lockdown	Lockdown reduces transmissibility until 30 April	NICD analysis[1]
Level four restrictions	Level four restrictions reduce transmissibility from 1 May to 31 May	Estimated through calibration
Level three restrictions	Social distancing and other NPIs reduce transmissibility - implemented after 31 May and assumed to continue thereafter	Global Intervention Impact analysis*[2]

*A country-specific timeline of Covid-19 NPIs (household confinement, mask wearing, quarantine of known positives, school closures and limiting social groups) was constructed including interventions implemented for a minimum of 5-days in the absence of any other intervention (HopkinsIDD_hit-covid). The median effective reproduction number (R_t) was estimated for each intervention period using country-specific confirmed case reports. The final dataset included 41 countries and US States and 74 intervention events. Using a linear mixed effects model to account for country specific variations and household confinement as baseline, only social group limits were significantly associated with interval specific Rt. In comparison to household confinement, there was a 10.2% (95% CI: 8.27%-12.33%) increase in the estimated marginal mean R_t associated with social group limits.

Table 2 summarises the projected ranges of the number of cases, required hospital and ICU beds, and deaths at a national level. It is important to realise that not all active cases will require healthcare. A substantial proportion of infections (75%) are assumed to be asymptomatic or very mildly ill such that they would not require an outpatient care visit and would be very unlikely to seek COVID testing. Approximately 96% of active symptomatic cases are predicted to be mildly ill, with only a fraction of those seeking outpatient care or COVID testing. Therefore, large case numbers do not necessarily present a large burden on the health system. As has been the experience of many countries around the world, the vast majority of COVID-19 cases will show no or mild symptoms.

Previous projections from the NCEM have assumed that while all hospitalised cases will receive a laboratory-confirmed diagnosis, only a fraction of mildly symptomatic cases will be detected. This fraction has been 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. Due to current backlogs in testing, detection is modelled to decrease in mid-May to detect 1 in 5 mild cases. However, a change in policy to prioritise testing of hospitalised patients, health care workers, elderly and individuals with co-morbidities with respiratory symptoms, has been implemented in the Western Cape and may be extended to other provinces. The Cumulative Detected Cases panel in Figure 1 shows both detected cases assuming the current testing policy (blue) and detected cases projected under a limited policy of detecting only hospitalised cases from mid-June. Projections of detected cases may deviate from observed detected cases if the testing policy changes.

The projected beds in use and cumulative deaths are estimated under an assumption of unlimited capacity, i.e. any patient who needs a bed is able to get one and no excess mortality results from hospital capacity being breached. A separate analysis presented in this report projects the impact of capacity constraints on bed usage and mortality. All figures in the report are rounded to the nearest 10 and 100.

The uncertainty in the model output takes into account both process and parametric uncertainty. For each scenario, we conduct 10,000 stochastic simulations, each one with parameters sampled from the ranges provided in Table 13. We then construct 90% prediction intervals from the daily 5% and 95% quantiles of these simulation runs. These prediction intervals are the uncertainty bands presented in the plots. Darker internal bands represent the 50% prediction intervals.

Figure 1. National projections

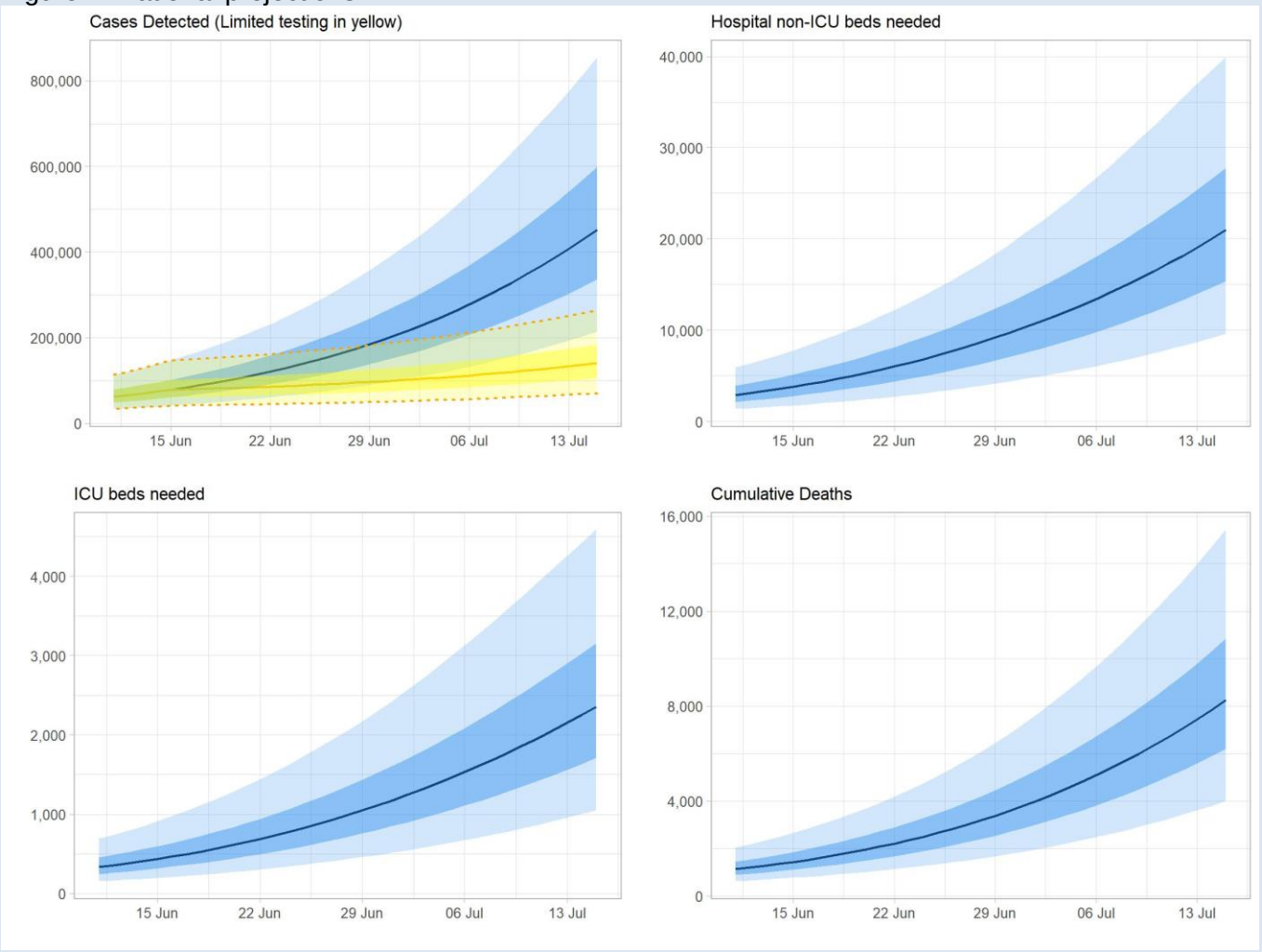


Table 2. National Projections

	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	**Total**	**Symptomatic**	**All**	**Symptomatic**	**Current Detection**	**Limited Detection**
2020-06-15	2,710,000 (1,390,000 - 5,030,000)	481,000 (243,000 - 917,000)	647,000 (292,000 - 1,310,000)	112,000 (49,500 - 234,000)	78,700 (41,600 - 147,000)	78,700 (41,600 - 147,000)
2020-06-22	4,170,000 (2,070,000 - 7,740,000)	746,000 (364,000 - 1,440,000)	998,000 (442,000 - 1,990,000)	175,000 (75,900 - 360,000)	121,000 (60,400 - 232,000)	85,900 (44,800 - 161,000)
2020-06-29	6,240,000 (3,050,000 - 11,500,000)	1,140,000 (541,000 - 2,200,000)	1,470,000 (659,000 - 2,890,000)	261,000 (114,000 - 526,000)	185,000 (89,500 - 358,000)	96,500 (49,600 - 182,000)
2020-07-06	9,080,000 (4,430,000 - 16,500,000)	1,690,000 (793,000 - 3,240,000)	2,080,000 (941,000 - 3,980,000)	371,000 (163,000 - 728,000)	278,000 (132,000 - 535,000)	112,000 (56,600 - 212,000)
2020-07-13	12,800,000 (6,290,000 - 21,900,000)	2,440,000 (1,140,000 - 4,530,000)	2,830,000 (1,310,000 - 4,910,000)	503,000 (227,000 - 922,000)	408,000 (193,000 - 775,000)	133,000 (66,500 - 251,000)

	Cumulative Admissions		Hospital beds needed		
Date	**Non-ICU**	**ICU**	**Non-ICU**	**ICU**	**Cumulative Deaths**
2020-06-15	11,400 (5,840 - 21,700)	1,470 (750 - 2,810)	3,810 (1,750 - 7,770)	440 (200 - 910)	1,440 (780 - 2,660)
2020-06-22	17,800 (8,710 - 34,200)	2,270 (1,110 - 4,470)	6,030 (2,720 - 12,200)	690 (300 - 1,440)	2,210 (1,140 - 4,190)
2020-06-29	27,200 (12,900 - 52,600)	3,470 (1,650 - 6,920)	9,190 (4,140 - 18,400)	1,050 (460 - 2,170)	3,380 (1,680 - 6,450)
2020-07-06	40,700 (19,200 - 78,600)	5,220 (2,430 - 10,300)	13,400 (6,070 - 26,700)	1,530 (670 - 3,130)	5,090 (2,480 - 9,670)
2020-07-13	59,300 (28,000 - 114,000)	7,640 (3,540 - 14,900)	19,100 (8,690 - 37,000)	2,150 (960 - 4,260)	7,440 (3,610 - 14,000)

Note:

- Hospital admissions and treatment pathways are based on national line list hospital data from the public and private sector, and sourced from the National Institute for Communicable Diseases DATCOV Platform. While this database contains a full hospital listing for the Western Cape, it is incomplete in the public sector for all other provinces. All parameters derived from this database were estimated from a patient cohort analysis. The cohort, constructed from the hospitalization data, was right-censored 35 days prior to data export, and followed to present, allowing for sufficient time for patients to experience an outcome (discharge or death). Where the sample of patients was too small to reliably determine parameter values, estimates were based on the patient cohort analysis from hospitals in all provinces.

- Estimates of lengths of hospital stay, care pathways and outcomes derived from the DATCOV Platform are not likely to be static over time. They will be influenced by evolving treatment practices, and admission to ICU is likely to be subject to criteria that change through time and as a function of resources available.

Projections by Province

Figure 2: Eastern Cape

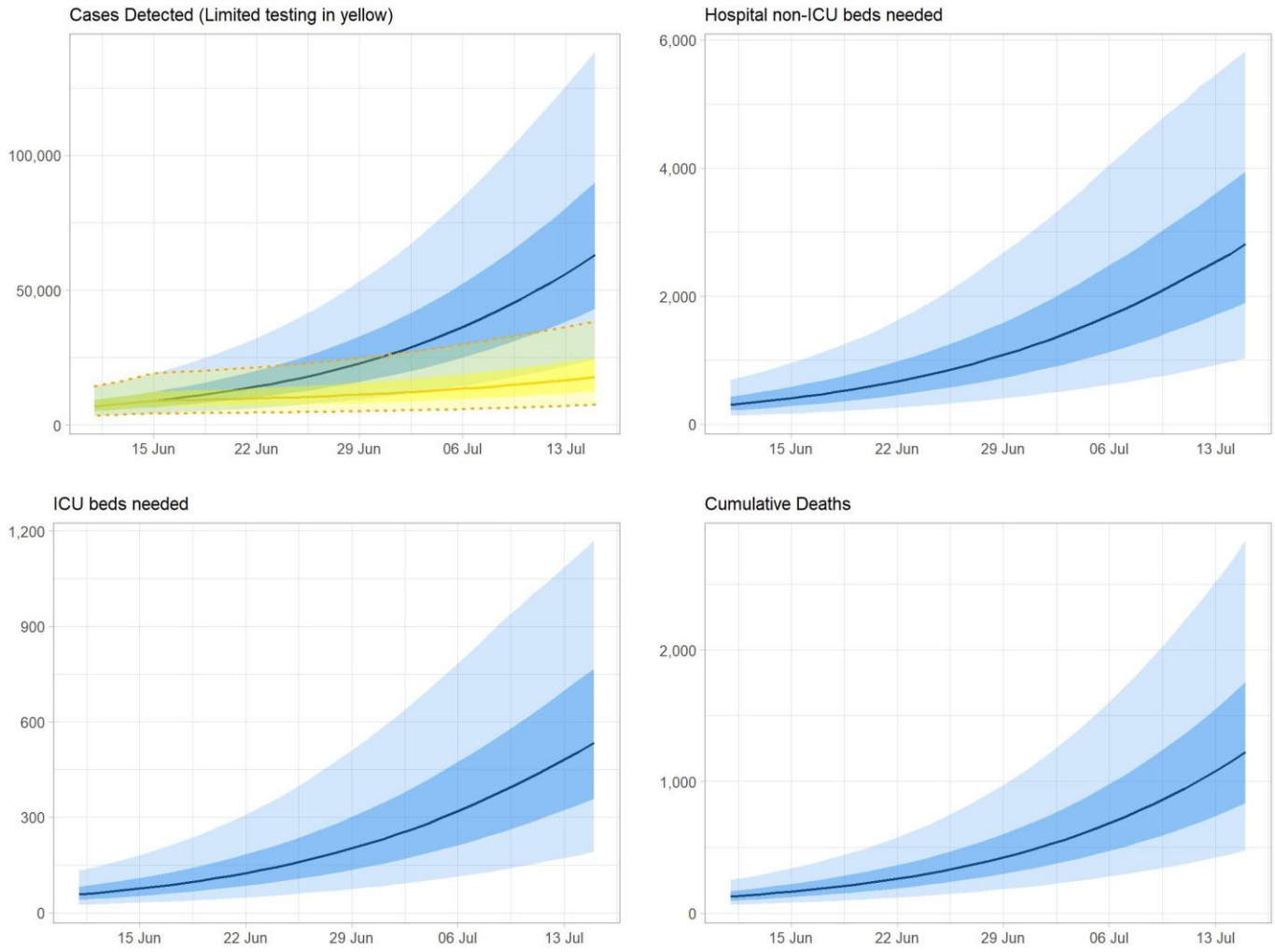


Table 3: Eastern Cape

Eastern Cape						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	330,000 (147,000 - 722,000)	56,300 (25,200 - 126,000)	80,400 (31,700 - 195,000)	13,900 (5,360 - 34,400)	9,000 (4,290 - 19,200)	9,000 (4,290 - 19,200)
2020-06-22	531,000 (225,000 - 1,190,000)	91,300 (38,500 - 212,000)	131,000 (49,400 - 325,000)	22,700 (8,350 - 57,700)	14,300 (6,350 - 32,200)	9,870 (4,620 - 21,300)
2020-06-29	840,000 (343,000 - 1,880,000)	147,000 (58,900 - 345,000)	207,000 (75,300 - 498,000)	36,100 (12,900 - 90,000)	22,800 (9,570 - 53,200)	11,300 (5,130 - 24,800)
2020-07-06	1,290,000 (517,000 - 2,710,000)	230,000 (89,500 - 527,000)	313,000 (114,000 - 685,000)	55,100 (19,300 - 127,000)	36,300 (14,500 - 84,200)	13,500 (5,920 - 29,900)
2020-07-13	1,880,000 (764,000 - 3,550,000)	348,000 (134,000 - 742,000)	441,000 (166,000 - 813,000)	78,400 (28,700 - 154,000)	56,100 (21,900 - 126,000)	16,600 (7,090 - 36,400)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	1,150 (530 - 2,520)	260 (120 - 550)	410 (170 - 950)	76 (31 - 180)	160 (80 - 340)
2020-06-22	1,860 (800 - 4,260)	410 (180 - 940)	670 (260 - 1,620)	120 (48 - 310)	260 (120 - 580)
2020-06-29	3,010 (1,220 - 7,090)	670 (270 - 1,560)	1,080 (400 - 2,680)	200 (74 - 510)	420 (180 - 970)
2020-07-06	4,790 (1,870 - 11,200)	1,070 (420 - 2,500)	1,700 (620 - 4,050)	320 (110 - 780)	680 (280 - 1,600)
2020-07-13	7,390 (2,820 - 16,500)	1,650 (630 - 3,730)	2,530 (920 - 5,460)	480 (170 - 1,090)	1,080 (420 - 2,520)

Figure 3: Free State

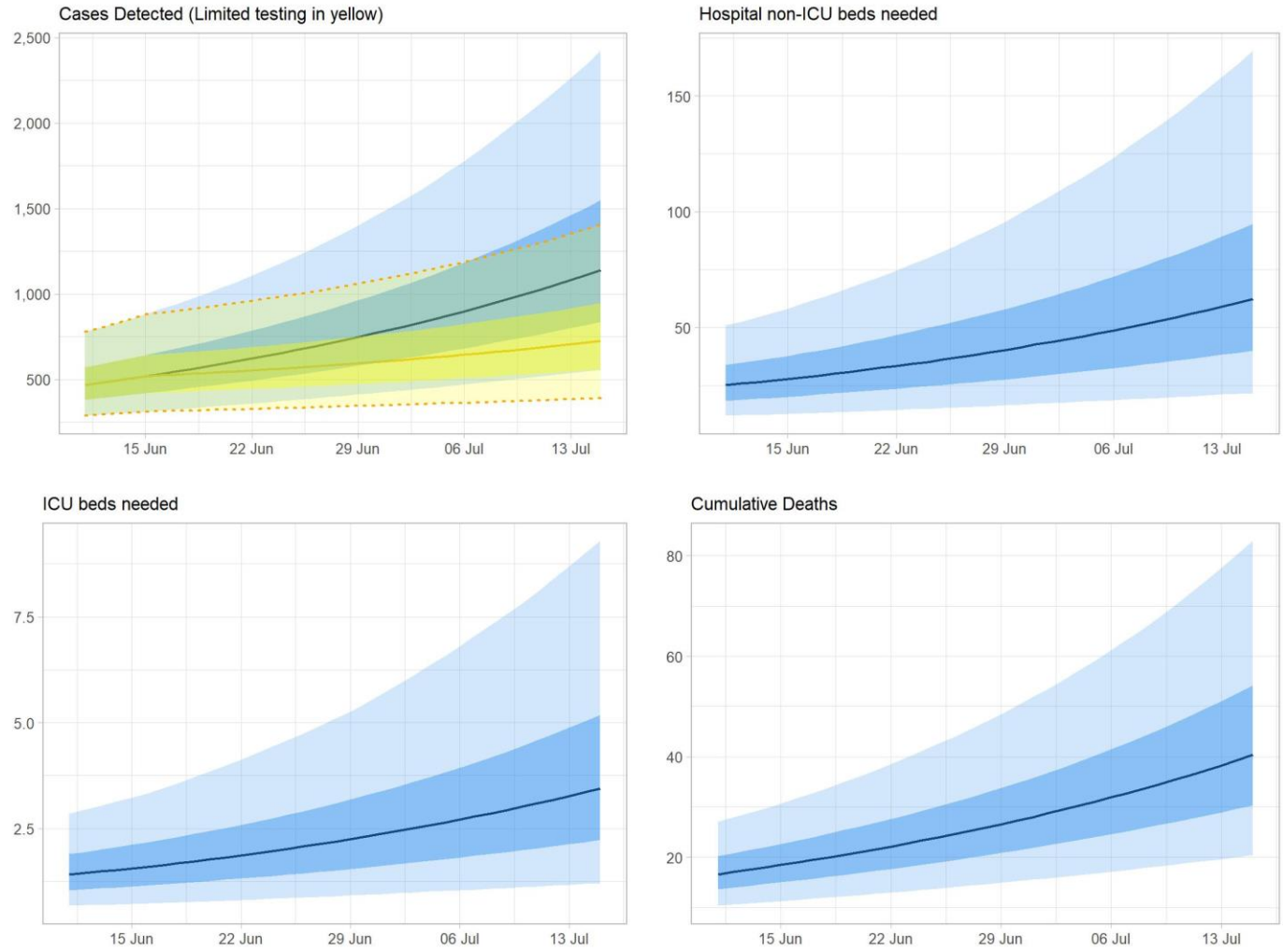


Table 4: Free State

Free State						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	10,500 (6,070 - 18,800)	2,320 (1,350 - 4,090)	1,490 (630 - 3,300)	280 (120 - 640)	520 (310 - 880)	520 (310 - 880)
2020-06-22	12,700 (6,940 - 23,900)	2,780 (1,550 - 5,130)	1,790 (720 - 4,280)	340 (140 - 820)	620 (360 - 1,110)	550 (330 - 960)
2020-06-29	15,300 (7,930 - 30,500)	3,350 (1,770 - 6,520)	2,170 (820 - 5,520)	420 (150 - 1,050)	750 (410 - 1,400)	590 (350 - 1,060)
2020-07-06	18,500 (9,070 - 39,000)	4,010 (2,010 - 8,290)	2,630 (930 - 7,140)	500 (170 - 1,360)	900 (470 - 1,780)	650 (360 - 1,190)
2020-07-13	22,300 (10,400 - 50,200)	4,840 (2,280 - 10,600)	3,160 (1,050 - 9,230)	600 (200 - 1,740)	1,080 (540 - 2,260)	710 (390 - 1,350)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	160 (95 - 280)	<10 (<10 - 15)	28 (13 - 58)	<10 (<10 - <10)	18 (11 - 31)
2020-06-22	200 (110 - 360)	11 (<10 - 19)	33 (14 - 75)	<10 (<10 - <10)	22 (13 - 39)
2020-06-29	230 (130 - 450)	13 (<10 - 24)	40 (16 - 95)	<10 (<10 - <10)	27 (15 - 48)
2020-07-06	280 (140 - 570)	16 (<10 - 31)	49 (19 - 120)	<10 (<10 - <10)	32 (17 - 61)
2020-07-13	340 (160 - 730)	19 (<10 - 40)	59 (21 - 160)	<10 (<10 - <10)	38 (20 - 78)

Figure 4: Gauteng

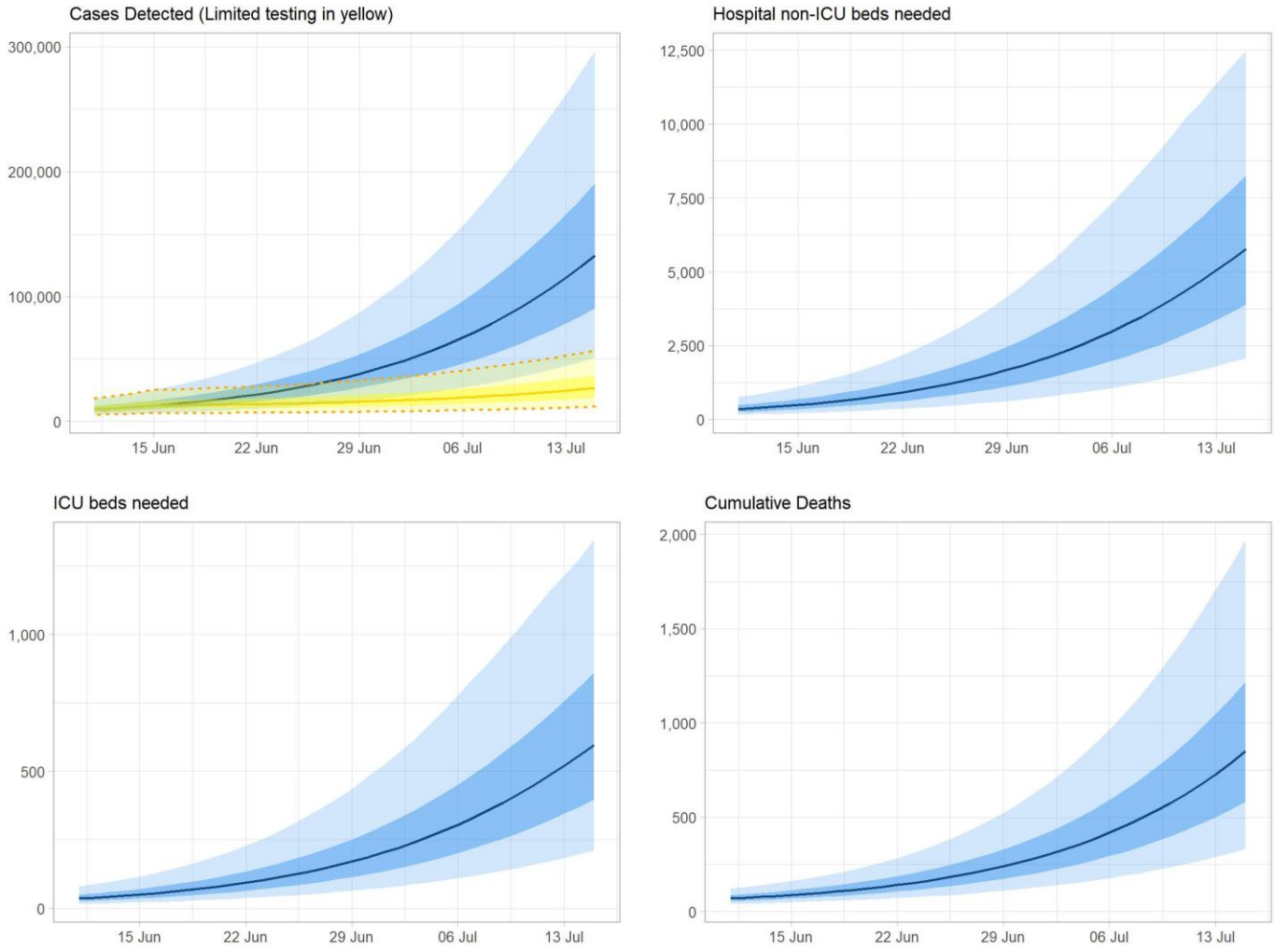


Table 5: Gauteng

Gauteng						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	537,000 (255,000 - 1,130,000)	88,700 (42,900 - 185,000)	134,000 (54,400 - 316,000)	22,600 (9,050 - 54,300)	12,800 (6,610 - 25,300)	12,800 (6,610 - 25,300)
2020-06-22	951,000 (413,000 - 2,130,000)	155,000 (68,700 - 349,000)	248,000 (93,500 - 613,000)	42,000 (15,700 - 107,000)	21,600 (10,200 - 47,000)	13,800 (7,030 - 27,900)
2020-06-29	1,680,000 (681,000 - 3,800,000)	274,000 (113,000 - 643,000)	446,000 (160,000 - 1,110,000)	76,000 (26,800 - 194,000)	38,100 (16,500 - 87,200)	15,700 (7,740 - 32,600)
2020-07-06	2,870,000 (1,120,000 - 6,170,000)	478,000 (186,000 - 1,110,000)	763,000 (270,000 - 1,750,000)	131,000 (45,300 - 314,000)	67,100 (27,000 - 157,000)	19,100 (8,940 - 40,800)
2020-07-13	4,600,000 (1,820,000 - 8,730,000)	800,000 (305,000 - 1,730,000)	1,200,000 (439,000 - 2,290,000)	208,000 (74,700 - 425,000)	115,000 (44,500 - 262,000)	24,600 (10,900 - 52,700)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	1,290 (650 - 2,580)	180 (91 - 360)	490 (210 - 1,120)	51 (22 - 120)	88 (49 - 160)
2020-06-22	2,200 (1,010 - 4,830)	310 (140 - 670)	920 (370 - 2,190)	93 (38 - 230)	140 (71 - 280)
2020-06-29	3,870 (1,640 - 9,000)	540 (230 - 1,260)	1,680 (630 - 4,150)	170 (65 - 440)	240 (110 - 520)
2020-07-06	6,810 (2,690 - 16,100)	950 (380 - 2,270)	2,980 (1,070 - 7,310)	310 (110 - 780)	420 (180 - 960)
2020-07-13	11,700 (4,420 - 26,500)	1,630 (620 - 3,790)	5,050 (1,800 - 11,400)	520 (180 - 1,210)	730 (290 - 1,710)

Figure 5: KwaZulu-Natal

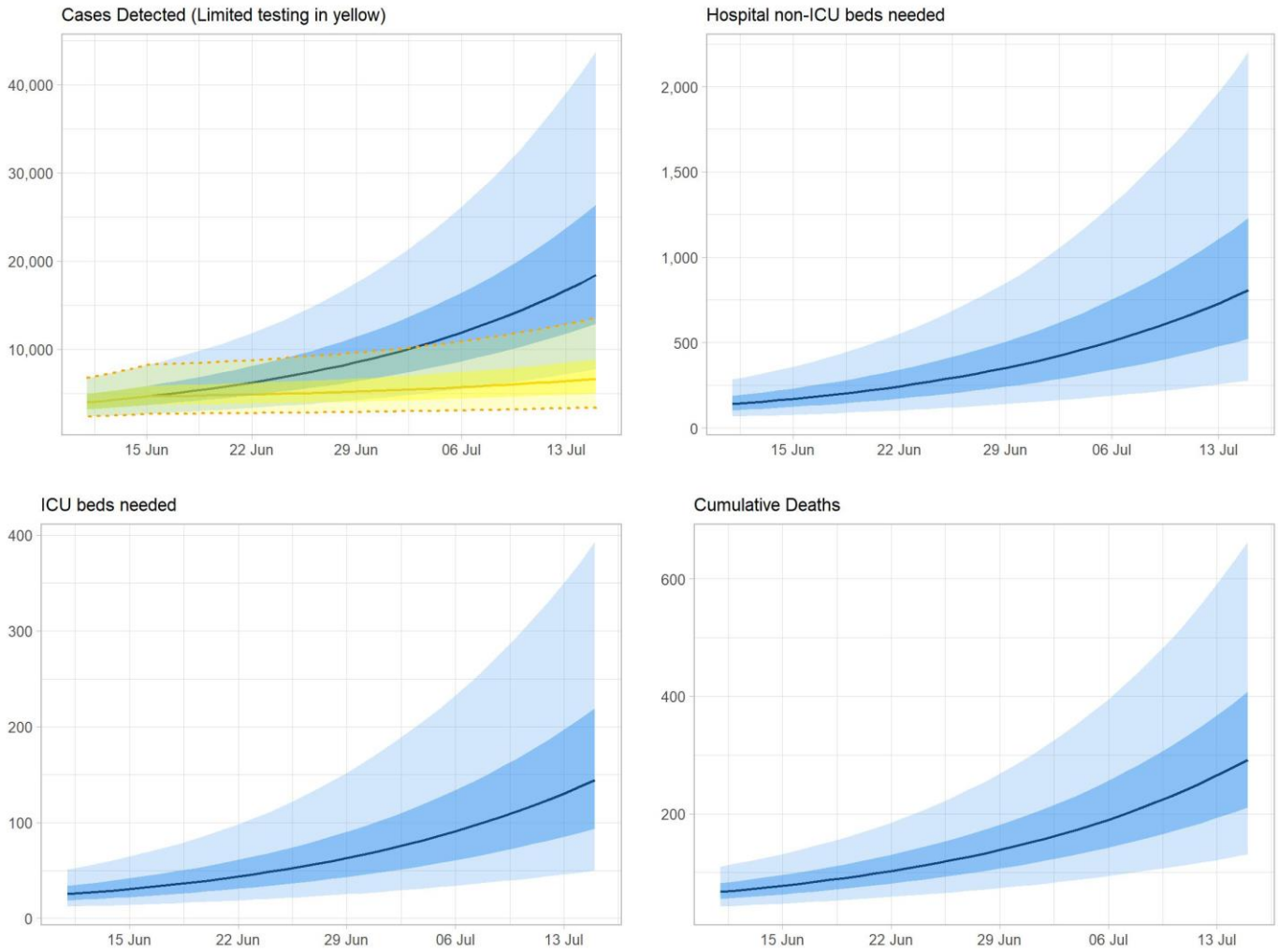


Table 6: KwaZulu-Natal

KwaZulu-Natal						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	131,000 (69,500 - 251,000)	25,900 (14,100 - 48,500)	25,400 (10,700 - 57,500)	4,470 (1,860 - 10,300)	4,660 (2,690 - 8,240)	4,660 (2,690 - 8,240)
2020-06-22	183,000 (89,900 - 377,000)	35,700 (18,000 - 71,600)	36,800 (14,400 - 89,300)	6,500 (2,520 - 16,000)	6,260 (3,380 - 11,800)	4,890 (2,790 - 8,790)
2020-06-29	259,000 (118,000 - 566,000)	49,800 (23,400 - 107,000)	53,300 (19,400 - 137,000)	9,410 (3,410 - 24,500)	8,550 (4,270 - 17,600)	5,230 (2,920 - 9,630)
2020-07-06	367,000 (154,000 - 854,000)	70,000 (30,500 - 160,000)	76,700 (26,100 - 209,000)	13,600 (4,580 - 37,000)	11,900 (5,520 - 26,100)	5,720 (3,100 - 10,900)
2020-07-13	518,000 (203,000 - 1,270,000)	98,900 (40,000 - 241,000)	110,000 (35,200 - 309,000)	19,400 (6,150 - 55,500)	16,700 (7,190 - 39,100)	6,430 (3,340 - 12,900)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	530 (300 - 970)	120 (69 - 220)	170 (78 - 360)	30 (14 - 64)	77 (47 - 130)
2020-06-22	720 (380 - 1,420)	170 (87 - 320)	240 (100 - 550)	44 (19 - 98)	100 (58 - 190)
2020-06-29	1000 (480 - 2,110)	230 (110 - 480)	350 (140 - 850)	63 (25 - 150)	140 (74 - 270)
2020-07-06	1,400 (630 - 3,160)	320 (140 - 720)	510 (190 - 1,310)	91 (34 - 230)	190 (94 - 390)
2020-07-13	1,970 (820 - 4,760)	460 (190 - 1,080)	730 (260 - 1,970)	130 (46 - 350)	270 (120 - 590)

Figure 6: Limpopo

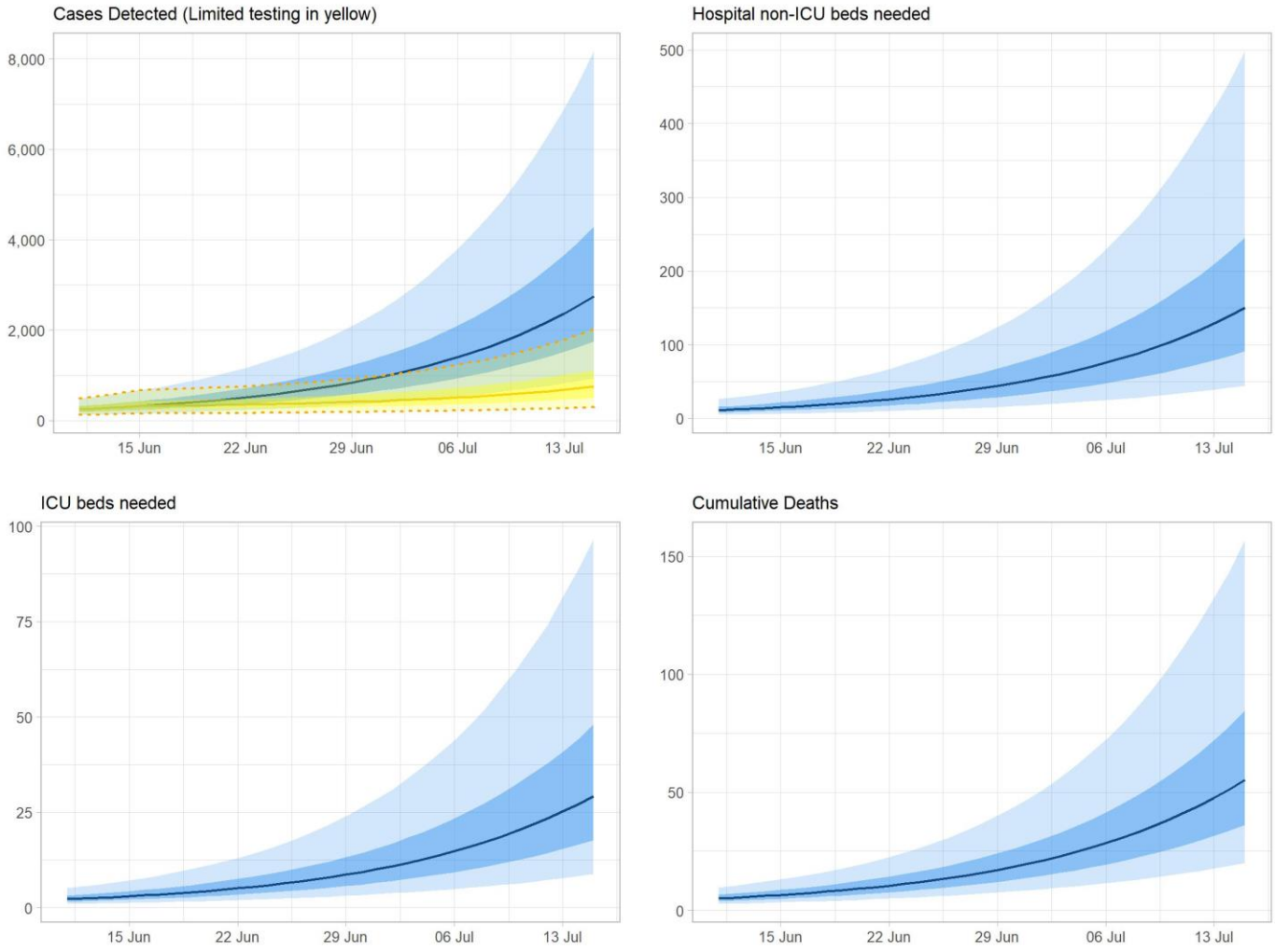


Table 7: Limpopo

Limpopo						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	11,700 (5,330 - 26,100)	1,990 (930 - 4,410)	2,860 (1,130 - 7,180)	490 (190 - 1,250)	320 (160 - 670)	320 (160 - 670)
2020-06-22	19,500 (8,190 - 47,100)	3,290 (1,410 - 7,940)	4,890 (1,780 - 13,300)	850 (300 - 2,310)	510 (230 - 1,170)	360 (170 - 760)
2020-06-29	32,900 (12,600 - 86,300)	5,510 (2,150 - 14,400)	8,320 (2,800 - 24,500)	1,440 (480 - 4,280)	840 (350 - 2,090)	410 (190 - 930)
2020-07-06	55,400 (19,600 - 159,000)	9,310 (3,330 - 26,400)	14,200 (4,350 - 45,300)	2,460 (750 - 7,900)	1,400 (540 - 3,800)	510 (220 - 1,230)
2020-07-13	93,800 (30,400 - 288,000)	15,700 (5,160 - 48,200)	24,100 (6,900 - 82,700)	4,170 (1,180 - 14,600)	2,370 (820 - 6,900)	680 (280 - 1,790)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	44 (21 - 95)	<10 (<10 - 21)	15 (<10 - 37)	<10 (<10 - <10)	<10 (<10 - 13)
2020-06-22	72 (32 - 170)	16 (<10 - 37)	26 (10 - 67)	<10 (<10 - 13)	10 (<10 - 23)
2020-06-29	120 (49 - 310)	26 (11 - 66)	44 (16 - 120)	<10 (<10 - 24)	17 (<10 - 40)
2020-07-06	200 (75 - 560)	44 (16 - 120)	76 (25 - 230)	15 (<10 - 44)	28 (11 - 72)
2020-07-13	340 (120 - 1,020)	74 (26 - 220)	130 (39 - 420)	25 (<10 - 81)	48 (18 - 130)

Figure 7: Mpumalanga

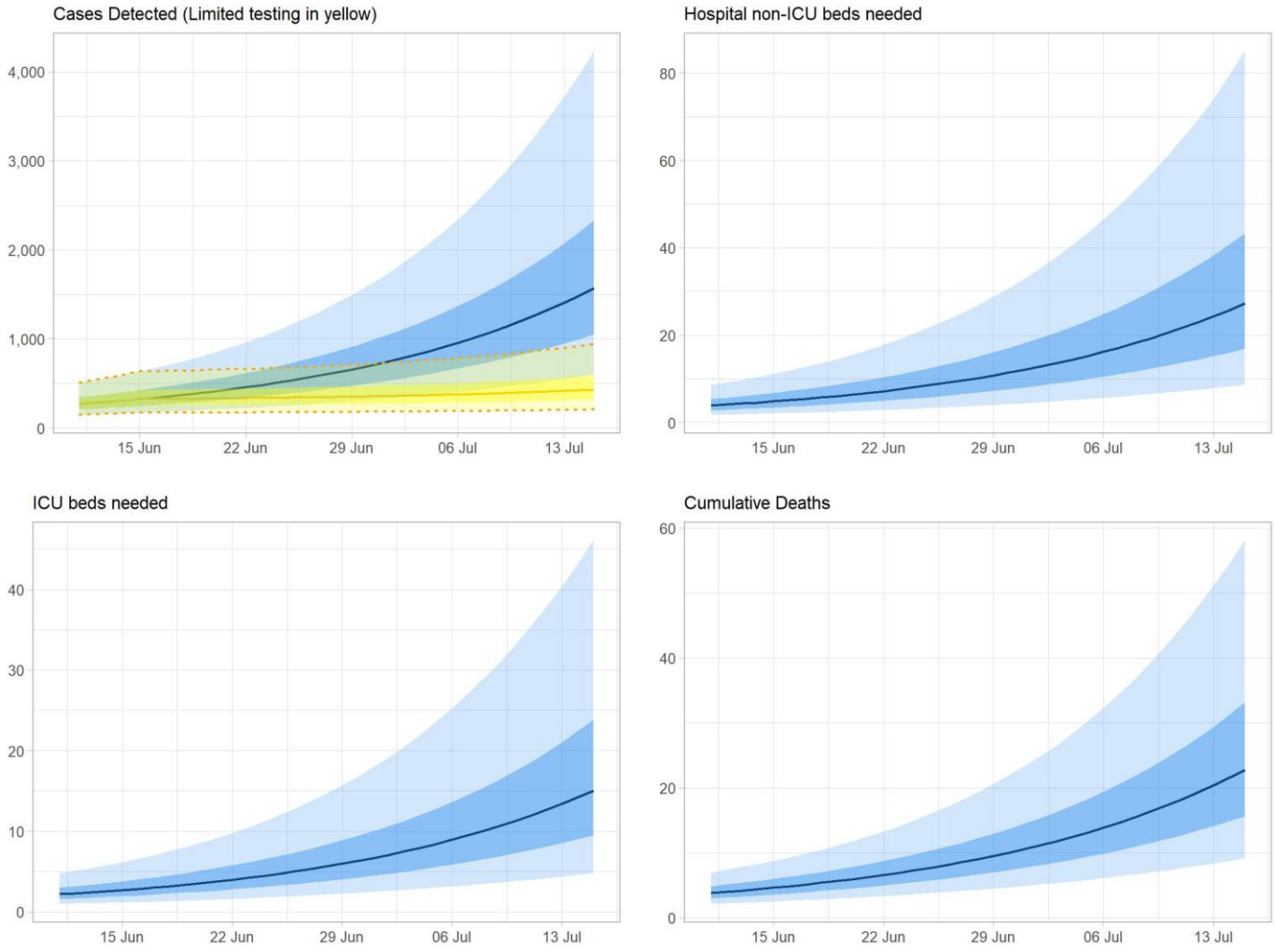


Table 8: Mpumalanga

Mpumalanga						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	10,300 (5,010 - 21,700)	1,920 (950 - 4,000)	2,200 (890 - 5,340)	380 (150 - 940)	320 (170 - 640)	320 (170 - 640)
2020-06-22	15,100 (6,810 - 34,100)	2,790 (1,290 - 6,250)	3,290 (1,240 - 8,590)	570 (210 - 1,510)	460 (230 - 960)	340 (180 - 660)
2020-06-29	22,300 (9,330 - 54,300)	4,090 (1,750 - 9,900)	4,940 (1,720 - 13,900)	850 (290 - 2,420)	660 (300 - 1,490)	350 (180 - 710)
2020-07-06	33,000 (12,800 - 86,800)	6,050 (2,400 - 15,700)	7,370 (2,390 - 22,200)	1,270 (410 - 3,860)	960 (400 - 2,340)	380 (190 - 780)
2020-07-13	48,900 (17,600 - 139,000)	8,960 (3,300 - 25,000)	11,000 (3,340 - 35,500)	1,900 (570 - 6,170)	1,410 (550 - 3,720)	410 (200 - 900)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	15 (<10 - 31)	10 (<10 - 20)	<10 (<10 - 11)	<10 (<10 - <10)	<10 (<10 - <10)
2020-06-22	22 (10 - 48)	15 (<10 - 32)	<10 (<10 - 18)	<10 (<10 - <10)	<10 (<10 - 13)
2020-06-29	32 (14 - 75)	21 (<10 - 50)	11 (<10 - 29)	<10 (<10 - 16)	<10 (<10 - 21)
2020-07-06	47 (19 - 120)	31 (13 - 79)	16 (<10 - 46)	<10 (<10 - 25)	14 (<10 - 32)
2020-07-13	70 (27 - 190)	46 (18 - 120)	24 (<10 - 74)	13 (<10 - 40)	20 (<10 - 51)

Figure 8: Northern Cape

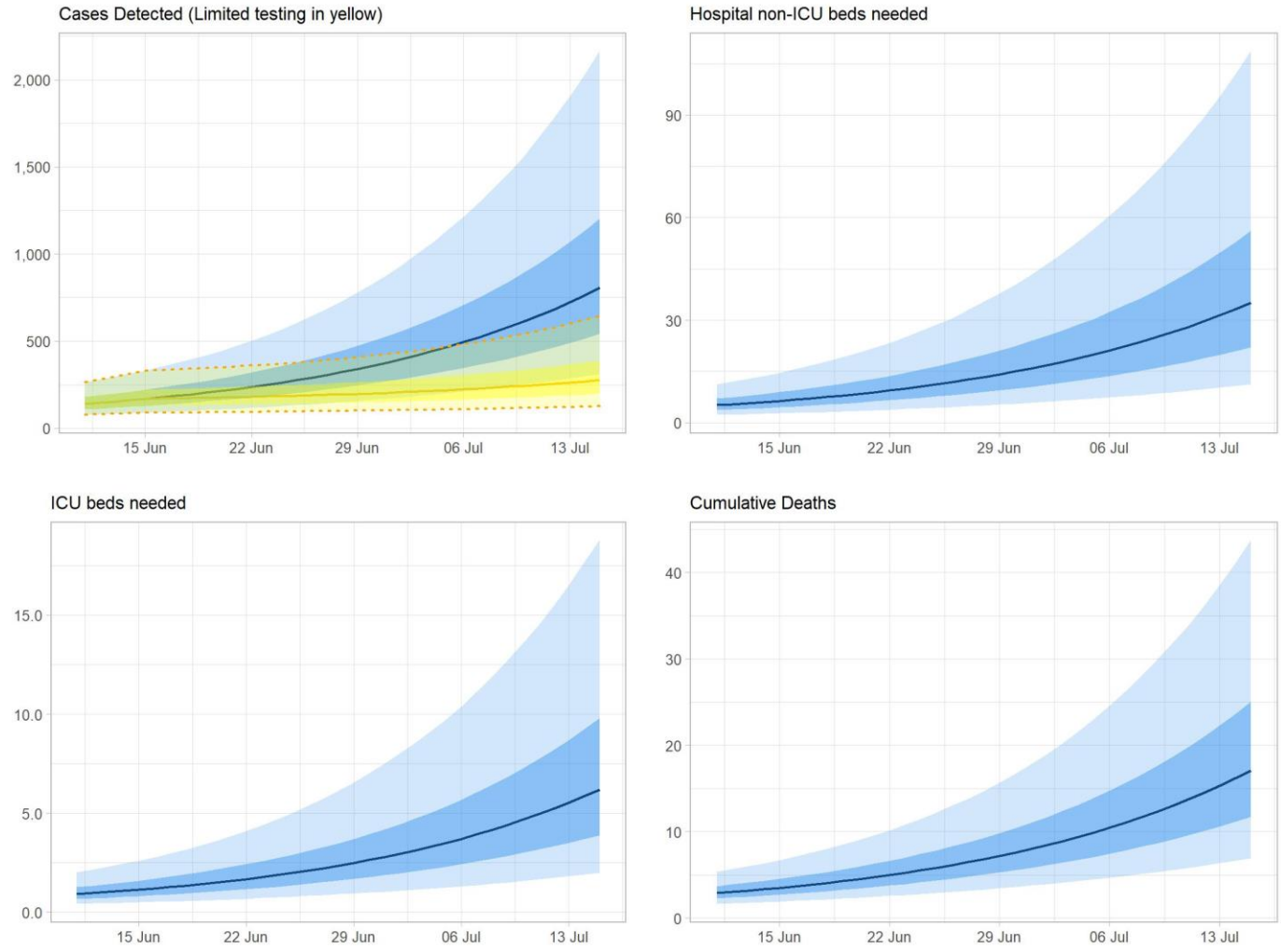


Table 9: Northern Cape

Northern Cape						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	5,020 (2,470 - 10,600)	940 (470 - 1,960)	1,070 (440 - 2,580)	190 (76 - 460)	170 (90 - 330)	170 (90 - 330)
2020-06-22	7,350 (3,360 - 16,600)	1,360 (630 - 3,030)	1,600 (610 - 4,160)	280 (110 - 740)	240 (120 - 500)	180 (95 - 360)
2020-06-29	10,800 (4,570 - 26,200)	1,990 (860 - 4,780)	2,400 (840 - 6,660)	420 (150 - 1,180)	340 (160 - 780)	200 (100 - 410)
2020-07-06	16,000 (6,260 - 41,700)	2,930 (1,170 - 7,560)	3,570 (1,160 - 10,700)	630 (200 - 1,890)	490 (210 - 1,210)	220 (110 - 480)
2020-07-13	23,600 (8,580 - 65,600)	4,310 (1,610 - 11,900)	5,290 (1,630 - 16,800)	930 (280 - 3,010)	720 (290 - 1,910)	260 (120 - 600)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	22 (12 - 46)	<10 (<10 - <10)	<10 (<10 - 15)	<10 (<10 - <10)	<10 (<10 - <10)
2020-06-22	32 (16 - 70)	<10 (<10 - 13)	<10 (<10 - 23)	<10 (<10 - <10)	<10 (<10 - 10)
2020-06-29	47 (21 - 110)	<10 (<10 - 21)	14 (<10 - 38)	<10 (<10 - <10)	<10 (<10 - 16)
2020-07-06	69 (29 - 170)	13 (<10 - 33)	21 (<10 - 60)	<10 (<10 - 10)	10 (<10 - 25)
2020-07-13	100 (39 - 270)	19 (<10 - 51)	31 (10 - 95)	<10 (<10 - 16)	15 (<10 - 39)

Figure 9: North West

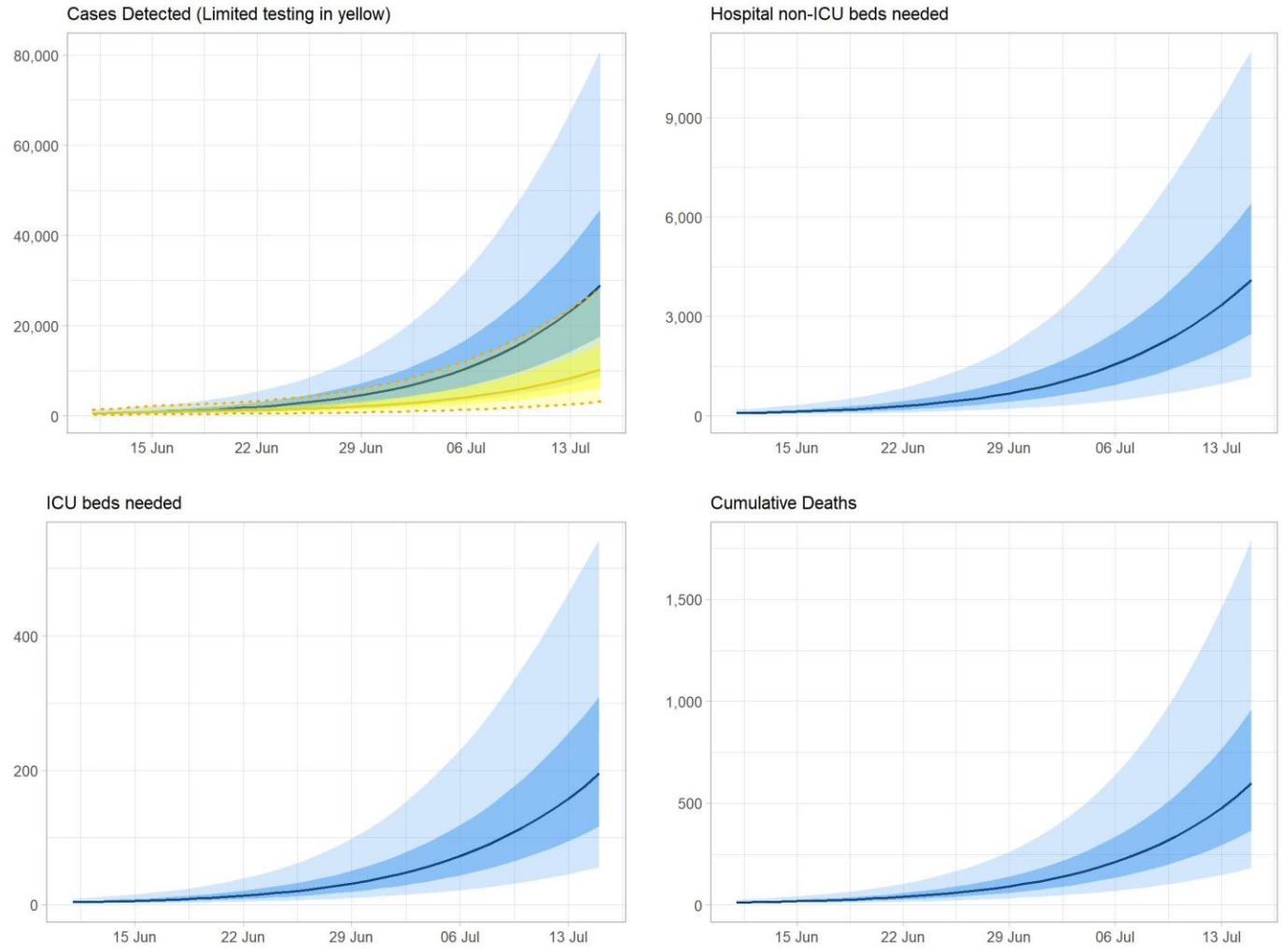


Table 10: North West

North West						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	47,100 (18,600 - 122,000)	6,440 (2,570 - 16,500)	13,500 (4,900 - 37,900)	2,270 (810 - 6,380)	900 (380 - 2,190)	900 (380 - 2,190)
2020-06-22	109,000 (39,100 - 305,000)	14,800 (5,360 - 41,500)	31,700 (10,500 - 95,800)	5,330 (1,750 - 16,300)	2,020 (780 - 5,430)	1,280 (510 - 3,290)
2020-06-29	249,000 (82,400 - 721,000)	34,100 (11,300 - 102,000)	73,000 (22,200 - 227,000)	12,400 (3,730 - 39,500)	4,610 (1,600 - 13,500)	2,150 (790 - 6,010)
2020-07-06	547,000 (172,000 - 1,490,000)	76,700 (23,600 - 230,000)	161,000 (46,900 - 478,000)	27,600 (7,870 - 84,900)	10,500 (3,360 - 32,000)	4,140 (1,380 - 12,300)
2020-07-13	1,100,000 (351,000 - 2,460,000)	163,000 (48,800 - 440,000)	326,000 (96,100 - 768,000)	56,800 (16,300 - 144,000)	23,300 (7,080 - 67,400)	8,380 (2,600 - 23,800)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	280 (120 - 700)	15 (<10 - 36)	120 (47 - 330)	<10 (<10 - 15)	18 (<10 - 42)
2020-06-22	640 (240 - 1,750)	33 (12 - 90)	290 (100 - 850)	14 (<10 - 39)	40 (16 - 100)
2020-06-29	1,480 (500 - 4,330)	76 (26 - 220)	680 (220 - 2,110)	32 (10 - 98)	92 (34 - 260)
2020-07-06	3,370 (1,060 - 10,300)	170 (54 - 530)	1,560 (460 - 4,890)	73 (22 - 230)	210 (71 - 640)
2020-07-13	7,400 (2,220 - 21,200)	380 (110 - 1,130)	3,360 (970 - 9,490)	160 (45 - 460)	480 (150 - 1,460)

Figure 10: Western Cape

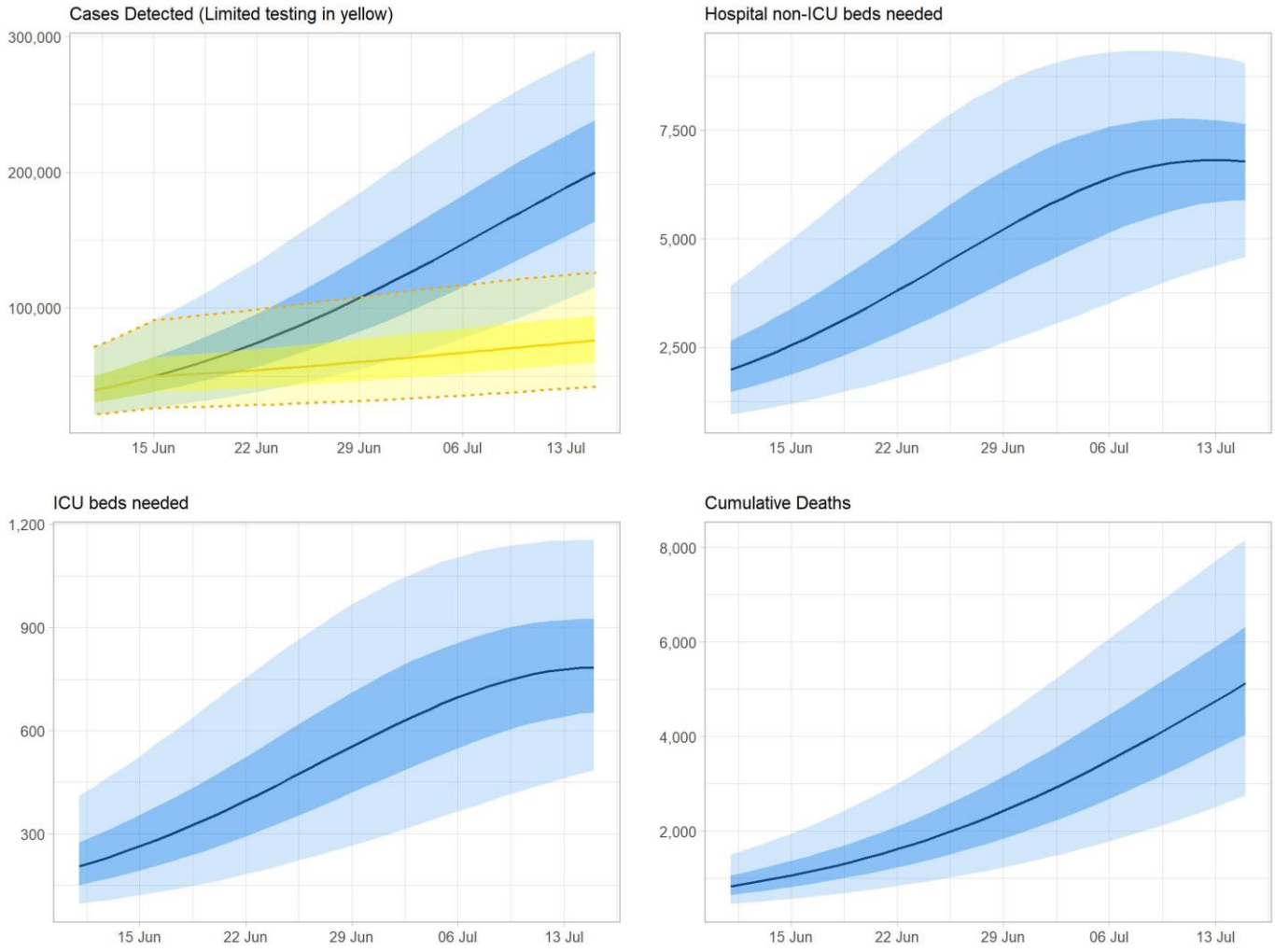


Table 11: Western Cape

Western Cape						
	Cumulative Incidence		Active Cases		Cumulative Detected Cases	
Date	Total	Symptomatic	All	Symptomatic	Current Detection	Limited Detection
2020-06-15	1,620,000 (859,000 - 2,760,000)	294,000 (151,000 - 540,000)	382,000 (181,000 - 698,000)	67,400 (31,100 - 129,000)	49,800 (26,400 - 91,000)	49,800 (26,400 - 91,000)
2020-06-22	2,330,000 (1,250,000 - 3,690,000)	437,000 (222,000 - 766,000)	534,000 (263,000 - 868,000)	95,700 (45,300 - 165,000)	74,300 (38,200 - 134,000)	54,300 (28,500 - 99,000)
2020-06-29	3,120,000 (1,750,000 - 4,500,000)	615,000 (319,000 - 1,000,000)	667,000 (361,000 - 911,000)	122,000 (63,300 - 180,000)	107,000 (55,000 - 185,000)	60,200 (31,600 - 108,000)
2020-07-06	3,860,000 (2,350,000 - 5,070,000)	804,000 (444,000 - 1,200,000)	713,000 (458,000 - 862,000)	132,000 (80,800 - 174,000)	147,000 (77,700 - 236,000)	67,200 (35,600 - 117,000)
2020-07-13	4,470,000 (2,980,000 - 5,440,000)	978,000 (584,000 - 1,350,000)	659,000 (500,000 - 779,000)	124,000 (88,800 - 159,000)	189,000 (106,000 - 279,000)	74,200 (40,500 - 124,000)

	Cumulative Admissions		Hospital beds needed		
Date	Non-ICU	ICU	Non-ICU	ICU	Cumulative Deaths
2020-06-15	7,890 (4,050 - 14,600)	860 (440 - 1,600)	2,550 (1,200 - 4,970)	260 (120 - 520)	1,060 (570 - 1,950)
2020-06-22	11,900 (5,990 - 21,800)	1,300 (650 - 2,390)	3,810 (1,790 - 6,990)	400 (180 - 750)	1,620 (840 - 3,010)
2020-06-29	17,300 (8,740 - 30,000)	1,890 (950 - 3,300)	5,220 (2,610 - 8,600)	550 (270 - 970)	2,420 (1,230 - 4,420)
2020-07-06	23,500 (12,300 - 37,800)	2,590 (1,350 - 4,230)	6,390 (3,520 - 9,290)	700 (370 - 1,100)	3,500 (1,780 - 6,080)
2020-07-13	29,800 (16,800 - 44,500)	3,320 (1,840 - 5,010)	6,820 (4,380 - 9,200)	780 (460 - 1,150)	4,750 (2,510 - 7,720)

Key parameter values

Table 12 below shows 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.

Table 12. Key model parameters

	Parameter	Value (range)	Sources
Infection severity	Proportion of cases that are asymptomatic	75% (70% - 80%) -	[3-6]
	Mild to moderate cases among the symptomatic	(89.6% - 98.16%)	Estimated through calibration to admissions and fatalities count data (DATCOV) [7]
	Severe cases among the symptomatic	(1.60% - 9.60%)	
	Critical cases among the symptomatic	(0.24% - 0.84%)	
	Fatal cases among the admitted (general)	(5.70% - 18.81%)	
	Fatal cases among the admitted (ICU ventilated)	(56.64% - 89.30%)	
	Fatal cases among the admitted (ICU non-ventilated)	(16.32% - 33.66%)	
	Proportion of cases in ICU requiring ventilation	(34.38% - 48.57%)	Estimated from NICD COVID-19 Hospital Sentinel Surveillance database (DATCOV) [7]
	Inflated mortality factor due to capacity breach (applied to current mortality rates)	1.066 (1.0 - 1.1) (non-ventilated & severe infection) 2.0 (1.8 - 2.1) (critical infection requiring ventilation)	Regression analysis based on data from CDC [8]
Timeframes & treatment durations	Time from infection to onset of infectiousness	4 days (2.0 - 6.0)	[9-18] with input from the National COVID-19 Modelling Consortium
	Time from onset of infectiousness to onset of symptoms	2 days (1.0 - 3.0)	
	Duration of infectiousness from onset of symptoms	5 days (4.0 - 6.0)	[18,19]
	Time from onset of symptoms to testing	4 days (3.0 - 5.0)	[9,10,20-24]
	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) [7]
	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)	

Data sources

The model has been informed by published and pre-print academic literature, Statistics South Africa population projections, expert input from members of the SA COVID-19 Modelling Consortium, and national case and hospitalisation details from the South African National Institute for Communicable Diseases and https://sacoronavirus.co.za/category/press-releases-and-notices/.

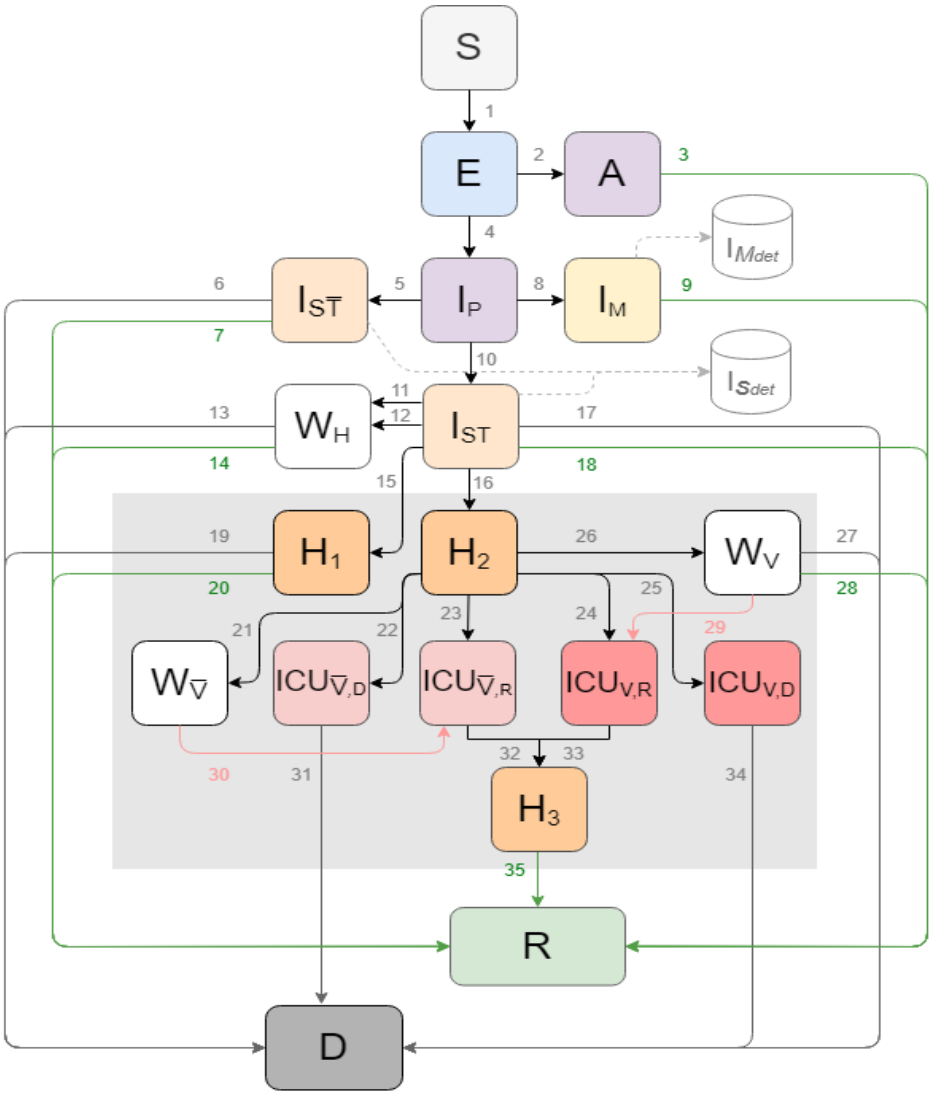
About the South African COVID-19 Modelling Consortium

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).

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 13. Contributors to the NCEM include Sheetal Silal, Jared Norman, Saadiyah Mayet, Rachel Hounsell, Juliet Pulliam, Roxanne Beauclair, Jeremy Bingham, Jonathan Dushoff, Reshma Kassanjee, Michael Li, Cari van Schalkwyk, Alex Welte, Lise Jamieson, Rachel Esra, Brooke Nichols and Gesine Meyer-Rath. For more information please contact Dr Sheetal Silal (sheetal.silal@uct.ac.za).

Figure 11. NCEM Model Structure (Generalised SEIR)



Model States

S	Susceptible
E	Exposed (not infectious)
A	Infected, asymptomatic (A)
I_P	Infected, pre-symptomatic (Ip)
I_M	Infected, mild
$I_{S\overline{T}}$	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 ($W_{\overline{V}}$)
	Infected, critical, in ICU, not ventilated, non-survivor ($ICU_{\overline{V},D}$)
	Infected, critical, in ICU, not ventilated, survivor ($ICU_{\overline{V},R}$)
	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 admitted to ICU
30. Waiting critical case not needing ventilation admitted to ICU
31. Death of critical case from ICU (not ventilated)
32. Critical case discharged from ICU (non-ventilated) to general ward
33. Critical case discharged from ICU (ventilated) to general ward
34. Death of critical case from ICU (ventilated)
35. Recovery of critical case (discharged from hospital)

Funders

MASHA

GN: 214236/Z/18Z

HE²RO

SACEMA

Appendix 1. Model performance: projections and observed data up to 5 June

Figure 12 shows the projected (black line) and observed (red dots) cumulative detected cases (left) and cumulative deaths (right) from 21 March to 5 June at a national level. The projections in Figure 12 and 13 were made on 8 May and show that the NCEM model closely estimated the actual cumulative detected cases observed for the month.

While the model appears to have under-estimated cumulative deaths, separating cumulative deaths in the Western Cape from cumulative deaths in the rest of the country accounts for this effect. Since releasing these projections, it came to light that the epidemic had seeded earlier in the Western Cape than previously assumed. Therefore, the incline in cases was experienced earlier than initially predicted. Figure 15 shows the projected cumulative deaths and actual deaths recorded for the Western Cape (left) and rest of the country (right). While the model under-estimated deaths for the Western Cape, cumulative deaths for the rest of the country were well projected by the NCEM model. This information on earlier seeding has been incorporated into this new set of projections.

Figure 12. Projected vs observed cumulative detected cases and cumulative deaths (National)

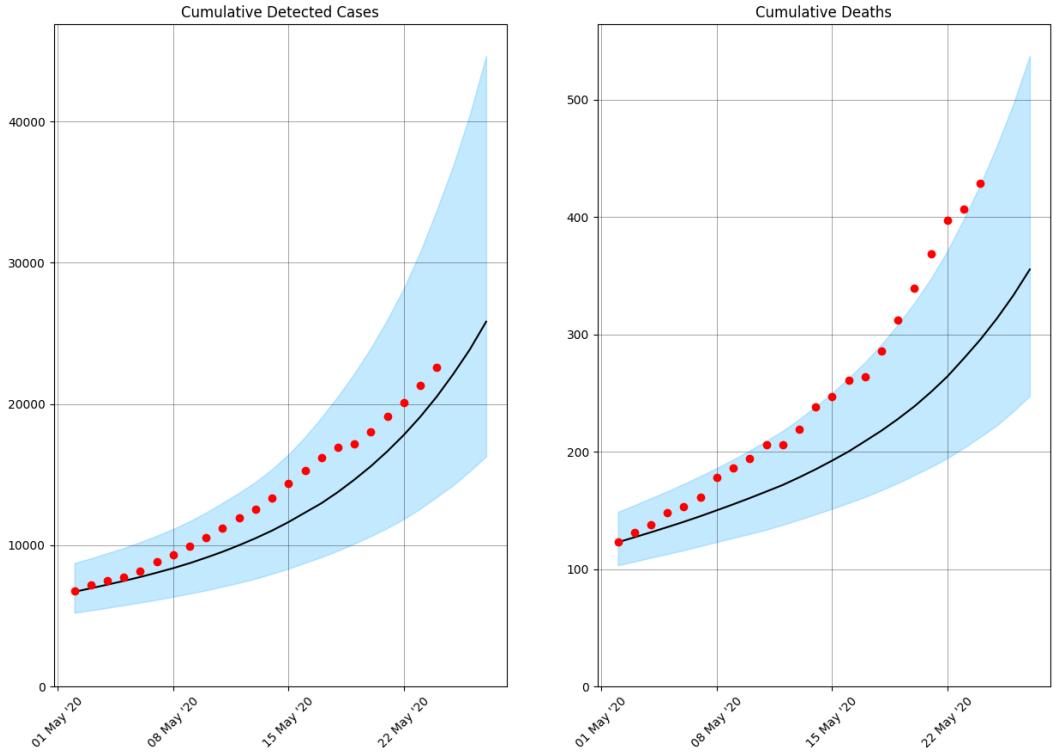
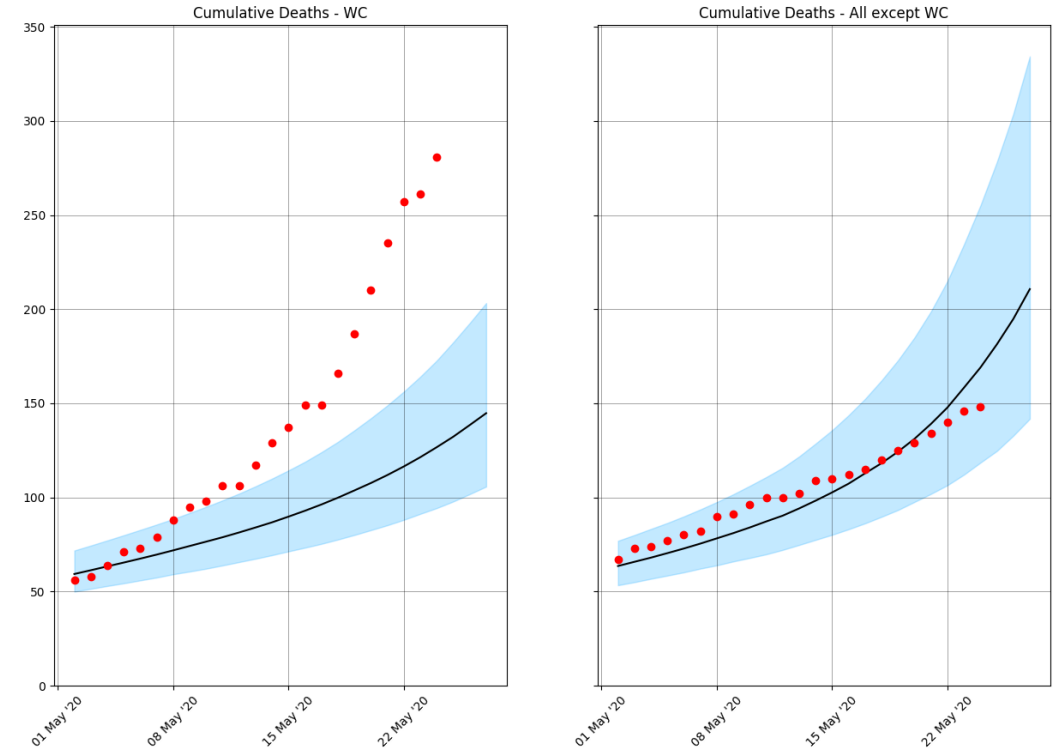
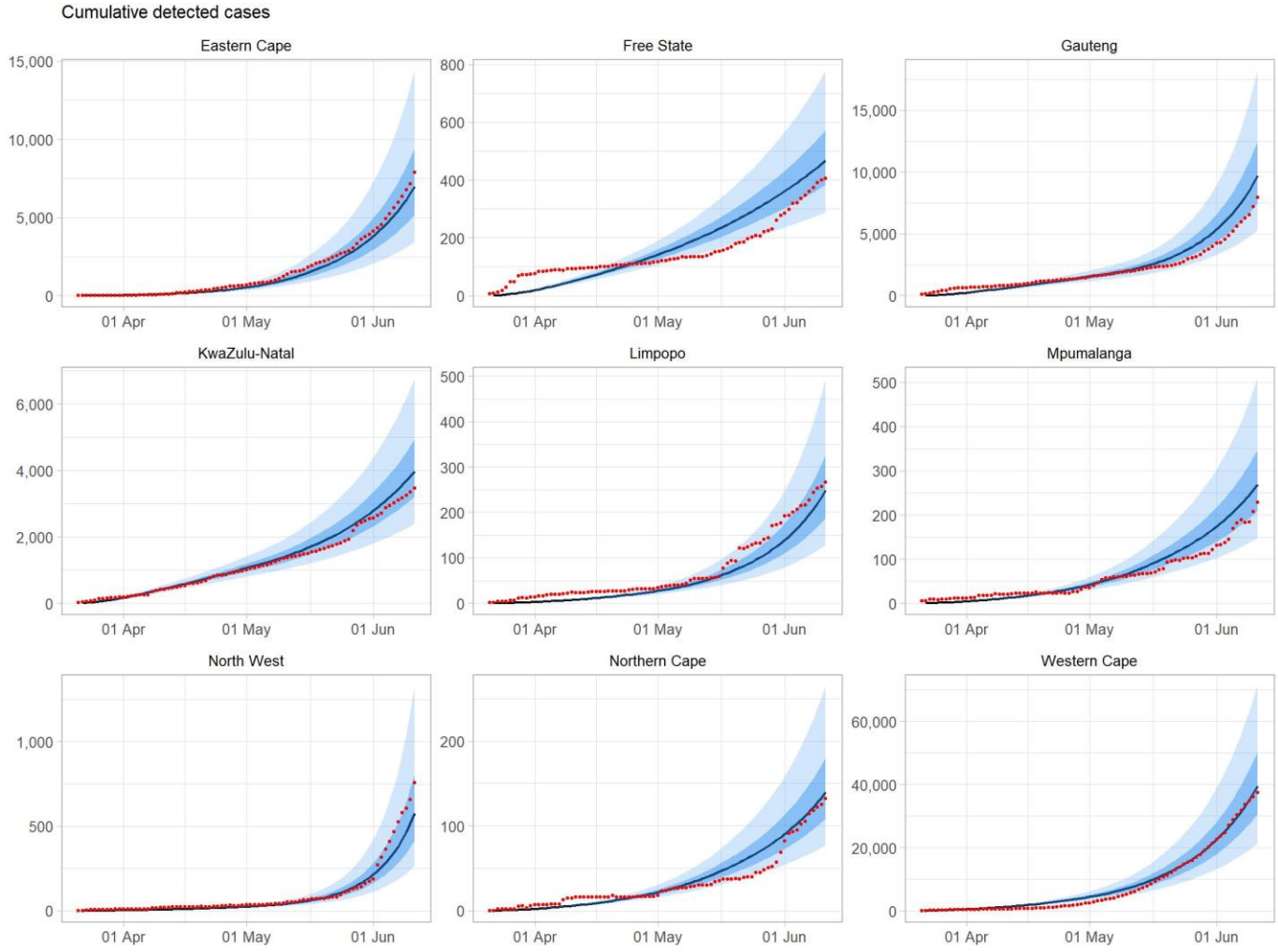


Figure 13. Cumulative deaths predicted and actual: Western Cape (left) and rest of country (right)

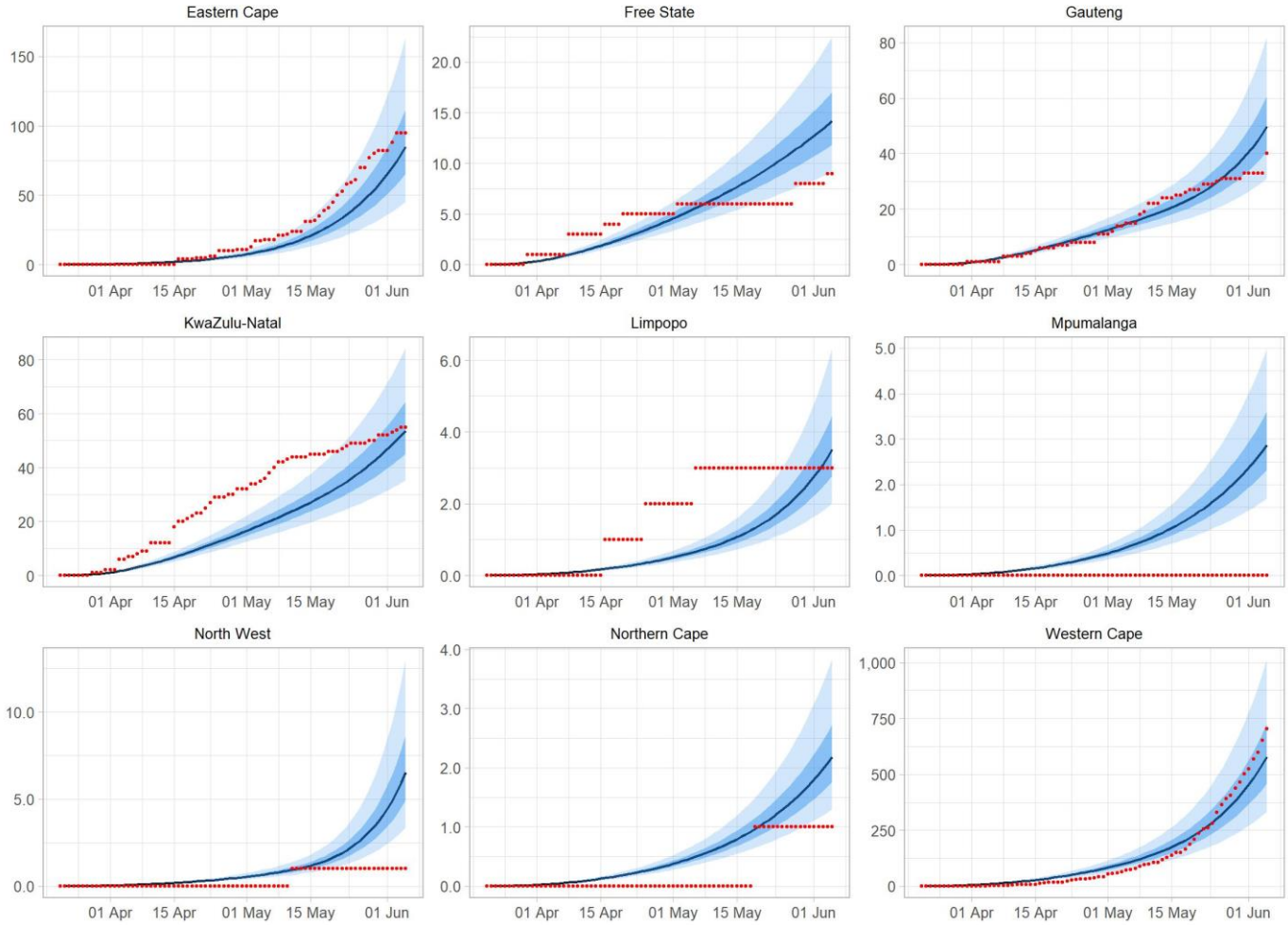


Appendix 2. Model data fitting for cumulative detected cases and cumulative deaths

Figure 14. Model data fitting by province



Cumulative deaths



References

1. National Institute for Communicable Diseases. The Initial and Daily COVID-19 Effective Reproductive Number (R) in South Africa 27 May 2020. [Internet]. 2020 May 27. Available from: https://www.nicd.ac.za/wp-content/uploads/2020/05/The-Initial-and-Daily-COVID-19-Effective-Reproductive-Number-R-in-South-Africa-002.pdf
2. Esra R, Letswalo D, Ngcobo N, Mngadi S, Estille J, Jamieson L, Meyer-Rath G, Keiser O (2020) Analysis of governmental non-pharmaceutical interventions for SARS-CoV-2 in the first months of the global pandemic (Unpublished)
3. Inui S, Fujikawa A, Jitsu M, Kunishima N, Watanabe S, Suzuki Y, et al. Chest CT Findings in Cases from the Cruise Ship "Diamond Princess" with Coronavirus Disease 2019 (COVID-19). Radiol Cardiothorac Imaging [Internet]. 2020 Apr 1 [cited 2020 Mar 23];2(2):e200110. Available from: http://pubs.rsna.org/doi/10.1148/ryct.2020200110
4. Sutton D, Fuchs K, D'Alton M, Goffman D. Universal Screening for SARS-CoV-2 in Women Admitted for Delivery. N Engl J Med [Internet]. 2020 Apr 13. Available from: https://www.nejm.org/doi/full/10.1056/NEJMc2009316
5. Day, M., 2020. Covid-19: four fifths of cases are asymptomatic, China figures indicate. BMJ [Internet]. 2020 Apr 2. Available from: https://doi.org/10.1136/bmj.m1375
6. Ing AJ, Cocks C, Green JP. COVID-19: in the footsteps of Ernest Shackleton. Thorax [Internet]. 2020 May 27 [cited 2020 Jun 4]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/32461231
7. National Institute for Communicable Diseases. COVID-19 Hospital Sentinel Surveillance database (DATCOV). [cited 2020 Jun 4]. (Unpublished)
8. CDC COVID-19 Response Team. Severe Outcomes Among Patients with Coronavirus Disease 2019 (COVID-19) — United States, February 12–March 16, 2020. 2020 Mar 27. CDC MMWR, 69(12), 343–346. Available from https://www.cdc.gov/mmwr/volumes/69/wr/pdfs/mm6912e2-H.pdf
9. Tindale L, Coombe M, Stockdale JE, Garlock E, Lau WYV, Saraswat M, et al. Transmission interval estimates suggest pre-symptomatic spread of COVID-19. medRxiv [Internet]. 2020 Mar 6;2020.03.03.20029983. Available from: https://www.medrxiv.org/content/10.1101/2020.03.03.20029983v1
10. Nie X, Fan L, Mu G, Tan Q, Wang M, Xie Y, et al. Epidemiological Characteristics and Incubation Period of 7015 Confirmed Cases With Coronavirus Disease 2019 Outside Hubei Province in China. J Infect Dis [Internet]. 2020 [cited 2020 Jun 10];1–8. Available from: https://academic.oup.com/jid/advance-article-abstract/doi/10.1093/infdis/jiaa211/5825699
11. Linton NM, Kobayashi T, Yang Y, Hayashi K, Akhmetzhanov AR, Jung S, et al. Incubation Period and Other Epidemiological Characteristics of 2019 Novel Coronavirus Infections with Right Truncation: A Statistical Analysis of Publicly Available Case Data. J Clin Med [Internet]. 2020 Feb 17 [cited 2020 Jun 10];9(2):538. Available from: https://www.mdpi.com/2077-0383/9/2/538
12. Thompson RN, Lovell-Read FA, Obolski U. Time from Symptom Onset to Hospitalisation of Coronavirus Disease 2019 (COVID-19) Cases: Implications for the Proportion of Transmissions from Infectors with Few Symptoms. J Clin Med [Internet]. 2020 May 1 [cited 2020 Jun 10];9(5):1297. Available from: https://www.mdpi.com/2077-0383/9/5/1297
13. Backer JA, Klinkenberg D, Wallinga J. Incubation period of 2019 novel coronavirus (2019- nCoV) infections among travellers from Wuhan, China, 20 - 28 January 2020. Vol. 25, Eurosurveillance.

European Centre for Disease Prevention and Control (ECDC); 2020. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7014672/

14. Jing Q, You C, Lin Q, Hu T, Yu S, Zhou X-H. Estimation of incubation period distribution of COVID-19 using disease onset forward time: a novel cross-sectional and forward follow-up study. medRxiv [Internet]. 2020 Mar 10;2020.03.06.20032417. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7217033/
15. Lauer SA, Grantz KH, Bi Q, Jones FK, Zheng Q, Meredith HR, et al. The incubation period of coronavirus disease 2019 (CoVID-19) from publicly reported confirmed cases: Estimation and application. Ann Intern Med [Internet]. 2020 May 5;172(9):577–82. Available from: https://www.acpjournals.org/doi/10.7326/M20-0504
16. Ganyani T, Kremer C, Chen D, Torneri A, Faes C, Wallinga J, et al. Estimating the generation interval for coronavirus disease (COVID-19) based on symptom onset data, March 2020. Eurosurveillance [Internet]. 2020 Apr 30;25(17). Available from: https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.17.2000257
17. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. Int J Infect Dis [Internet]. 2020 Mar [cited 2020 Mar 16]; Available from: https://linkinghub.elsevier.com/retrieve/pii/S1201971220301193
18. He X, Lau EHY, Wu P, Deng X, Wang J, Hao X, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. Nat Med [Internet]. 2020 May 1;26(5):672–5. Available from: https://www.nature.com/articles/s41591-020-0869-5
19. Wölfel R, Corman VM, Guggemos W, Seilmaier M, Zange S, Müller MA, et al. Virological assessment of hospitalized patients with COVID-2019. Nature. 2020 May 28;581(7809):465–9. Available from: https://www.nature.com/articles/s41586-020-2196-x
20. World Health Organization. Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) [Internet]. 2020 [cited 2020 Mar 14]. Available from: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf
21. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet [Internet]. 2020 [cited 2020 Mar 14];395:497. Available from: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30183-5/fulltext
22. Gaythorpe K, Imai N, Cuomo-Dannenburg G, Baguelin M, Bhatia S, Boonyasiri A, et al. Report 8: Symptom progression of COVID-19 [Internet]. 2020 Mar [cited 2020 Mar 18]. Available from: https://doi.org/10.25561/77344
23. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet [Internet]. 2020 Mar [cited 2020 Mar 14];0(0). Available from: https://linkinghub.elsevier.com/retrieve/pii/S0140673620305663
24. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical Characteristics of 138 Hospitalized Patients with 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. JAMA - J Am Med Assoc. 2020 Mar 17;323(11):1061–9. Available from: https://jamanetwork.com/journals/jama/fullarticle/2761044
25. StatsSA. Mid-year population estimates 2019. Statistical release P0302. 2019. Available from: http://www.statssa.gov.za/publications/P0302/P03022019.pdf