Estimating male circumcision prevalence for the evaluation public health programmes in South Africa.

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February 21, 2020

1 Introduction

Voluntary medical male circumcision (VMMC) has emerged in recent years as a powerful intervention to reduce HIV transmission risk. It is estimated that cicumcision reduces the risk of female-to-male transmission of HIV by up to 60% (Auvert *et al.*, 2005; Bailey *et al.*, 2007; Gray *et al.*, 2007), with some evidence to suggest a reduction in the risk of male-to-male transition of HIV (Pintye & Baeten, 2019). Male Circumcision (MC) is a one-time, efficient, safe and cost-effective HIV prevention method. The World Health Organization (WHO) and the Joint United Nations Programme on HIV/AIDS (UNAIDS) identified South Africa as a 'priority' country in which prevalence of HIV is high and prevalence of male circumcision is low (UNAIDS, 2011). As a result, programmes to scale up the number scale up the number of circumcised men have been introduced (Davis *et al.*, 2018; World Health Organization, 2018).

There is a need to produce accurate estimates of MC coverage in South Africa, particularly at a subnational level and how these are developing over time as a result of the scale up in VMMC programmes. This allows an evaluation the effectiveness of public health campaigns and allow more focussed planning for future target setting. Overall MC prevalence combines not only VMMC but also traditional circumcision (TMC), which is influenced by community-established values, beliefs, and motivational factors that vary with religious, ethnic and cultural identities. Due to TMC, there is likely to be substantial spatial variation in MC coverage in South Africa. In this paper, comprehensive estimates of MC, TMC and VMMC coverage by 5-year age groups at a national, province and district level annually in South Africa are produced. The spatial distribution of MC coverage across South Africa and the associated changes over time are examined at a subnational level that are observed as a results of the VMMC campaigns.

2 Methods

2.1 Data

Data from five nationally representative household surveys that asked men about their circumcision status conducted in South Africa between 2002 and 2017 were included in the analysis; South African National HIV Prevalence, HIV Incidence, Behaviour and Communication Survey (SABSSM) from 2002, 2008, 2012 and 2017 as well as the Demographic and Health Survey (DHS) from 2016. Information related to age, residence, circumcision status, location of circumcision was extracted for a total 51,886 individuals. Data were aggregated to obtain survey-weighted circumcision prevalence in each 5-year age group (0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64 and 65+) in time at a district level.

In order to distinguish between medical and traditional male circumcision, circumcisions that took place in a hospital or a clinic were classed as 'Medical', with circumcisions taking place at home, in a circumcision camp, in an initiation school, in the mountain or in the bush classed as 'traditional'. For individuals where the location of the circumcision was missing, circumcisions performed by a doctor, nurse or a healthcare worker were classed as 'Medical', with circumcisions performed by spiritual leaders, religious leaders or a traditional circumciser classed as 'traditional'.

2.2 Statistical Methods

MC prevalence was modelled using binomial generalised linear mixed effects model with a logit link function. The linear predictor included an intercept, a random walk on time, a random walk on age group and an autocorrelated spatial random effect for the district along with interaction terms between region and time, time and age along with region and age, to account for any intra-region/time/age effects on circumcision observed. Models were implemented using integrated nested Laplace approximations (INLA) (Rue *et al.*, 2009). Separate models were run to obtain total, medical and traditional male circumcision prevalence. See Supplementary material for more details.

In order to aggregate prevalence to a province and national levels, as well as aggregated age groups (e.g. 15-49), samples of MC prevalence for each age group, district and time were generated from the joint posterior distributions and multiplied to the corresponding estimate of population in each stratum. These samples are then summarised to produce point estimates, and associated uncertainty for MC coverage.

3 Results

The coverage of male circumcision varies considerably in South Africa. In 2002, Vhembe (74.4%), Mopani (65.5%) and Buffalo City (65.0%) districts observed the highest level of circumcision among men aged 15-49, largely attributable to TMC (Figures 1-2, B.1-2), with Umkhanyakude (3.8%), Namakwa (3.8%) and Harry Gwala (6.4%) districts with the lowest level of circumcision coverage in the same age group. VMMC prevalence around 2002 was relatively low, with the largest coverages observed in Sedibeng (27.5%), Capricorn (24.9%) and Mopani (24.3%) districts (Figure 1).

The estimated prevalence has changed considerably over time in South Africa particularly upon the onset of the VMMC public health campaigns (Figures 2-3, B.3-10). It is observed that MC coverage increased in all districts (Figure 2), largely due to changes in the VMMC coverage (Figures 3, B.3, B.6, B.9) with the TMC coverage remaining consistent between 2002 and 2017 (Figures B.4, B.7, B.10). In 2017, the districts with the largest total MC coverage were Vhembe (88.6%), Sekhukhune (85.5%) and Mopani (83.1%) with Namakwa (10.6%), ZF Mgcawu (26.1%) and Overberg (29.0%) districts containing the lowest coverage. The largest change in MC coverage among men aged 15-49 was experienced in J T Gaetsewe (from 11.8% in 2002 to 53.0% in 2017), Harry Gwala (from 6.4% in 2002 to 38.5% in 2017) and Johannesburg (from 29.2% in 2002 to 64.2% in 2017) districts with Namakwa district had the smallest change in MC coverage during the same period (from 3.8% in 2002 to 10.6% in 2017).

Despite the increases in MC coverage, it is estimated that 7.6 million men aged 15-49 are uncircumcised (Figures 3, B.11, B.12). Only 37.3% of these men reside in metropolitan areas such as eThekwini, Cape Town, Johannesburg, Ekurhuleni and Tshwane therefore more work will need to be done across South Africa, if the MC prevalence is to increase above the WHO and UNAIDS targets of 80%coverage.

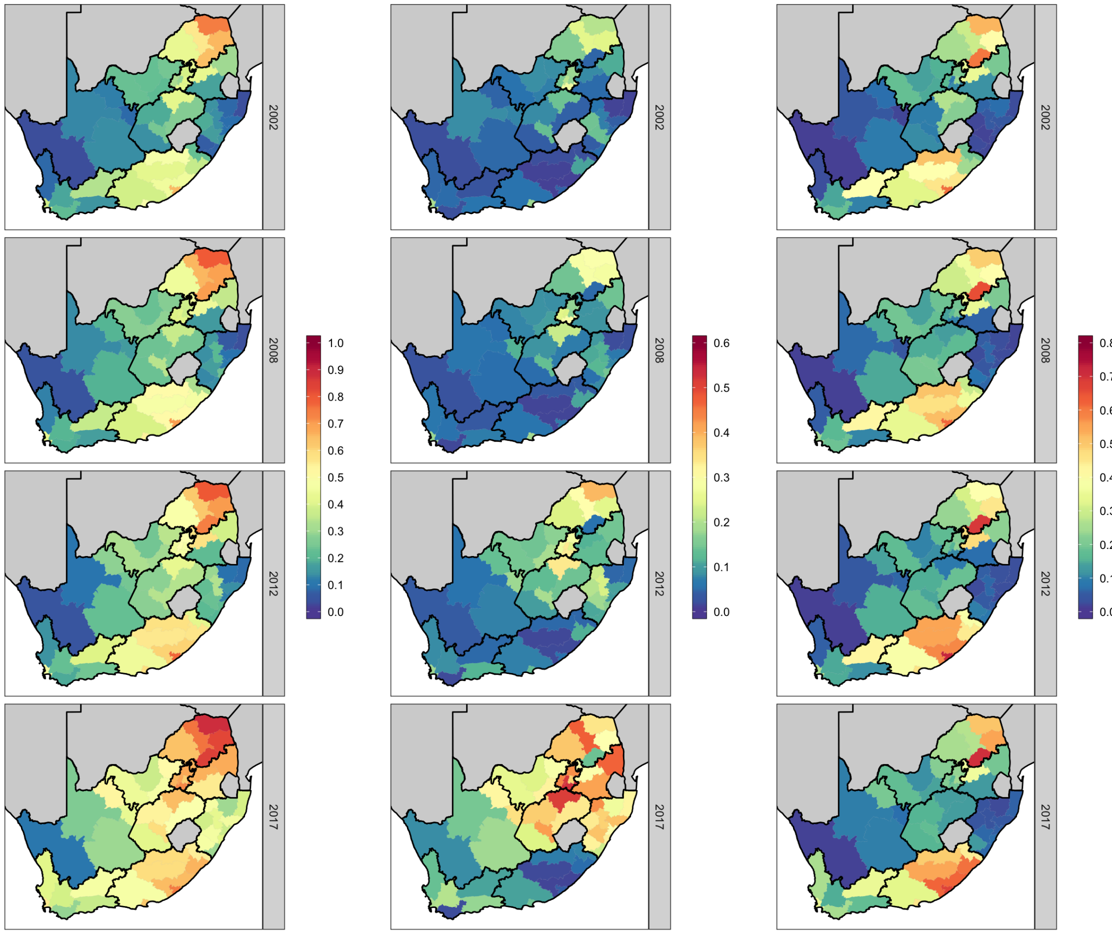
4 Discussion

In order to track the progress of VMMC public health campaigns in South Africa, comprehensive estimates of MC coverage in South Africa at subnational levels over time are required. In this paper, a model to estimate the coverage of VMMC, TMC and total MC in 5-year age groups over time at a district level has been developed. Data from 5 surveys in South Africa were utilised and it was observed that circumcision coverage varied considerably across South Africa at a district level. MC coverage increased between 2002 and 2017 in all districts, attributable to the increase in VMMC as TMC remained consistent during this period. Furthermore, while MC coverage is still increasing there remain over 7 million men aged 15-49 that remain uncircumcised, and so more work will need to be done in most districts in order to reach high coverage of VMMC.

5 Next Steps

Future developments of this model include

- Incorporating language or population group as a covariate. Initial analysis has shown that language group is indicative of circumcision prevalence and how it may change over time (see Figure 6). This will allow key groups with low circumcision coverage to be identified
- Model age-specific circumcision rate over time, integrating data from surveys as well as VMMC programme data about number of MCs conducted.



(a) Total (b) Medical (c) Traditional

Figure 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a district level.

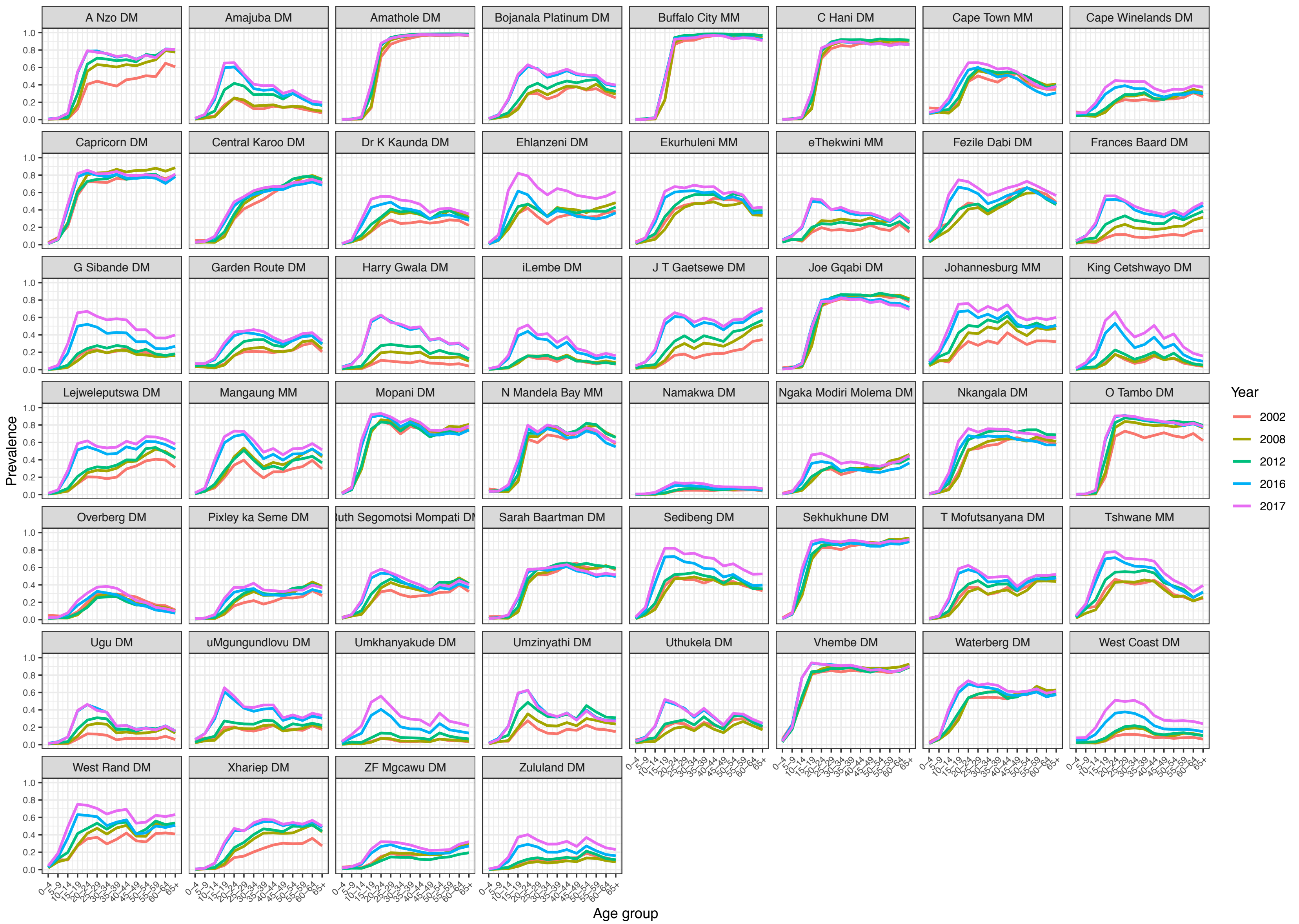


Figure 2: Total male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a district level. Lines denotes the estimated median prevalence.

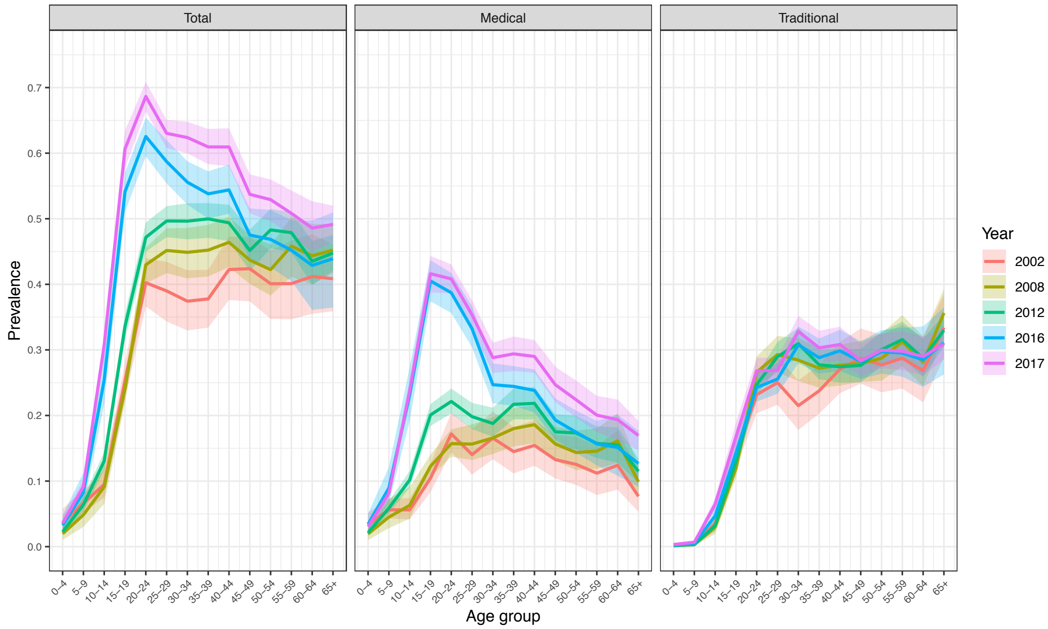


Figure 3: Total, medical and traditional male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a national level. Lines denotes the estimated median prevalence and bars denote the 95% CI.

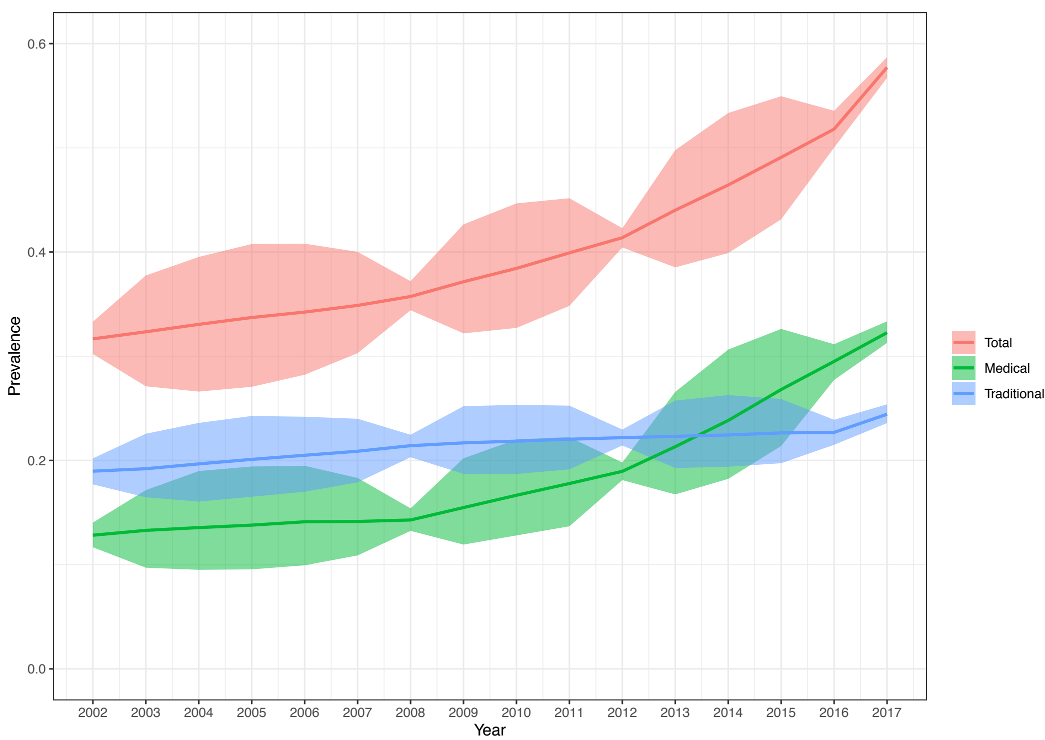


Figure 4: Total, medical and traditional circumcision prevalence for men aged 15-49 over time at a national level. Lines denotes the estimated median prevalence and bars denote the 95% CI.

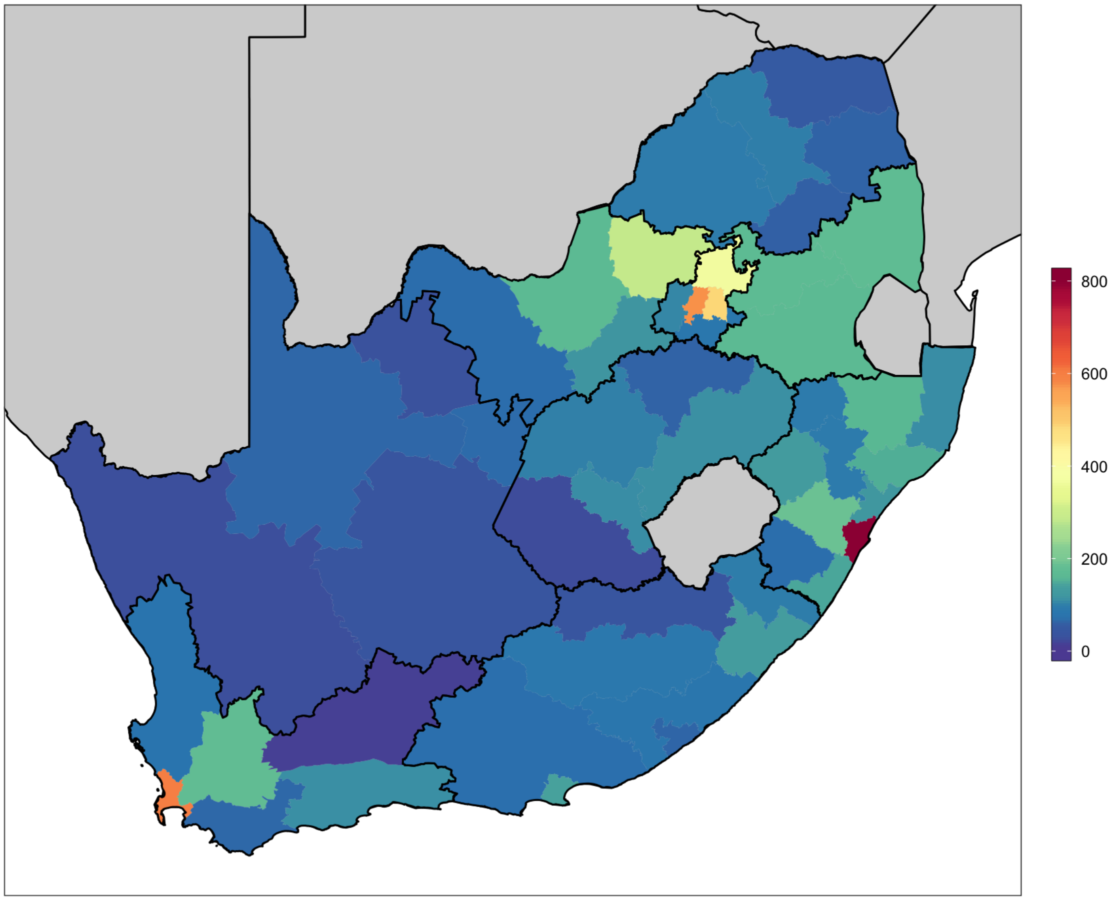


Figure 5: Estimated number of uncircumcised men aged 15-49 in 2017 at a district level.

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

		Total		Medical		Traditional	
Region	**Year**	**Median**	**Uncertainty**	**Median**	**Uncertainty**	**Median**	**Uncertainty**
South Africa	2002	31.7	(30.2–33.3)	12.8	(11.7–14.0)	19.0	(17.7–20.2)
	2008	35.7	(34.4–37.2)	14.3	(13.2–15.4)	21.4	(20.3–22.5)
	2012	41.4	(40.4–42.3)	19.0	(18.1–19.8)	22.2	(21.4–23.0)
	2017	57.7	(56.7–58.7)	32.3	(31.3–33.3)	24.4	(23.6–25.4)
Eastern Cape	2002	43.2	(39.8–46.2)	7.0	(5.3–9.1)	36.5	(33.2–39.5)
	2008	49.7	(47.2–52.2)	7.8	(6.4–9.6)	42.5	(39.4–45.1)
	2012	57.7	(56.0–59.7)	7.4	(6.2–8.7)	50.7	(48.7–52.6)
	2017	62.4	(60.1–64.6)	6.8	(5.6–8.3)	53.6	(51.1–56.0)
Buffalo City	2002	65.0	(58.7–70.5)	4.3	(1.8–9.3)	61.3	(53.4–67.6)
	2008	70.1	(65.4–74.4)	6.9	(3.8–12.3)	62.4	(55.2–67.8)
	2012	77.8	(74.9–80.5)	5.9	(3.6–9.2)	72.3	(68.0–75.8)
	2017	74.8	(69.2–78.8)	3.9	(1.8–8.2)	67.2	(59.5–72.9)
Sarah Baartman	2002	38.0	(29.4–47.1)	6.0	(2.9–11.9)	32.6	(23.7–43.8)
	2008	39.0	(31.5–46.4)	6.1	(3.7–10.3)	34.0	(26.4–42.4)
	2012	44.7	(38.8–50.2)	7.2	(4.8–10.5)	38.2	(32.1–44.3)
	2017	47.4	(41.0–53.3)	10.2	(6.9–14.9)	33.0	(27.2–39.0)
Amathole	2002	45.4	(39.6–51.0)	0.9	(0.3–3.1)	45.4	(38.6–52.0)
	2008	51.7	(46.9–56.4)	1.4	(0.5–3.6)	51.5	(45.1–57.0)
	2012	61.0	(56.9–64.7)	1.9	(0.8–4.4)	58.4	(53.4–62.6)
	2017	64.8	(58.6–69.8)	1.4	(0.4–3.8)	62.3	(55.8–68.2)
C Hani	2002	41.9	(36.0–47.5)	1.2	(0.4–3.4)	40.5	(33.6–47.5)
	2008	47.6	(42.3–52.5)	1.3	(0.6–3.2)	46.4	(40.5–51.8)
	2012	56.1	(52.0–59.7)	1.7	(0.8–3.3)	55.0	(50.5–59.0)
	2017	58.9	(53.2–64.2)	1.9	(0.8–4.2)	54.6	(47.8–60.4)
Joe Gqabi	2002	47.6	(37.9–56.4)	2.3	(0.8–6.7)	50.9	(40.2–60.2)
	2008	51.5	(43.8–59.0)	3.5	(1.6–7.9)	50.8	(41.4–59.3)
	2012	57.9	(50.2–64.5)	5.0	(2.6–9.7)	54.9	(46.8–61.8)
	2017	59.2	(50.1–66.7)	6.9	(3.6–13.3)	49.6	(40.9–57.6)
O Tambo	2002	36.2	(29.6–43.4)	10.3	(6.1–16.8)	24.8	(17.2–32.0)
	2008	46.6	(40.7–51.9)	10.5	(7.0–16.1)	36.0	(29.7–42.4)
	2012	56.9	(52.9–60.6)	11.4	(8.5–15.1)	44.5	(40.0–49.1)
	2017	66.1	(62.8–69.2)	5.4	(3.6–8.2)	60.9	(56.5–64.6)
A Nzo	2002	22.2	(13.3–33.3)	2.5	(0.8–7.5)	19.5	(10.0–32.2)
	2008	32.5	(24.9–41.4)	3.7	(1.7–7.9)	29.1	(20.5–39.3)
	2012	41.7	(34.7–48.4)	4.8	(2.5–8.6)	38.2	(30.5–45.7)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

		Total		**Medical**		**Traditional**	
Region	**Year**	**Median**	**Uncertainty**	**Median**	**Uncertainty**	**Median**	**Uncertainty**
	2017	54.4	(46.2–61.8)	7.4	(4.0–13.4)	43.8	(35.1–53.6)
N Mandela Bay	2002	48.1	(40.6–55.4)	17.9	(11.8–24.4)	29.0	(21.7–37.5)
	2008	53.7	(48.6–58.5)	18.6	(14.1–23.6)	35.7	(30.9–40.5)
	2012	58.7	(54.5–62.8)	13.2	(10.4–16.6)	46.0	(41.8–50.4)
	2017	62.6	(57.4–67.0)	14.3	(10.6–18.8)	45.6	(40.0–50.9)
Free State	2002	26.4	(21.7–31.7)	9.6	(6.4–13.7)	16.0	(12.4–20.8)
	2008	29.2	(25.8–33.1)	11.9	(9.3–14.9)	17.0	(13.8–20.6)
	2012	33.8	(31.1–36.8)	18.7	(16.4–21.3)	14.7	(12.7–16.7)
	2017	55.5	(51.9–58.6)	39.4	(36.3–43.2)	15.2	(12.8–17.9)
Xhariep	2002	14.4	(7.9–25.3)	3.8	(1.3–9.3)	10.9	(4.5–21.7)
	2008	23.1	(15.7–33.0)	5.5	(2.6–10.3)	20.2	(12.1–30.7)
	2012	27.7	(20.9–35.2)	9.8	(5.8–15.3)	17.6	(12.3–25.4)
	2017	41.5	(32.5–51.4)	23.9	(16.7–33.1)	16.0	(10.3–23.3)
Lejweleputswa	2002	18.4	(12.7–26.0)	8.1	(4.7–13.4)	9.3	(5.7–15.5)
	2008	23.6	(18.8–29.7)	9.0	(6.0–13.3)	14.7	(10.6–20.2)
	2012	27.9	(23.1–32.8)	12.9	(9.9–16.8)	15.1	(12.0–19.4)
	2017	53.5	(46.1–61.1)	37.1	(30.0–44.6)	15.8	(11.2–21.6)
T Mofutsanyana	2002	26.7	(19.0–34.9)	4.2	(2.0–8.2)	21.6	(14.6–31.3)
	2008	24.7	(18.9–30.7)	6.8	(4.4–10.9)	17.0	(12.2–23.0)
	2012	33.7	(28.8–38.9)	14.2	(10.7–18.0)	18.2	(14.4–22.9)
	2017	48.7	(42.6–54.6)	33.6	(27.9–39.4)	13.0	(9.4–17.6)
Fezile Dabi	2002	41.8	(30.9–53.4)	14.0	(7.9–23.3)	26.8	(17.0–38.3)
	2008	36.5	(27.5–46.7)	21.9	(14.3–31.4)	13.1	(7.6–20.4)
	2012	42.5	(35.1–50.6)	33.6	(26.9–41.9)	8.8	(5.4–13.2)
	2017	64.7	(56.0–72.1)	51.1	(42.4–59.6)	13.0	(8.5–20.2)
Mangaung	2002	24.9	(13.9–38.9)	13.4	(6.4–25.9)	9.2	(3.4–20.1)
	2008	34.4	(26.8–41.9)	13.2	(8.6–19.7)	20.5	(14.3–28.5)
	2012	34.1	(28.9–39.7)	19.2	(14.9–24.3)	14.0	(10.7–18.2)
	2017	59.1	(53.6–64.4)	41.9	(35.6–47.8)	17.4	(13.6–21.5)
Gauteng	2002	35.5	(32.2–39.4)	19.4	(16.5–22.4)	16.3	(13.8–19.2)
	2008	38.9	(35.8–42.1)	20.9	(18.5–23.6)	17.6	(15.2–19.9)
	2012	48.5	(46.2–50.6)	29.3	(27.3–31.5)	18.7	(16.9–20.6)
	2017	66.7	(64.4–68.9)	45.3	(43.0–47.8)	20.5	(18.5–22.6)
Sedibeng	2002	41.0	(29.7–52.5)	27.5	(18.0–39.9)	10.7	(5.5–18.9)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

Region	Year	Total: Median	Total: Uncertainty	Medical: Median	Medical: Uncertainty	Traditional: Median	Traditional: Uncertainty
	2008	40.3	(32.3–50.1)	28.8	(21.2–37.7)	9.5	(5.8–15.5)
	2012	46.7	(39.7–53.4)	33.0	(26.5–40.1)	10.6	(7.1–15.5)
	2017	72.9	(69.5–76.0)	52.9	(49.1–56.3)	19.1	(16.1–22.1)
West Rand	2002	32.5	(25.1–41.2)	14.9	(9.9–21.9)	16.6	(11.3–23.2)
	2008	39.5	(31.4–48.3)	24.4	(17.8–33.1)	13.4	(8.1–20.2)
	2012	45.5	(38.3–52.6)	27.0	(21.0–33.3)	19.0	(14.1–25.1)
	2017	65.9	(61.5–70.4)	43.9	(39.3–48.9)	21.3	(17.6–25.7)
Ekurhuleni	2002	40.3	(33.5–47.3)	17.5	(12.3–23.5)	23.4	(17.7–30.8)
	2008	37.2	(31.5–43.2)	16.4	(12.4–21.4)	20.5	(16.0–26.1)
	2012	47.3	(42.9–51.4)	24.1	(20.5–28.8)	22.7	(19.2–26.7)
	2017	61.6	(57.3–65.8)	36.6	(32.4–41.4)	24.6	(21.1–28.5)
Johannesburg	2002	29.2	(24.3–34.7)	20.5	(16.3–25.7)	8.8	(6.2–13.0)
	2008	40.7	(36.6–45.4)	23.9	(20.0–28.4)	16.7	(13.2–20.5)
	2012	49.3	(46.0–52.8)	33.5	(30.3–36.8)	15.8	(13.3–18.5)
	2017	68.5	(64.2–72.1)	51.7	(47.3–56.2)	15.9	(12.8–19.6)
Tshwane	2002	38.5	(31.7–46.0)	18.0	(12.8–24.4)	20.8	(15.1–28.3)
	2008	37.5	(32.1–43.1)	17.3	(13.2–21.9)	19.2	(15.0–24.1)
	2012	49.8	(44.9–54.1)	27.8	(23.9–32.7)	21.1	(17.4–25.2)
	2017	68.0	(64.0–72.0)	43.1	(38.7–47.6)	23.1	(19.3–27.6)
KwaZulu-Natal	2002	12.8	(10.5–15.2)	9.2	(7.5–11.4)	3.5	(2.3–5.2)
	2008	16.6	(14.4–18.8)	10.5	(8.8–12.6)	6.1	(4.9–7.6)
	2012	19.8	(18.3–21.4)	14.7	(13.3–16.1)	5.0	(4.2–5.9)
	2017	40.5	(38.6–42.5)	33.2	(31.3–35.0)	6.3	(5.4–7.4)
Ugu	2002	7.2	(3.0–15.3)	5.7	(2.1–13.1)	2.0	(0.5–7.2)
	2008	14.0	(8.4–22.7)	8.2	(4.1–15.3)	6.2	(2.8–13.2)
	2012	19.8	(15.1–24.9)	10.9	(7.6–15.6)	8.6	(5.7–13.1)
	2017	30.4	(25.1–36.3)	22.4	(17.5–28.0)	6.5	(4.1–9.8)
uMgungundlovu	2002	16.4	(10.3–23.7)	14.0	(8.5–22.2)	1.6	(0.6–4.2)
	2008	16.4	(11.4–23.3)	12.1	(8.1–18.2)	4.2	(2.2–7.5)
	2012	22.9	(18.0–28.6)	18.5	(14.1–23.6)	4.8	(2.9–7.6)
	2017	46.2	(39.5–53.0)	38.2	(32.5–44.8)	6.5	(4.1–10.7)
Uthukela	2002	18.4	(9.6–32.6)	14.4	(6.8–27.9)	2.1	(0.6–7.5)
	2008	14.4	(8.7–21.9)	10.9	(6.1–19.2)	2.8	(1.1–7.1)
	2012	22.0	(16.7–28.1)	20.3	(15.4–27.3)	2.6	(1.3–5.1)
	2017	37.8	(34.2–41.8)	33.4	(29.7–37.3)	4.0	(2.9–5.8)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

		Total		Medical		Traditional	
Region	**Year**	**Median**	**Uncertainty**	**Median**	**Uncertainty**	**Median**	**Uncertainty**
Umzinyathi	2002	14.2	(7.7–25.5)	7.1	(2.9–15.1)	4.7	(1.9–11.7)
	2008	20.5	(12.9–31.1)	11.6	(6.3–19.4)	6.4	(2.9–13.2)
	2012	33.3	(25.2–40.3)	23.4	(17.7–30.7)	6.4	(3.8–11.2)
	2017	42.3	(38.4–46.1)	36.7	(32.9–40.6)	3.8	(2.6–5.5)
Amajuba	2002	14.7	(7.8–25.3)	6.2	(2.8–13.3)	5.9	(2.5–13.4)
	2008	15.7	(10.5–23.1)	9.4	(5.4–15.2)	4.9	(2.4–10.0)
	2012	29.8	(23.5–37.4)	22.3	(16.7–29.3)	5.2	(2.8–9.1)
	2017	46.8	(37.7–55.9)	43.1	(33.6–52.1)	3.9	(1.8–7.6)
Zululand	2002	8.1	(3.9–16.3)	1.2	(0.3–3.9)	7.4	(2.9–17.6)
	2008	5.9	(3.0–11.0)	2.1	(0.9–5.1)	3.1	(1.3–7.5)
	2012	9.8	(6.1–14.9)	4.7	(2.7–8.7)	3.6	(1.7–7.6)
	2017	30.6	(23.8–38.4)	27.2	(21.1–34.6)	2.5	(1.2–5.3)
Umkhanyakude	2002	3.8	(0.8–14.0)	1.2	(0.2–7.0)	2.8	(0.5–14.7)
	2008	4.0	(1.3–10.4)	2.4	(0.6–7.9)	1.7	(0.4–7.2)
	2012	8.7	(5.1–14.9)	5.1	(2.5–10.3)	3.2	(1.3–7.9)
	2017	38.5	(30.5–46.7)	31.9	(24.4–40.7)	5.6	(3.0–10.9)
King Cetshwayo	2002	9.3	(4.8–17.5)	3.9	(1.4–9.5)	4.4	(1.5–10.9)
	2008	10.0	(5.5–16.2)	6.5	(3.3–13.1)	2.7	(1.0–6.8)
	2012	14.2	(9.8–19.5)	10.1	(6.6–15.1)	3.1	(1.7–5.4)
	2017	45.8	(42.1–49.3)	38.4	(34.8–41.7)	4.5	(3.3–6.1)
iLembe	2002	9.7	(4.4–18.7)	5.1	(2.1–12.6)	3.4	(1.2–10.3)
	2008	11.0	(6.1–18.9)	7.7	(3.9–14.7)	3.4	(1.3–7.8)
	2012	12.0	(7.8–17.8)	9.7	(5.9–15.3)	2.7	(1.3–5.3)
	2017	37.0	(33.3–40.8)	29.9	(26.6–33.6)	5.4	(4.0–7.4)
Harry Gwala	2002	6.4	(2.3–16.5)	3.9	(1.0–11.3)	2.7	(0.6–10.5)
	2008	13.2	(6.6–24.2)	5.8	(2.3–13.4)	7.9	(3.1–17.3)
	2012	20.8	(14.5–28.0)	10.6	(6.4–17.4)	9.4	(5.8–15.1)
	2017	47.1	(38.5–55.3)	32.2	(24.4–40.1)	12.7	(7.9–18.8)
eThekwini	2002	15.3	(12.4–18.9)	13.3	(10.4–16.8)	2.3	(1.2–4.1)
	2008	23.6	(20.4–27.2)	14.8	(12.3–17.9)	8.9	(7.0–11.3)
	2012	21.5	(19.5–23.3)	16.6	(14.7–18.4)	5.1	(4.1–6.3)
	2017	40.7	(37.5–44.2)	32.5	(29.2–35.7)	7.4	(5.9–9.5)
Limpopo	2002	61.9	(57.3–66.7)	19.0	(14.9–23.7)	42.6	(37.5–48.3)
	2008	67.6	(63.0–71.7)	22.1	(18.4–26.3)	45.2	(40.7–49.2)
	2012	68.4	(65.7–70.7)	25.7	(23.2–28.6)	42.1	(39.2–45.0)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

Region	Year	Total Median	Total Uncertainty	Medical Median	Medical Uncertainty	Traditional Median	Traditional Uncertainty
	2017	80.3	(77.6–82.5)	32.7	(29.7–35.8)	46.7	(43.8–49.7)
Mopani	2002	65.5	(54.9–74.9)	24.4	(15.6–35.1)	41.0	(30.6–52.4)
	2008	69.3	(61.4–76.3)	27.8	(20.0–36.8)	40.8	(32.5–49.8)
	2012	70.2	(64.8–75.2)	24.6	(19.7–30.5)	45.2	(38.1–51.7)
	2017	83.1	(78.7–86.9)	29.9	(23.9–36.7)	54.9	(48.5–61.3)
Vhembe	2002	74.4	(63.9–82.3)	20.4	(12.3–32.0)	52.7	(41.1–65.2)
	2008	79.2	(70.0–85.7)	29.1	(20.1–39.6)	49.5	(39.5–59.0)
	2012	79.7	(74.3–84.5)	39.2	(33.2–46.3)	39.5	(33.4–45.3)
	2017	88.6	(84.4–92.0)	34.2	(28.4–40.5)	50.6	(43.6–57.2)
Capricorn	2002	56.2	(47.2–64.9)	24.9	(17.0–34.6)	29.7	(21.9–39.2)
	2008	65.7	(58.6–72.9)	28.4	(21.6–36.1)	36.4	(29.1–43.4)
	2012	62.6	(57.7–67.6)	30.6	(25.7–36.5)	30.8	(25.7–36.3)
	2017	75.6	(69.9–80.5)	47.2	(39.6–54.6)	27.1	(21.2–34.1)
Waterberg	2002	42.9	(32.5–53.1)	16.0	(10.4–25.5)	25.5	(17.1–36.0)
	2008	45.0	(38.4–52.6)	14.4	(10.0–20.3)	29.9	(23.4–37.8)
	2012	48.1	(43.4–53.6)	23.8	(19.3–28.4)	23.5	(19.4–28.3)
	2017	63.8	(56.6–70.3)	37.8	(31.5–45.3)	25.5	(19.8–32.1)
Sekhukhune	2002	64.3	(54.1–73.0)	4.5	(2.1–9.9)	60.2	(48.9–69.8)
	2008	69.9	(62.6–76.4)	5.1	(2.7–8.8)	65.2	(57.3–72.1)
	2012	74.1	(69.1–78.6)	6.0	(3.9–8.9)	68.8	(62.7–74.0)
	2017	84.5	(81.1–87.3)	14.1	(10.9–17.8)	70.6	(65.8–75.1)
Mpumalanga	2002	31.1	(26.1–36.3)	8.8	(6.1–12.5)	22.9	(18.3–27.8)
	2008	33.7	(30.1–37.6)	11.4	(8.9–14.3)	21.6	(18.3–24.8)
	2012	40.5	(37.7–43.4)	13.2	(11.4–15.3)	27.2	(24.7–29.6)
	2017	64.0	(61.7–66.0)	39.1	(36.9–41.5)	23.8	(21.8–25.9)
G Sibande	2002	17.1	(11.2–25.7)	5.3	(2.7–9.5)	11.6	(6.6–19.9)
	2008	15.9	(11.6–20.8)	9.1	(6.2–13.1)	5.9	(3.6–9.3)
	2012	21.3	(17.3–26.3)	12.9	(10.1–16.8)	7.6	(5.3–10.2)
	2017	55.5	(52.5–58.9)	41.5	(38.4–44.4)	12.7	(10.7–15.0)
Nkangala	2002	42.5	(33.8–51.0)	8.1	(4.6–13.3)	34.9	(26.2–43.9)
	2008	44.8	(39.2–50.6)	8.9	(6.1–13.1)	34.7	(28.0–40.9)
	2012	57.7	(53.5–61.9)	11.6	(9.1–14.8)	47.5	(42.6–52.1)
	2017	66.6	(62.4–70.4)	29.3	(25.3–33.8)	36.3	(32.1–40.7)
Ehlanzeni	2002	30.7	(23.3–39.6)	11.1	(6.8–17.5)	20.2	(14.0–28.4)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

		Total		Medical		Traditional	
Region	**Year**	**Median**	**Uncertainty**	**Median**	**Uncertainty**	**Median**	**Uncertainty**
	2008	35.8	(29.4–42.3)	14.3	(10.1–19.9)	20.6	(15.8–26.5)
	2012	38.0	(33.1–42.7)	14.5	(11.7–18.3)	22.3	(18.5–26.8)
	2017	67.4	(64.1–70.9)	47.0	(43.4–50.8)	19.7	(16.7–22.8)
Northern Cape	2002	10.6	(7.9–14.1)	6.4	(4.2–9.5)	4.7	(3.0–7.1)
	2008	15.7	(13.2–18.9)	7.6	(5.8–9.9)	8.2	(6.3–10.8)
	2012	19.9	(17.5–22.3)	11.4	(9.7–13.7)	8.3	(6.7–10.3)
	2017	36.3	(33.0–39.3)	24.9	(22.0–27.9)	10.4	(8.5–12.3)
J T Gaetsewe	2002	11.8	(6.1–22.5)	4.5	(1.6–11.5)	7.5	(3.0–16.1)
	2008	19.8	(12.8–29.3)	5.7	(2.6–11.4)	14.6	(8.7–23.5)
	2012	28.0	(20.8–36.3)	13.3	(8.6–20.8)	13.6	(8.6–21.0)
	2017	53.0	(44.0–61.1)	31.6	(24.0–41.2)	20.1	(13.8–27.2)
Namakwa	2002	3.8	(1.5–9.4)	2.3	(0.8–6.3)	1.1	(0.2–4.8)
	2008	4.9	(2.2–9.8)	2.8	(1.2–6.5)	1.2	(0.3–4.3)
	2012	5.0	(2.8–8.8)	3.6	(1.8–6.9)	1.0	(0.3–3.6)
	2017	10.6	(5.9–18.4)	8.3	(4.3–16.2)	1.4	(0.4–4.9)
Pixley ka Seme	2002	13.9	(9.2–20.6)	4.9	(2.5–9.3)	8.9	(4.9–15.2)
	2008	19.5	(14.4–25.9)	5.7	(3.4–9.3)	14.5	(9.4–21.4)
	2012	22.2	(17.8–27.6)	7.3	(4.9–10.7)	15.2	(11.0–20.4)
	2017	30.1	(24.9–35.7)	18.4	(14.8–23.4)	9.5	(6.7–12.9)
ZF Mgcawu	2002	13.0	(7.2–22.4)	8.3	(4.0–16.9)	4.4	(1.6–10.9)
	2008	13.4	(9.8–19.0)	6.2	(3.9–10.5)	6.9	(4.1–11.6)
	2012	10.3	(7.7–13.4)	6.1	(4.2–8.4)	4.6	(3.0–6.9)
	2017	26.1	(21.5–31.1)	14.9	(11.6–18.9)	9.3	(6.8–12.8)
Frances Baard	2002	8.4	(4.8–13.3)	7.5	(4.1–12.8)	1.9	(0.8–4.4)
	2008	16.0	(12.2–20.7)	11.6	(8.4–15.9)	4.3	(2.6–6.8)
	2012	24.6	(20.8–29.1)	18.1	(14.9–22.1)	6.2	(4.4–8.5)
	2017	43.1	(38.0–48.2)	34.9	(29.4–40.3)	7.5	(5.3–10.6)
North West	2002	23.4	(18.5–28.1)	8.1	(5.5–11.5)	15.2	(11.6–19.9)
	2008	26.4	(22.4–30.4)	8.9	(6.7–11.5)	17.6	(14.1–21.3)
	2012	31.3	(28.1–34.7)	16.5	(14.1–19.1)	14.5	(12.1–17.0)
	2017	46.9	(43.8–50.1)	28.0	(25.3–30.9)	17.6	(15.3–20.0)
Bojanala Platinum	2002	24.5	(18.7–32.0)	8.4	(5.2–13.7)	15.3	(10.1–21.8)
	2008	27.0	(21.6–32.8)	8.5	(5.8–12.4)	18.8	(13.7–24.4)
	2012	34.5	(29.2–39.8)	16.7	(13.1–21.5)	17.0	(13.4–21.6)
	2017	51.8	(47.8–55.5)	28.7	(25.2–32.4)	21.6	(18.6–24.9)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

		Total		Medical		Traditional	
Region	**Year**	**Median**	**Uncertainty**	**Median**	**Uncertainty**	**Median**	**Uncertainty**
Ngaka Modiri Molema	2002	22.2	(13.8–33.2)	8.5	(4.0–16.8)	13.4	(7.4–24.3)
	2008	22.8	(16.5–31.2)	8.7	(5.0–14.7)	13.5	(8.6–21.0)
	2012	24.2	(19.0–30.0)	14.4	(10.5–19.8)	9.9	(6.7–14.4)
	2017	37.1	(30.1–44.6)	24.0	(18.3–31.3)	11.4	(7.6–16.8)
Ruth Segomotsi Mompati	2002	22.7	(14.2–35.7)	5.9	(2.6–13.6)	17.8	(9.6–29.4)
	2008	27.4	(18.8–38.3)	7.7	(4.0–14.4)	19.4	(12.1–29.7)
	2012	32.7	(25.1–42.2)	14.9	(9.7–22.0)	17.2	(11.6–24.4)
	2017	44.2	(35.8–52.1)	25.2	(18.0–33.4)	17.4	(12.0–24.8)
Dr K Kaunda	2002	21.2	(13.8–30.7)	7.1	(3.7–13.4)	14.6	(7.9–24.0)
	2008	28.1	(21.6–36.5)	10.0	(6.3–15.4)	17.8	(12.4–24.5)
	2012	31.0	(25.7–36.1)	19.0	(14.6–24.0)	11.3	(8.3–15.2)
	2017	47.2	(41.1–53.4)	32.1	(26.8–38.1)	13.8	(10.5–18.7)
Western Cape	2002	30.0	(26.3–34.1)	14.3	(11.6–17.2)	15.2	(12.4–18.7)
	2008	33.7	(30.5–36.8)	13.6	(11.4–16.1)	20.7	(18.2–23.6)
	2012	37.3	(35.0–39.6)	15.0	(13.2–16.8)	22.0	(19.9–24.1)
	2017	49.4	(46.3–52.4)	18.4	(16.0–21.0)	29.9	(26.9–32.8)
Cape Town	2002	37.7	(32.7–42.9)	19.4	(15.5–23.6)	16.6	(13.0–21.1)
	2008	42.1	(38.1–46.2)	17.9	(14.8–21.4)	24.3	(21.0–28.5)
	2012	45.9	(42.9–49.0)	18.4	(16.1–20.9)	26.8	(24.1–29.6)
	2017	55.6	(51.6–59.6)	19.7	(16.5–23.1)	35.2	(31.4–39.3)
West Coast	2002	8.2	(3.6–17.1)	4.7	(2.0–11.5)	3.1	(0.8–10.5)
	2008	12.2	(6.8–20.9)	6.3	(3.0–12.9)	5.1	(2.0–12.0)
	2012	14.7	(9.8–21.4)	8.2	(4.8–14.2)	5.4	(2.8–9.8)
	2017	41.0	(33.3–49.0)	13.5	(9.2–19.4)	25.9	(19.8–33.0)
Cape Winelands	2002	17.4	(11.0–26.9)	5.3	(2.7–9.8)	14.0	(8.0–23.3)
	2008	20.0	(14.9–26.0)	5.8	(3.6–9.1)	16.5	(11.9–22.7)
	2012	22.2	(17.4–27.1)	8.7	(6.1–12.1)	14.4	(10.7–19.2)
	2017	38.3	(31.4–45.2)	20.3	(15.1–26.9)	15.0	(10.7–21.3)
Overberg	2002	21.6	(11.5–36.7)	2.5	(0.7–8.6)	18.1	(8.7–33.1)
	2008	19.0	(10.8–31.3)	1.6	(0.5–5.3)	18.7	(9.3–32.9)
	2012	18.1	(11.2–28.8)	1.9	(0.6–5.7)	14.7	(7.6–25.2)
	2017	29.0	(19.4–40.4)	2.2	(0.6–6.7)	25.5	(16.4–36.7)
Garden Route	2002	15.2	(8.4–25.1)	6.1	(2.8–13.2)	9.7	(4.2–19.8)
	2008	16.5	(11.2–23.6)	6.9	(3.9–11.8)	10.2	(6.0–16.6)
	2012	24.1	(18.5–30.3)	11.8	(8.2–16.9)	11.4	(7.5–16.6)

Table 1: Total, medical and traditional male circumcision prevalence in men aged 15-49 in 2002, 2008, 2012 and 2017 at a national, province and district, province level.

		Total		**Medical**		**Traditional**	
Region	**Year**	**Median**	**Uncertainty**	**Median**	**Uncertainty**	**Median**	**Uncertainty**
	2017	36.4	(28.1–44.7)	17.5	(11.8–24.3)	17.5	(11.9–24.6)
Central Karoo	2002	33.5	(16.0–52.8)	2.9	(0.6–10.6)	39.6	(18.5–59.6)
	2008	36.2	(21.1–51.5)	3.4	(1.0–10.5)	41.9	(24.6–58.1)
	2012	39.9	(25.0–54.4)	5.0	(1.6–13.4)	42.2	(26.1–56.4)
	2017	47.1	(31.7–62.8)	10.4	(4.2–23.9)	35.0	(19.8–50.4)

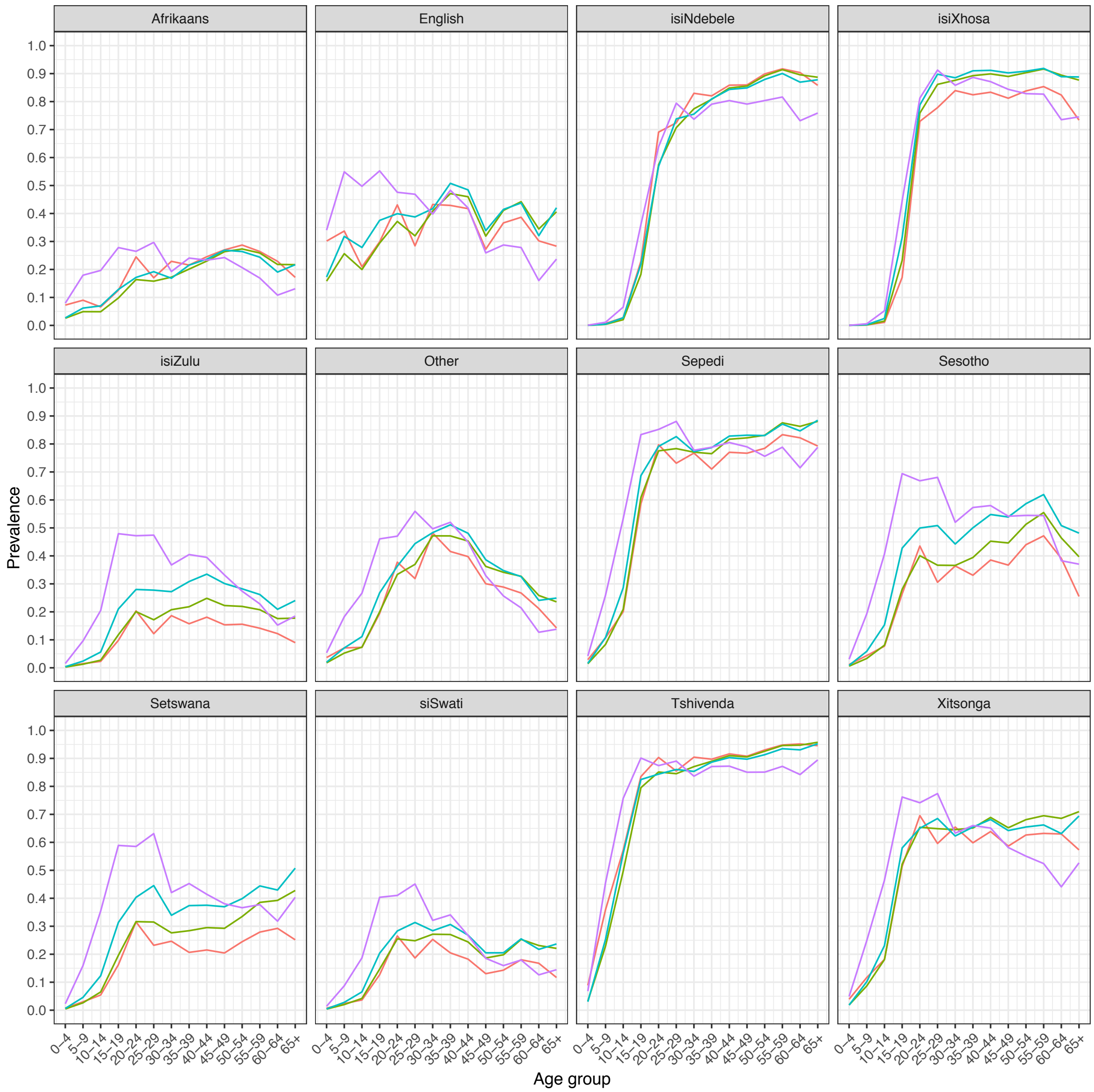


Figure 6: Total male circumcision prevalence in 5-year age groups in 2002, 2008, 2012 and 2016 by language group at a national level. Lines denotes the estimated median prevalence

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Appendices: Estimating male circumcision prevalence for the evaluation public health programmes in South Africa.

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February 21, 2020

A Statistical Methodology

A.1 Statistical Model

The aim is to produce estimates of the proportion of circumcised males in 5-year age groups over time for each district in South Africa. Suppose that N_{iat} individuals in age group $a = 1, ..., N_A$, are surveyed at time $t = 1, ..., N_T$ in region $i = 1, ..., N_I$, with Y_{iat} individuals who are circumcised, then the prevalence of circumcision is modelled using

$$
\begin{aligned}
Y_{iat} &\sim Bin(N_{iat}, p_{iat}) \\
\text{logit}(p_{iat}) &= \alpha + \beta_i + \gamma_t + \delta_a + \theta_{it} + \phi_{ia} + \psi_{at}
\end{aligned}
$$

A.1.1 Spatial random effects

In space, i, the random effects, β_i and θ_{it}, are assigned an intrinsic conditional autoregressive (ICAR) prior (Besag & Kooperberg, 1995). Under this specification it is assumed that β_i and θ_{it} are a weighted average its neighbours

$$
\begin{aligned}
\beta_i | \beta_{i'}, i' \in \mathcal{N}_i &\sim \mathrm{N}\left(\frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} \beta_j, \frac{\tau_\beta}{|\mathcal{N}_i|}\right) \\
\theta_{it} | \theta_{i't}, i' \in \mathcal{N}_i &\sim \mathrm{N}\left(\frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} \theta_{jt}, \frac{\tau_\theta}{|\mathcal{N}_i|}\right) \\
\phi_{ia} | \phi_{i'a}, i' \in \mathcal{N}_i &\sim \mathrm{N}\left(\frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} \phi_{ja}, \frac{\tau_\theta}{|\mathcal{N}_i|}\right)
\end{aligned}
$$

Here, $\mathcal{N}_i$ is the set of neighbours of district i, $|\mathcal{N}_i|$ is the number of neighbours and τ_β and τ_θ is the marginal precision controlling the scale of the random effect.

A.1.2 Temporal random effects

In time, t, the random effects, γ_t, θ_{it} and ψ_{at}, are assigned random walk process of order 1 (RW2) prior,

$$
\begin{aligned}
\gamma_t &\sim N(\gamma_{t-1}, \tau_\gamma^{-1}) \\
\theta_{it} &\sim N(\theta_{i(t-1)}, \tau_\theta^{-1}) \\
\psi_{at} &\sim N(\psi_{a(t-1)}, \tau_\theta^{-1})
\end{aligned}
$$

where τ_γ^{-1}, τ_θ^{-1} and τ_ψ^{-1} are the precisions of the process controlling the scale of the changes between time points.

A.1.3 Age random effects

Across age groups, a, the random effects, δ_a, ϕ_{ia}, and ψ_{at}, an random walk process of order 2 (RW2)

$$\delta_a \sim N(\delta_{a-1}, \tau_\delta^{-1})$$
$$\phi_{ia} \sim N(\phi_{i(a-1)}, \tau_\phi^{-1})$$
$$\psi_{at} \sim N(\psi_{(a-1)t}, \tau_\psi^{-1})$$

where τ_δ^{-1}, τ_ϕ^{-1} and τ_ψ^{-1} are the precisions of the process controlling the scale of the changes between age groups.

A.1.4 Priors

Gaussian priors $N(0, 1000)$ are assigned to the intercept α. Penalised Complexity (PC) priors are used for the precisions (τ_β, τ_γ, τ_δ, τ_θ, τ_ϕ, τ_ψ), chosen such that $\mathbb{P}(\tau_{(\cdot)}^{-1} > 0.1) = 0.1$. (Simpson *et al.*, 2017).

A.2 Inference

The model presented is a latent Gaussian model (LGM) and therefore advantages can be taken of methods offering efficient computation when performing Bayesian inference (Rue & Held, 2005; Rue *et al.*, 2009). LGMs can be implemented by using approximate Bayesian inference using integrated nested Laplace approximations (INLAs) as proposed in Rue *et al.* (2009) by using the R-INLA software (Rue *et al.*, 2012).

B Supplementary figures

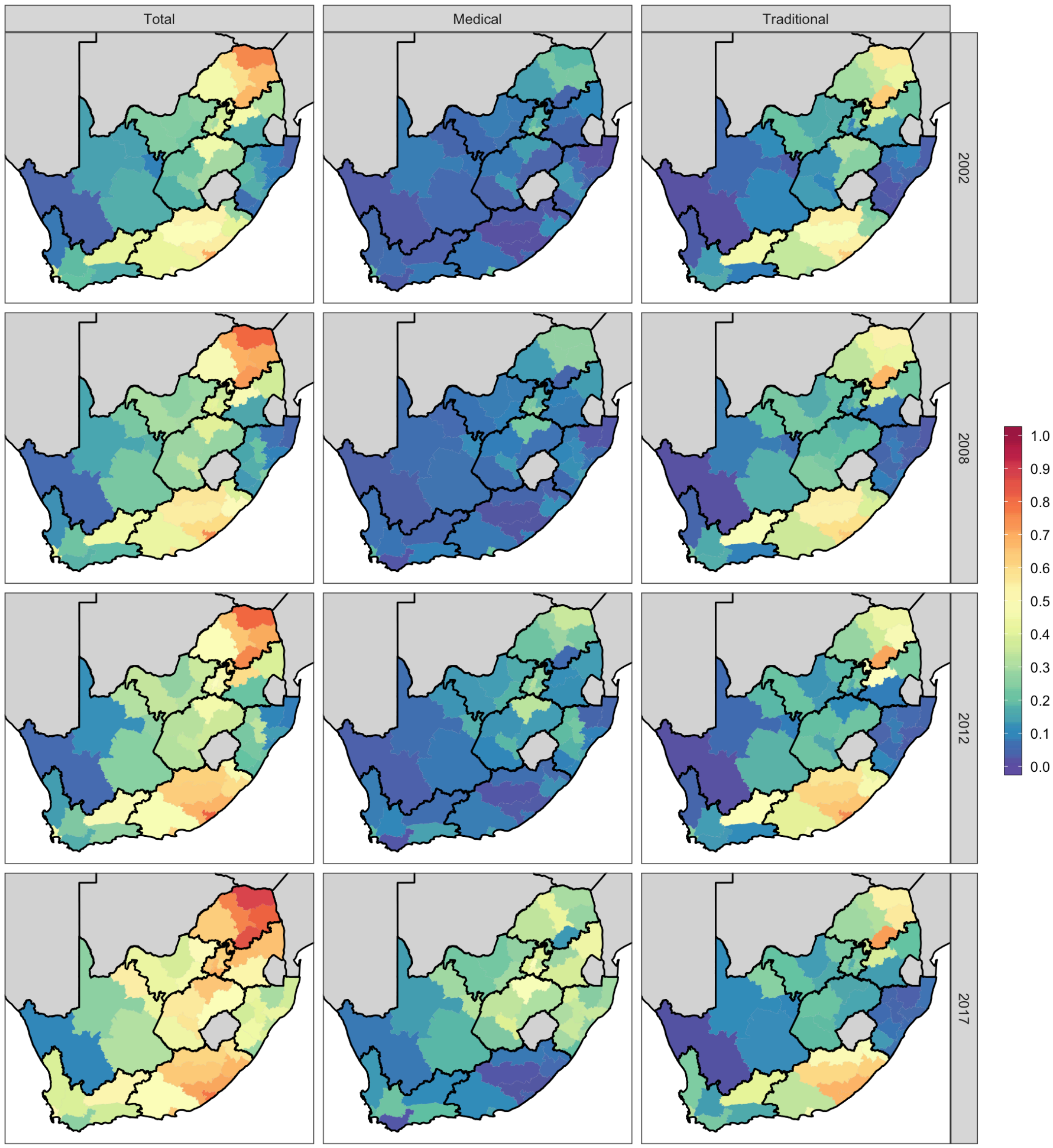

Figure B.1: Total, medical and tradtional male circumcision prevalence in men aged 15+ in 2002, 2008, 2012 and 2017 at a district level.

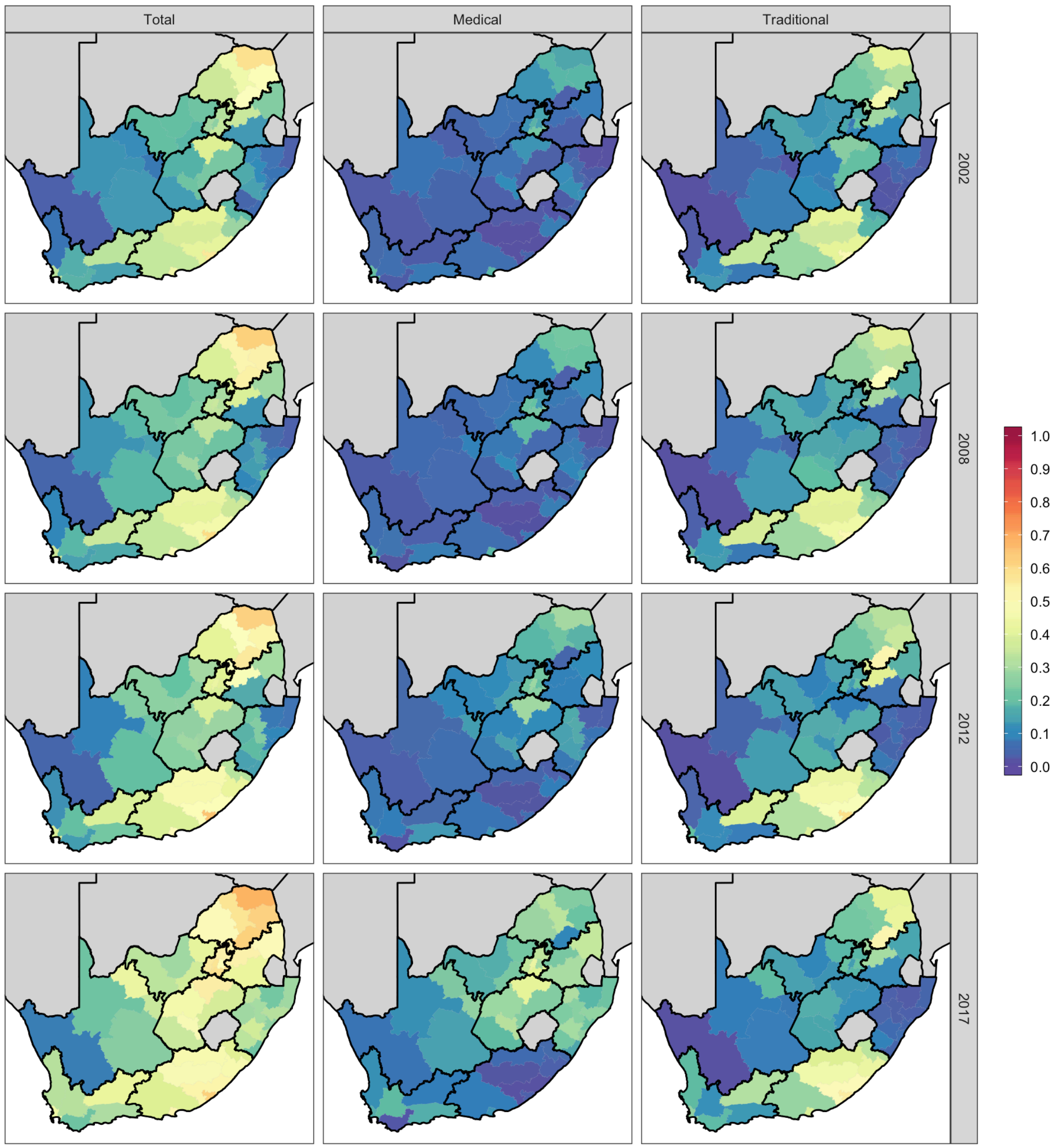

Figure B.2: Total, medical and tradtional male circumcision prevalence in all men in 2002, 2008, 2012 and 2017 at a district level.

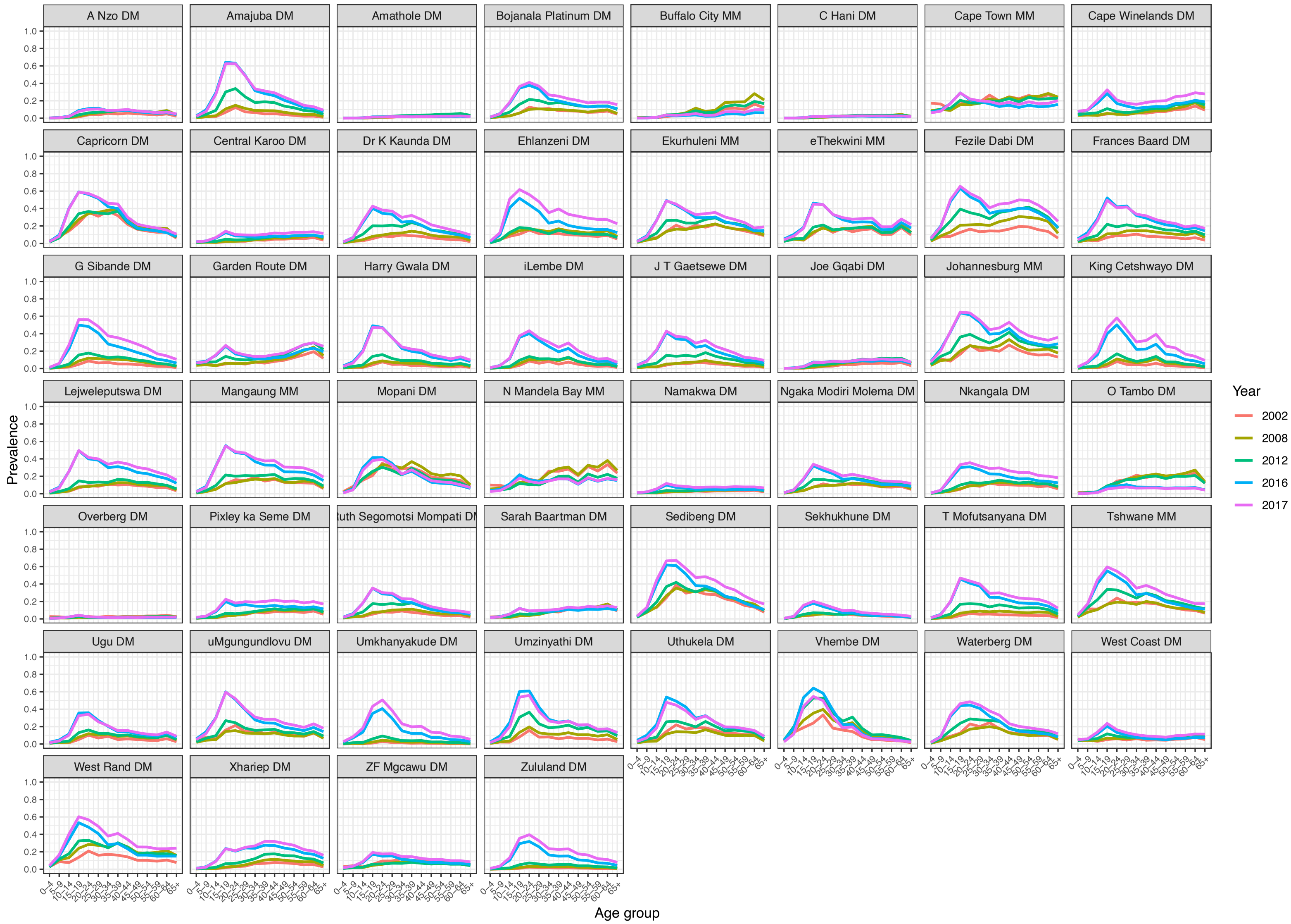

Figure B.3: Medical male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a district level. Lines denotes the estimated median prevalence.

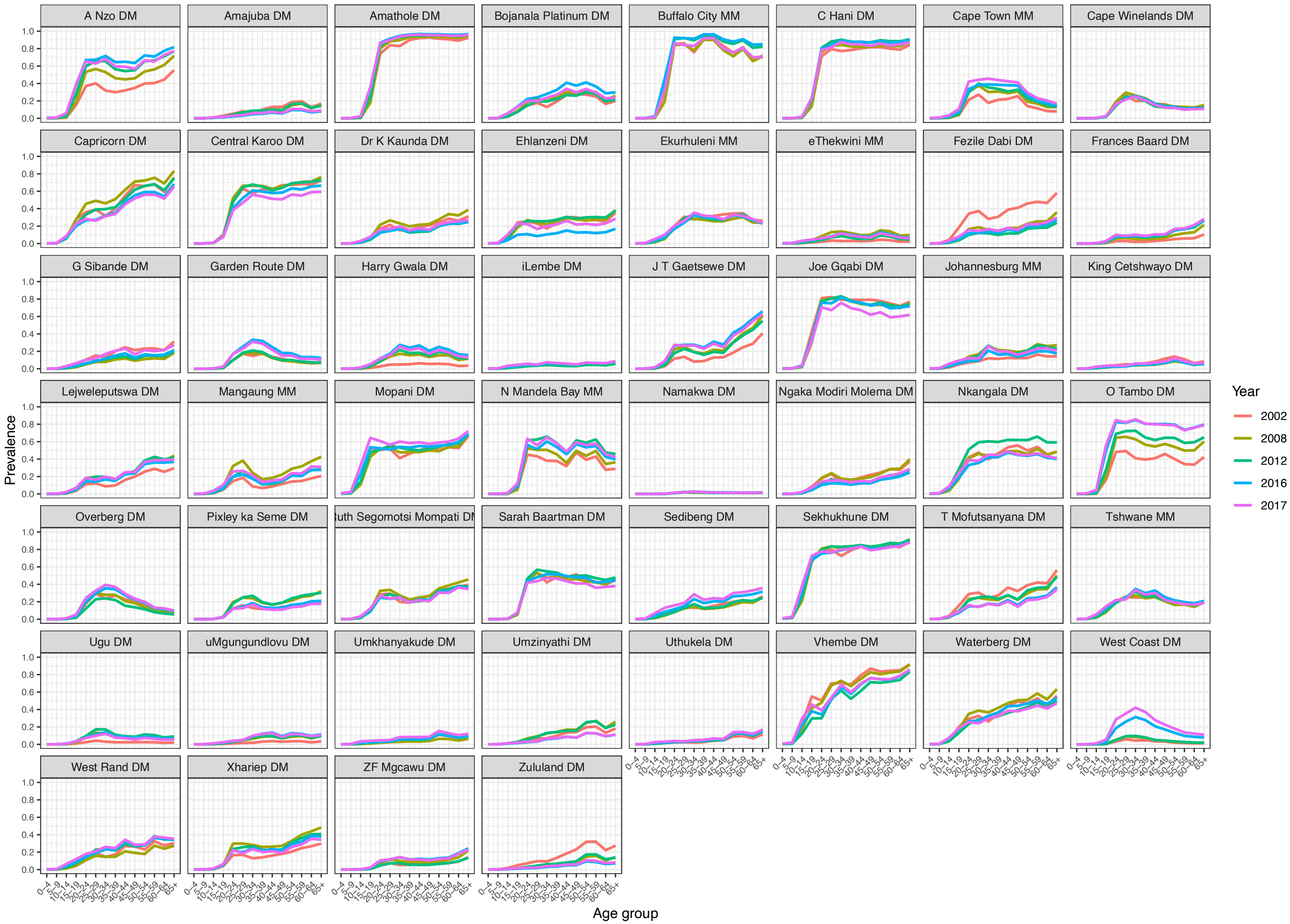

Figure B.4: Traditional male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a district level. Lines denotes the estimated median prevalence.

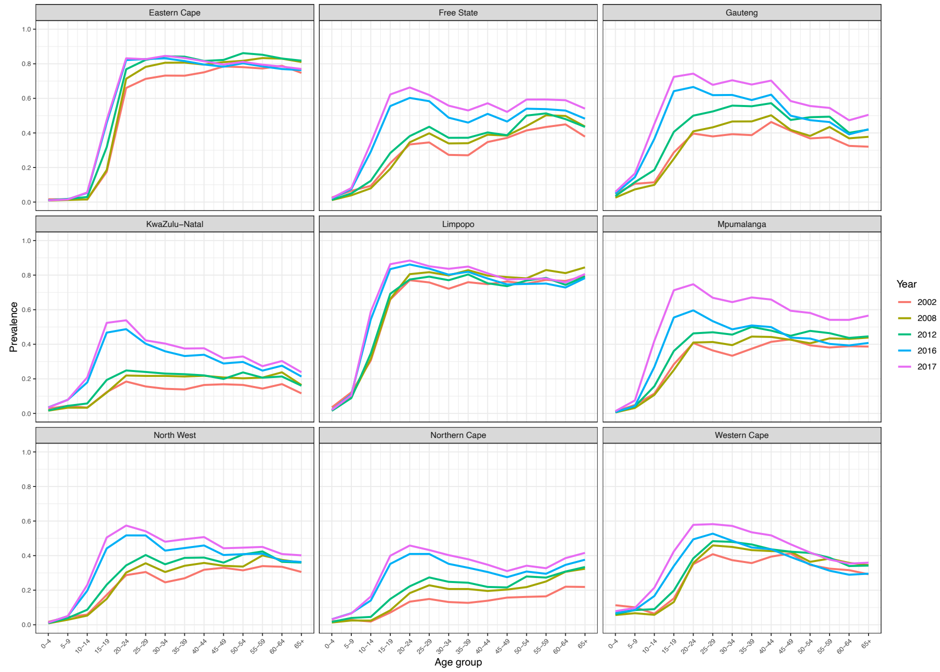

Figure B.5: Total male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a province level. Lines denotes the estimated median prevalence.

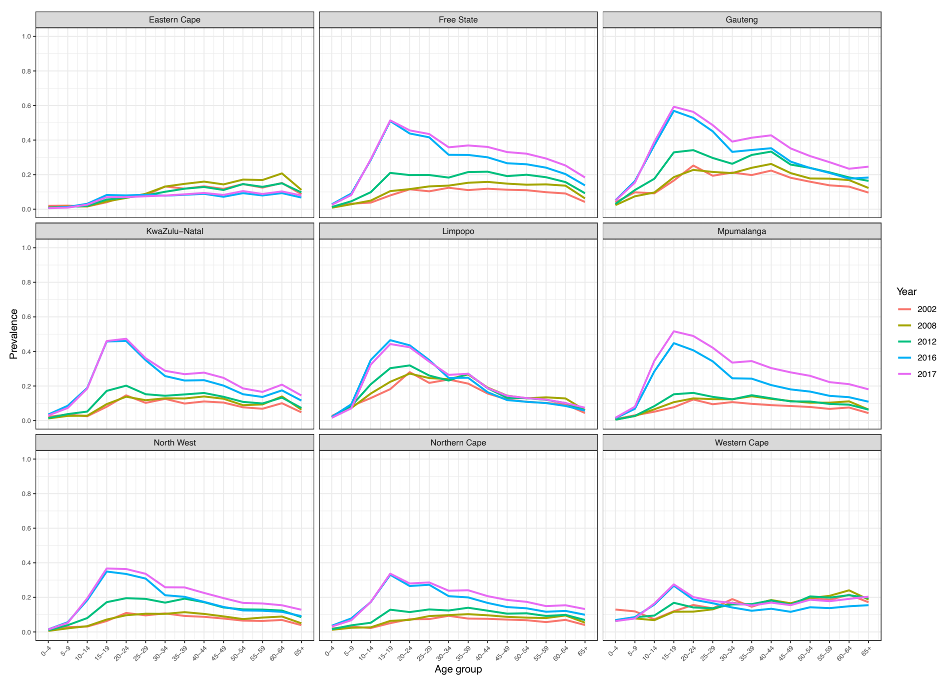

Figure B.6: Medical male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a province level. Lines denotes the estimated median prevalence.

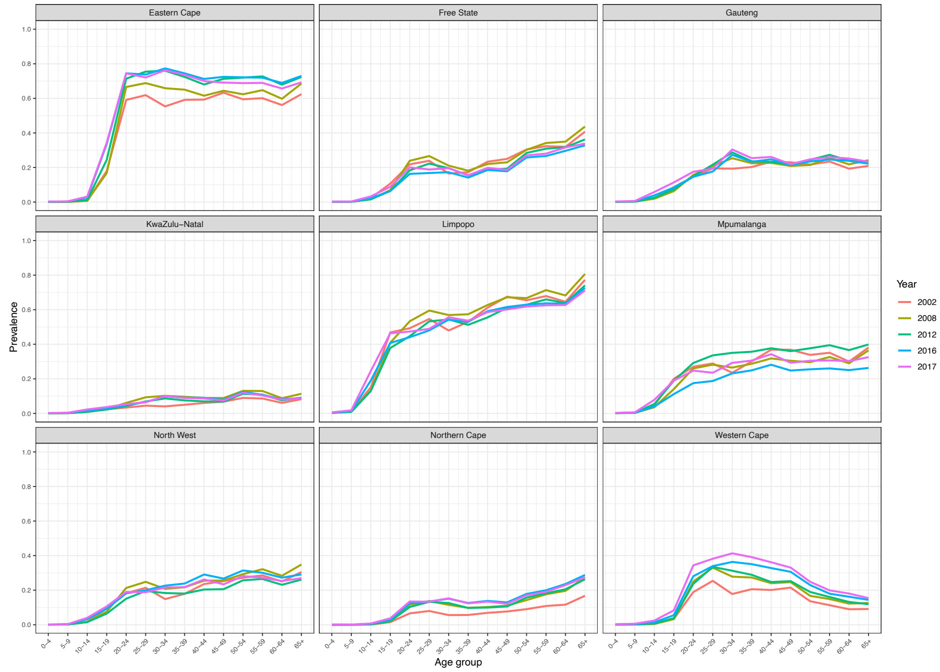

Figure B.7: Traditional male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a province level. Lines denotes the estimated median prevalence.

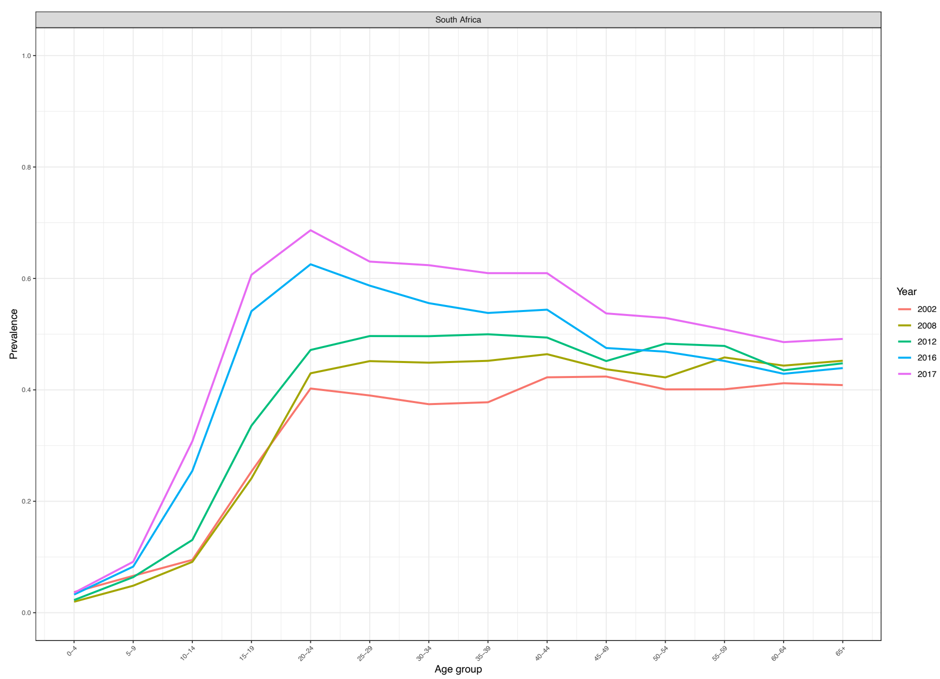

Figure B.8: Total male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a national level. Lines denotes the estimated median prevalence.

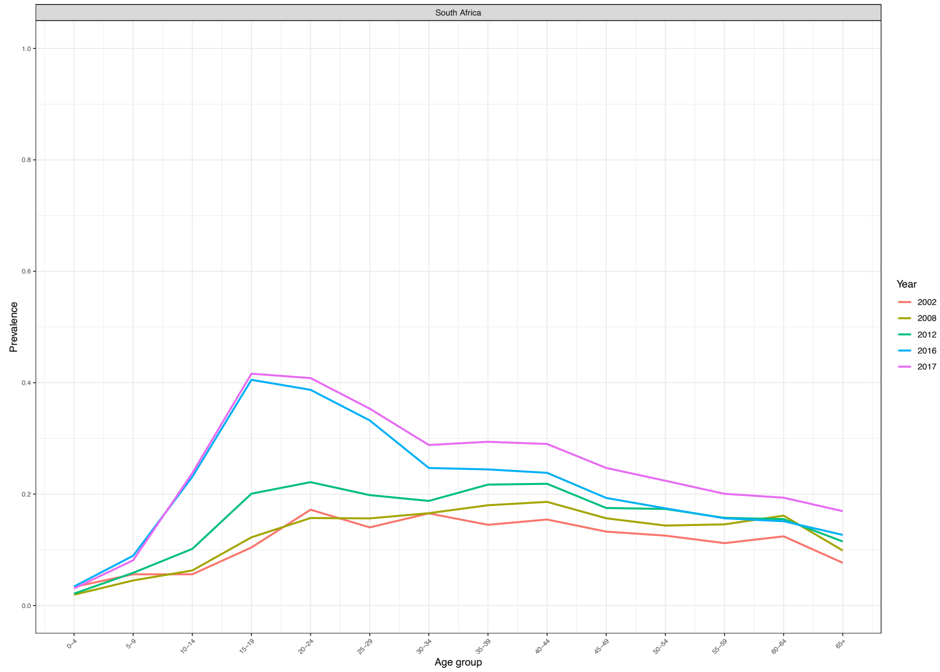

Figure B.9: Medical male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a national level. Lines denotes the estimated median prevalence.

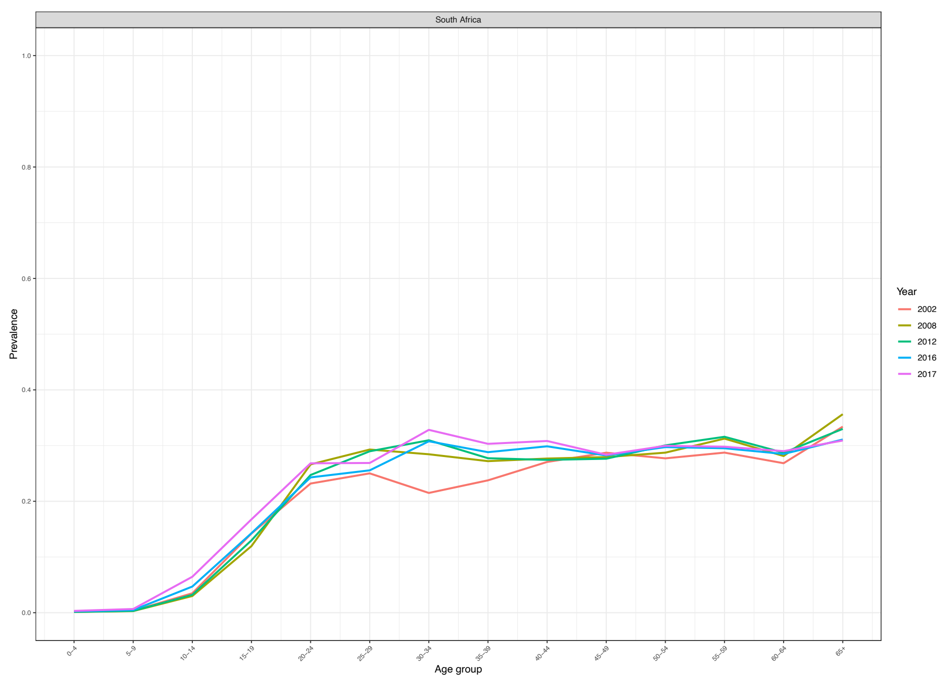

Figure B.10: Traditional male circumcision prevalence in 5-year age groups in 2002, 2008, 2012, 2016 and 2017 at a national level. Lines denotes the estimated median prevalence.

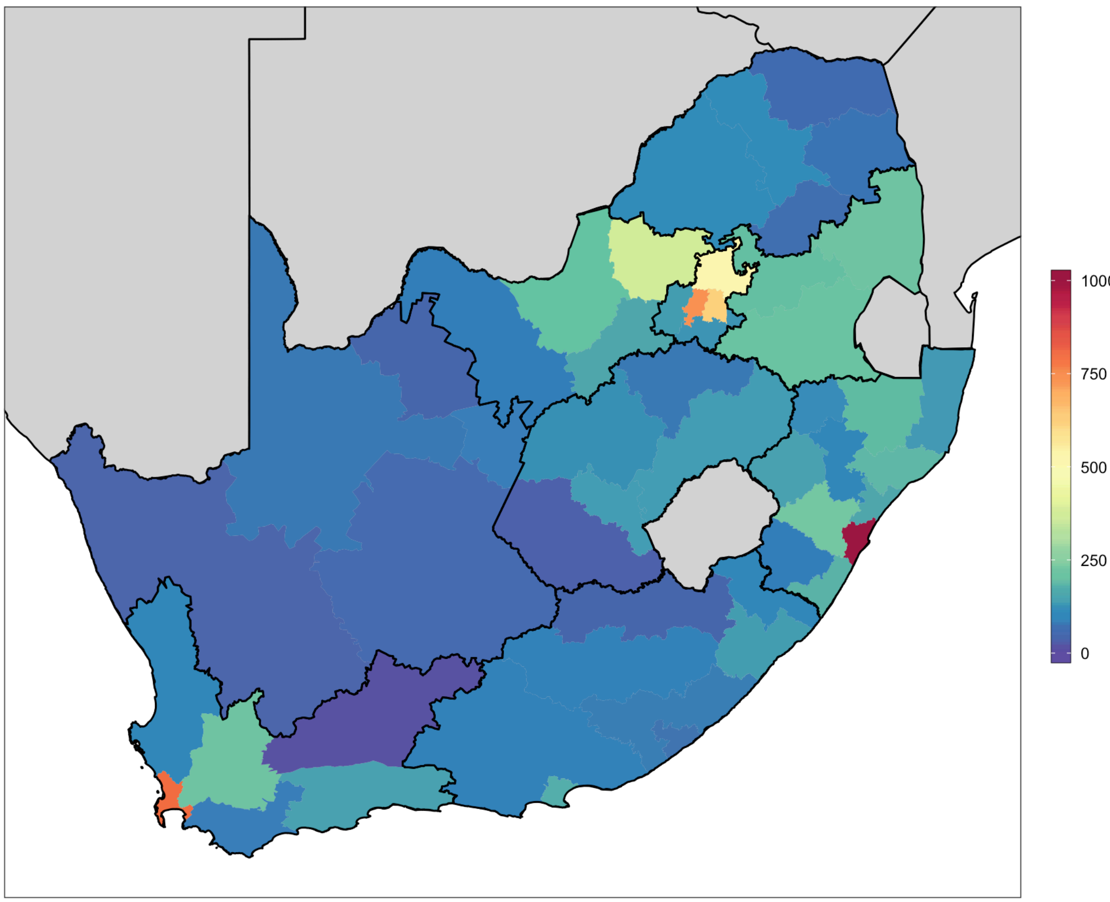

Figure B.11: Estimated number of uncircumcised men aged 15+ in 2017 at a district level.

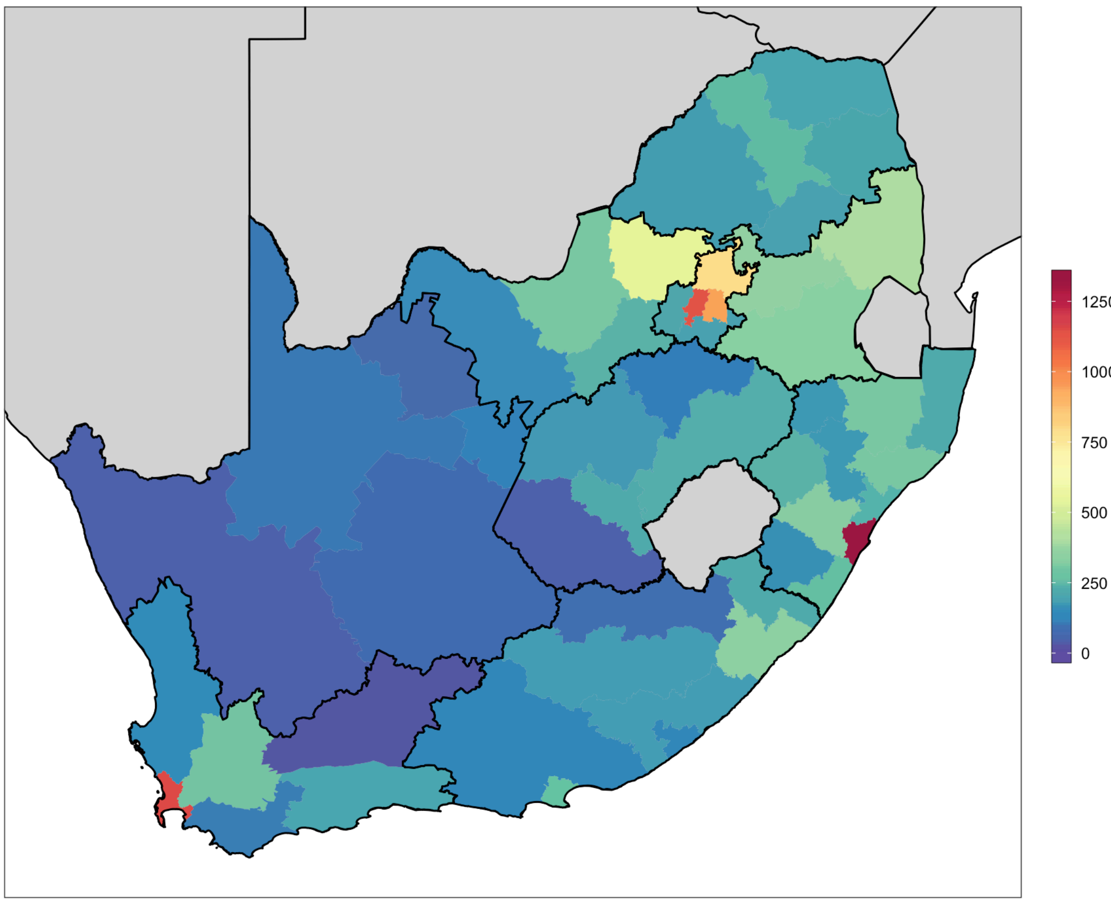

Figure B.12: Estimated total number of uncircumcised men in 2017 at a district level.

C Model fit

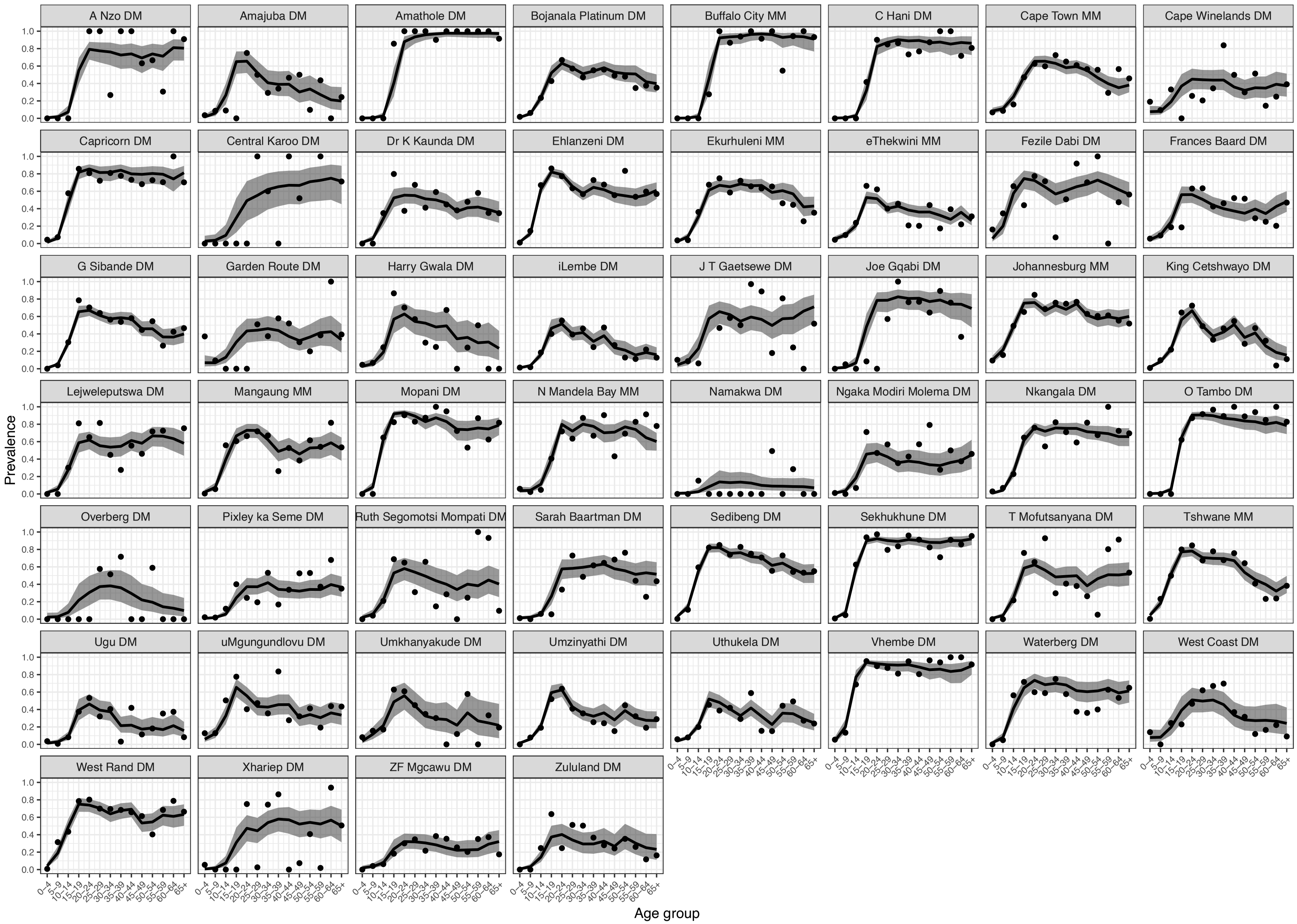

Figure C.1: Total male circumcision prevalence in 5-year age groups in 2017 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2017 SABSSM survey.

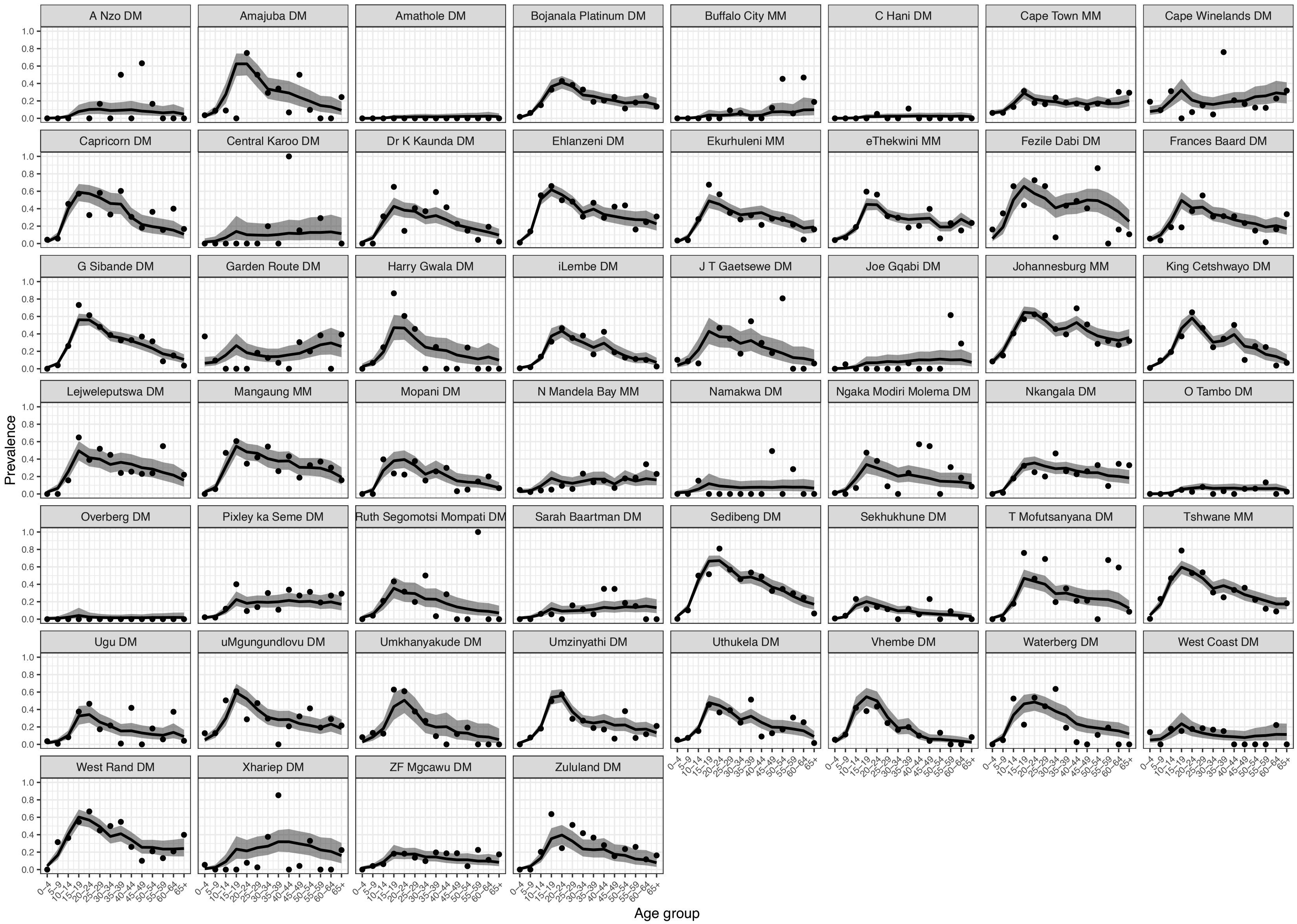

Figure C.2: Medical male circumcision prevalence in 5-year age groups in 2017 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2017 SABSSM survey.

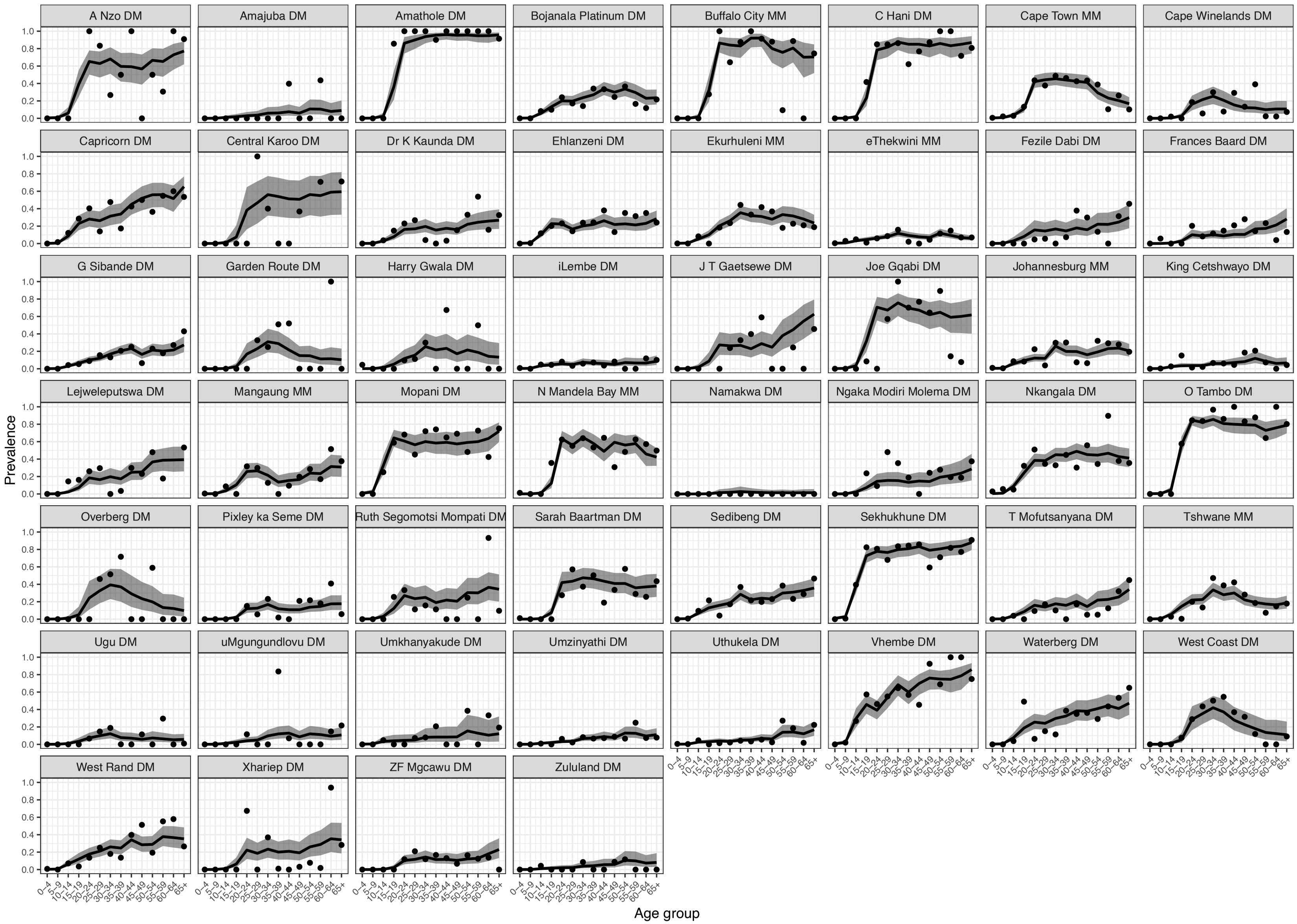

Figure C.3: Traditional male circumcision prevalence in 5-year age groups in 2017 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2017 SABSSM survey.

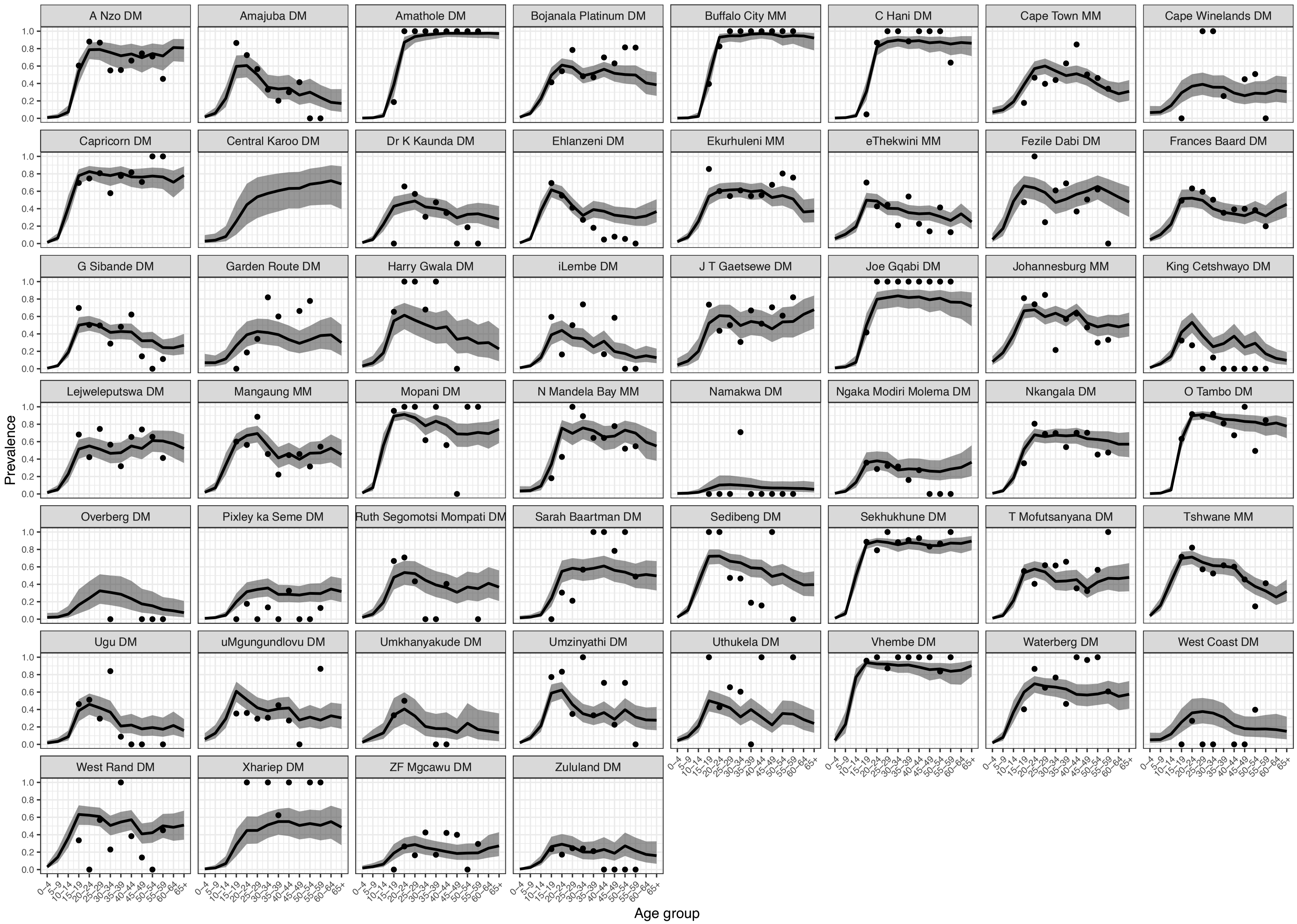

Figure C.4: Total male circumcision prevalence in 5-year age groups in 2016 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2016 SABSSM survey.

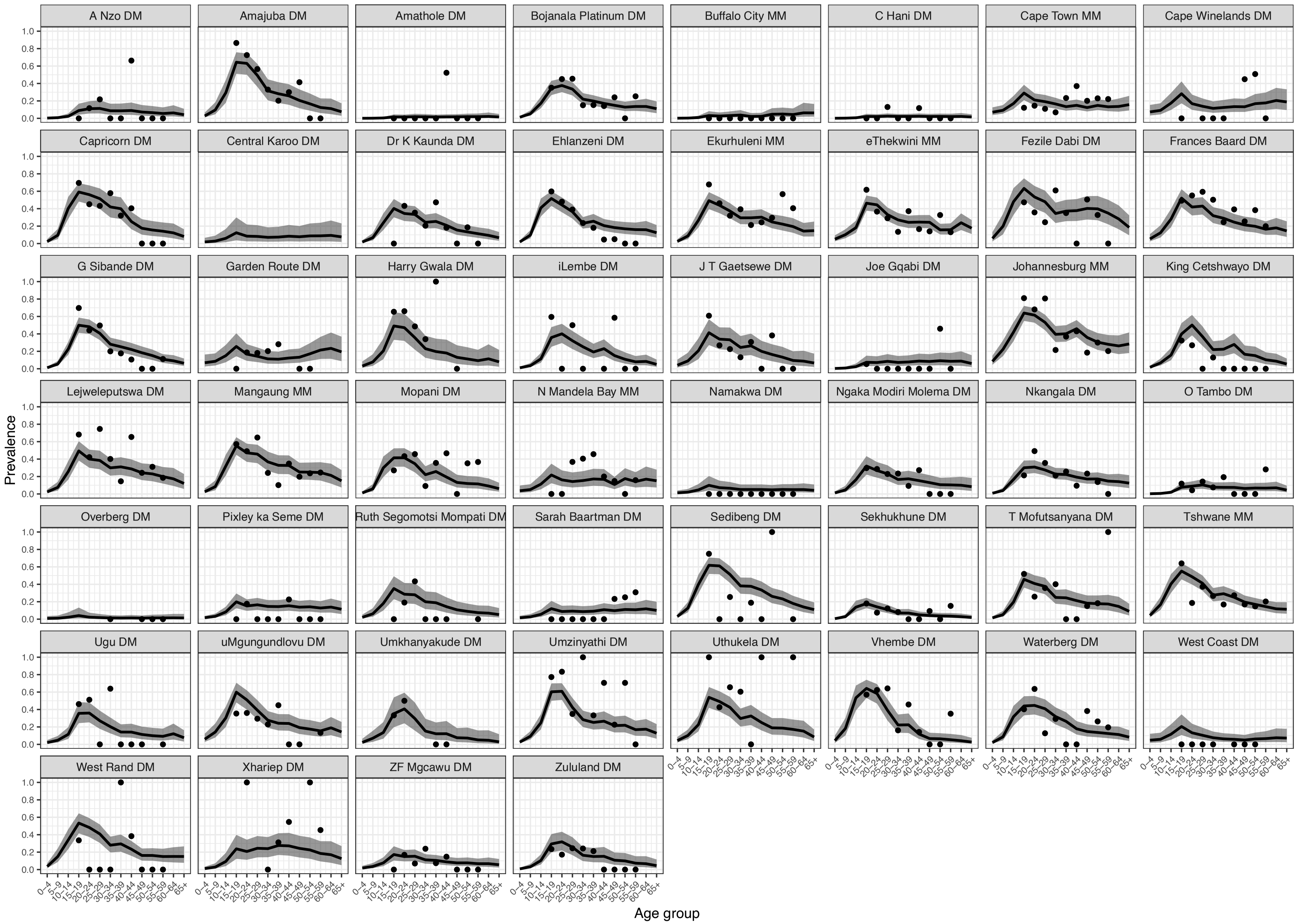

Figure C.5: Medical male circumcision prevalence in 5-year age groups in 2016 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2016 SABSSM survey.

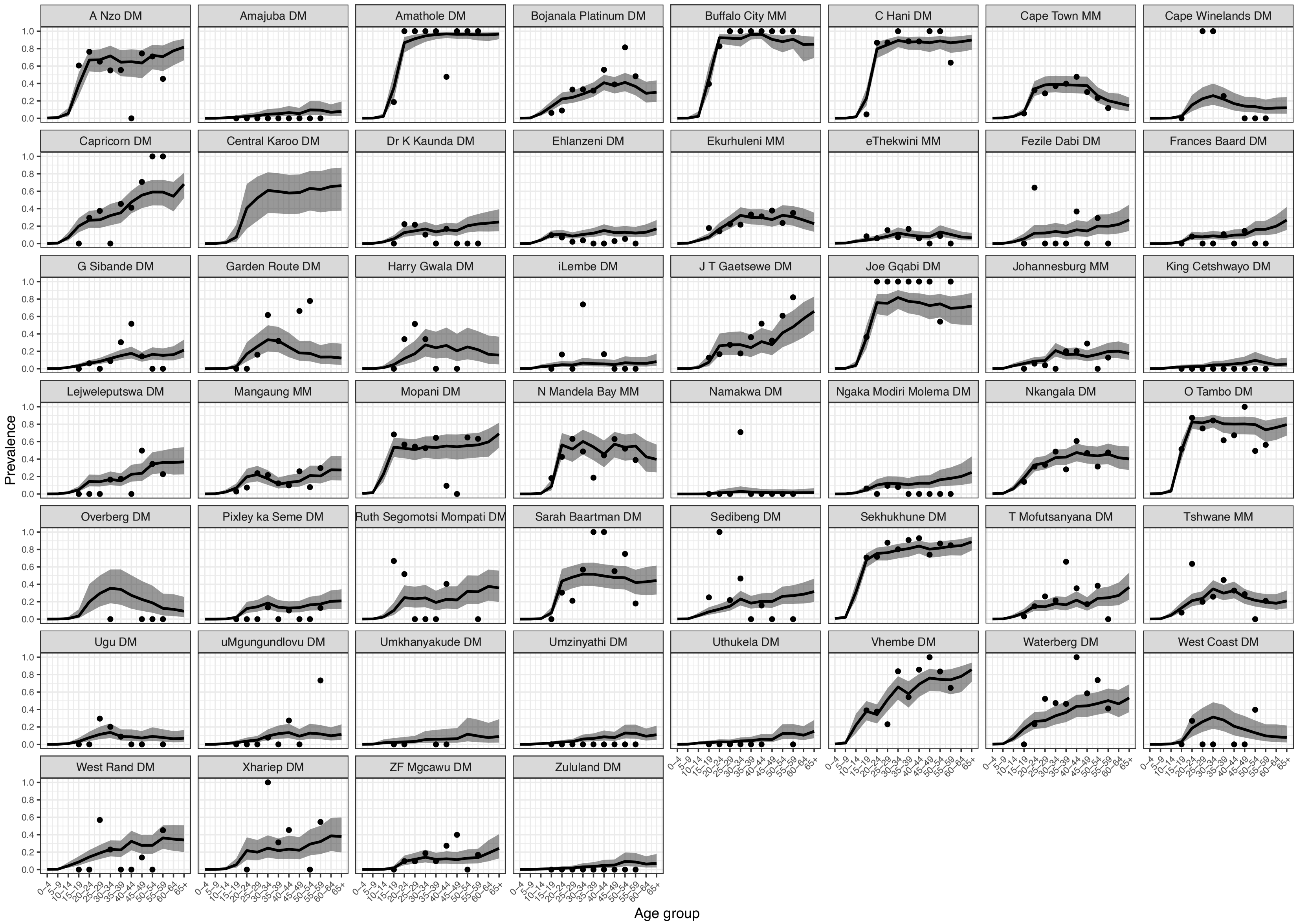

Figure C.6: Traditional male circumcision prevalence in 5-year age groups in 2016 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2016 SABSSM survey.

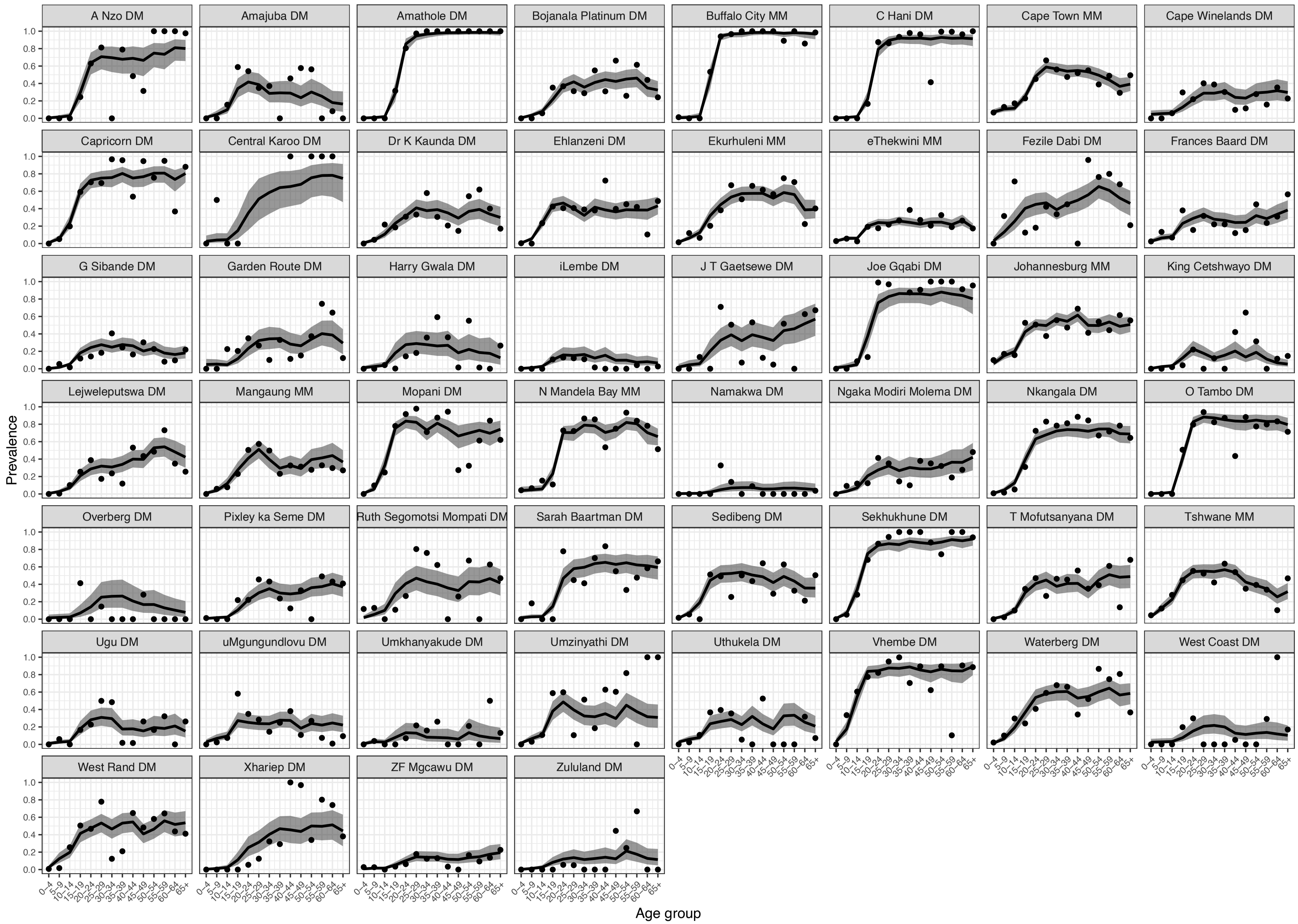

Figure C.7: Total male circumcision prevalence in 5-year age groups in 2012 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2012 SABSSM survey.

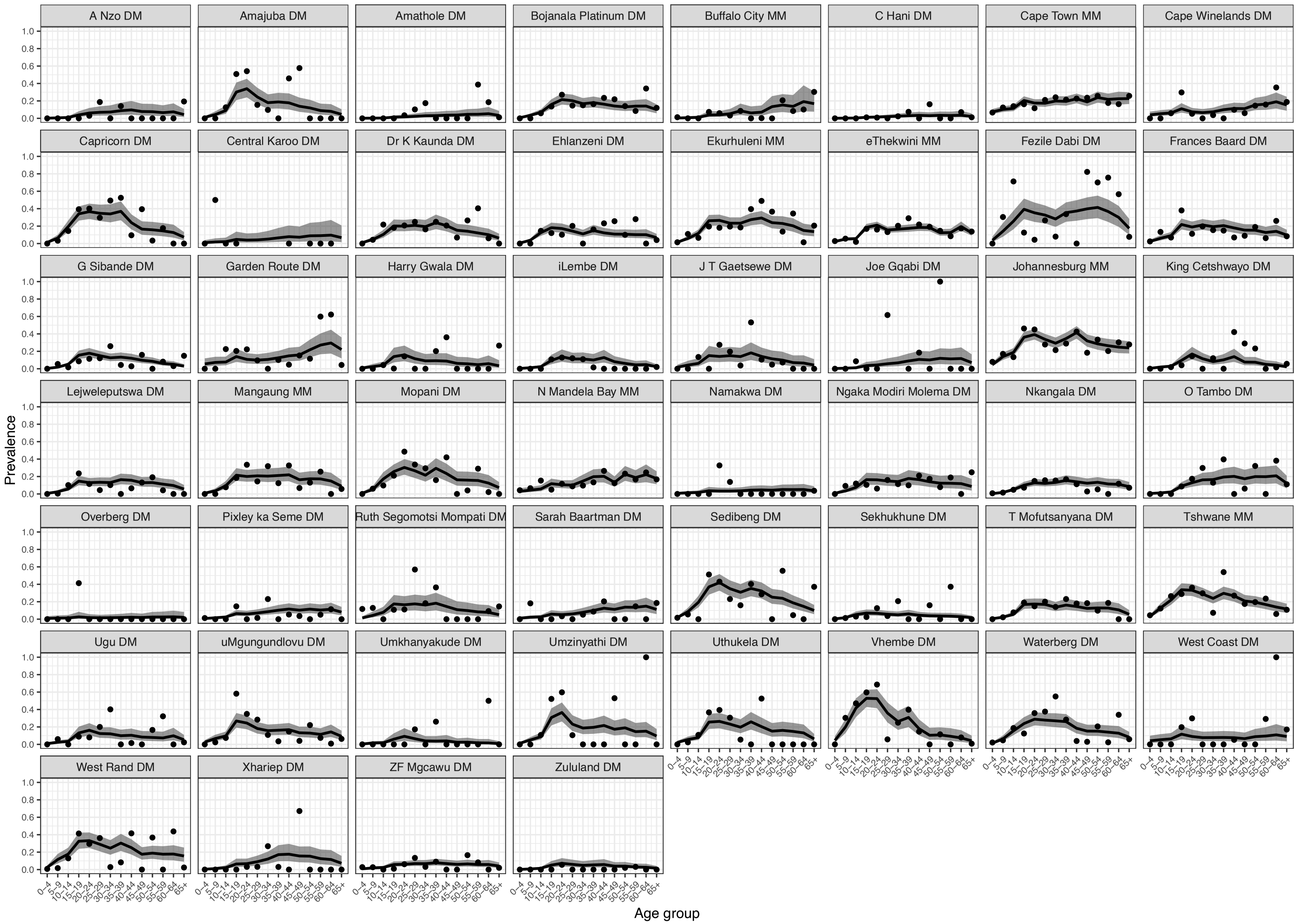

Figure C.8: Medical male circumcision prevalence in 5-year age groups in 2012 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2012 SABSSM survey.

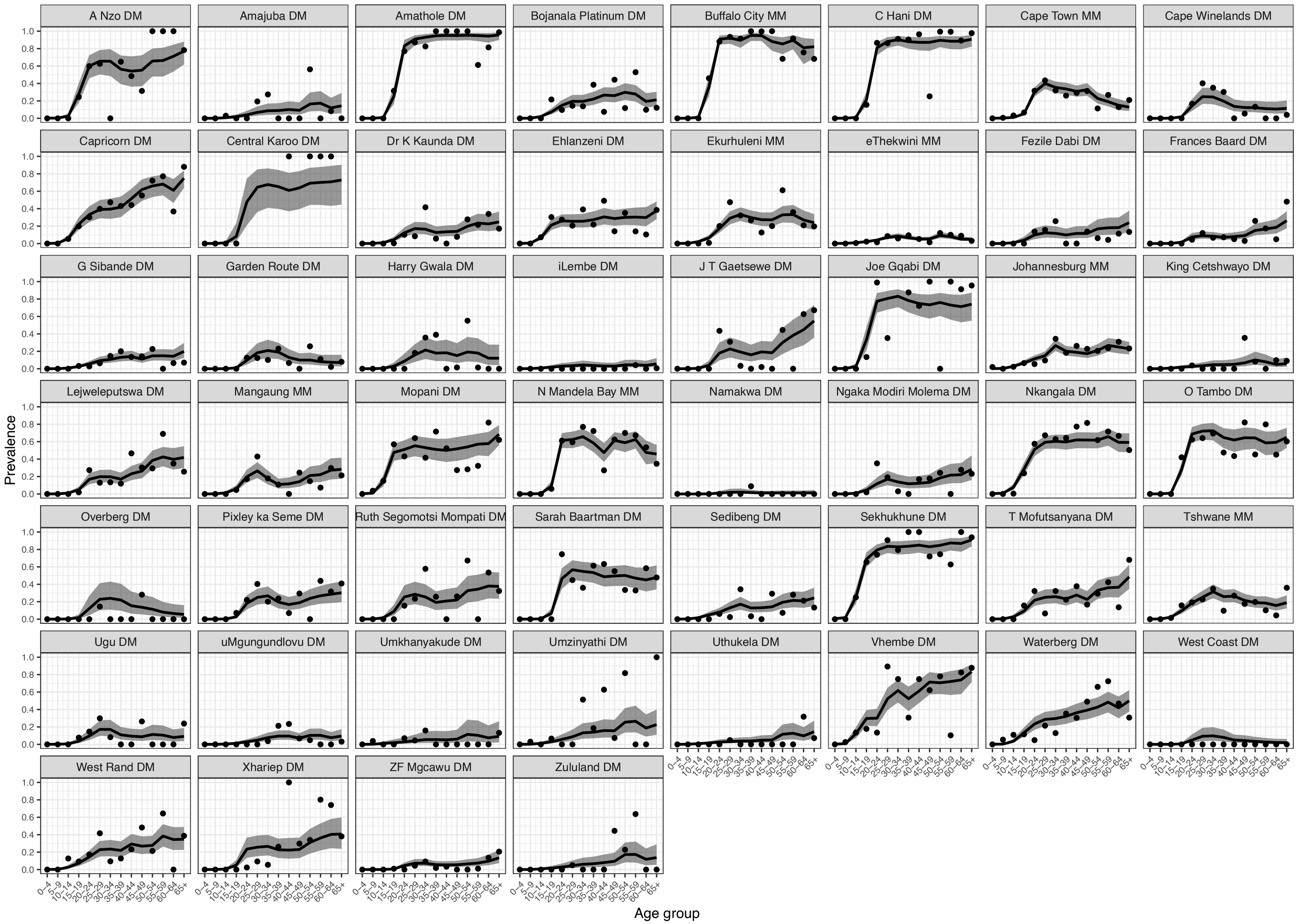

Figure C.9: Traditional male circumcision prevalence in 5-year age groups in 2012 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2012 SABSSM survey.

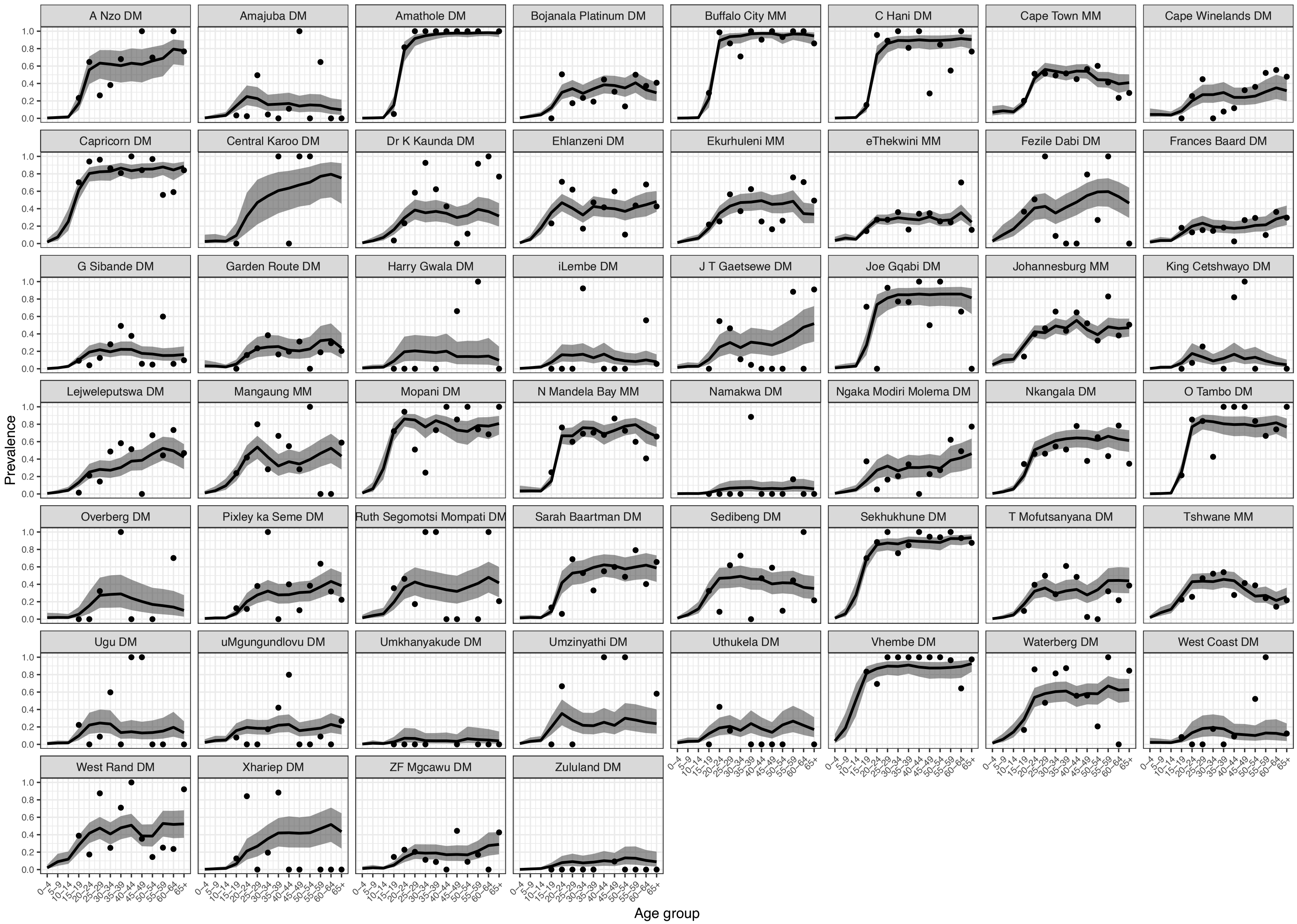

Figure C.10: Total male circumcision prevalence in 5-year age groups in 2008 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2008 SABSSM survey.

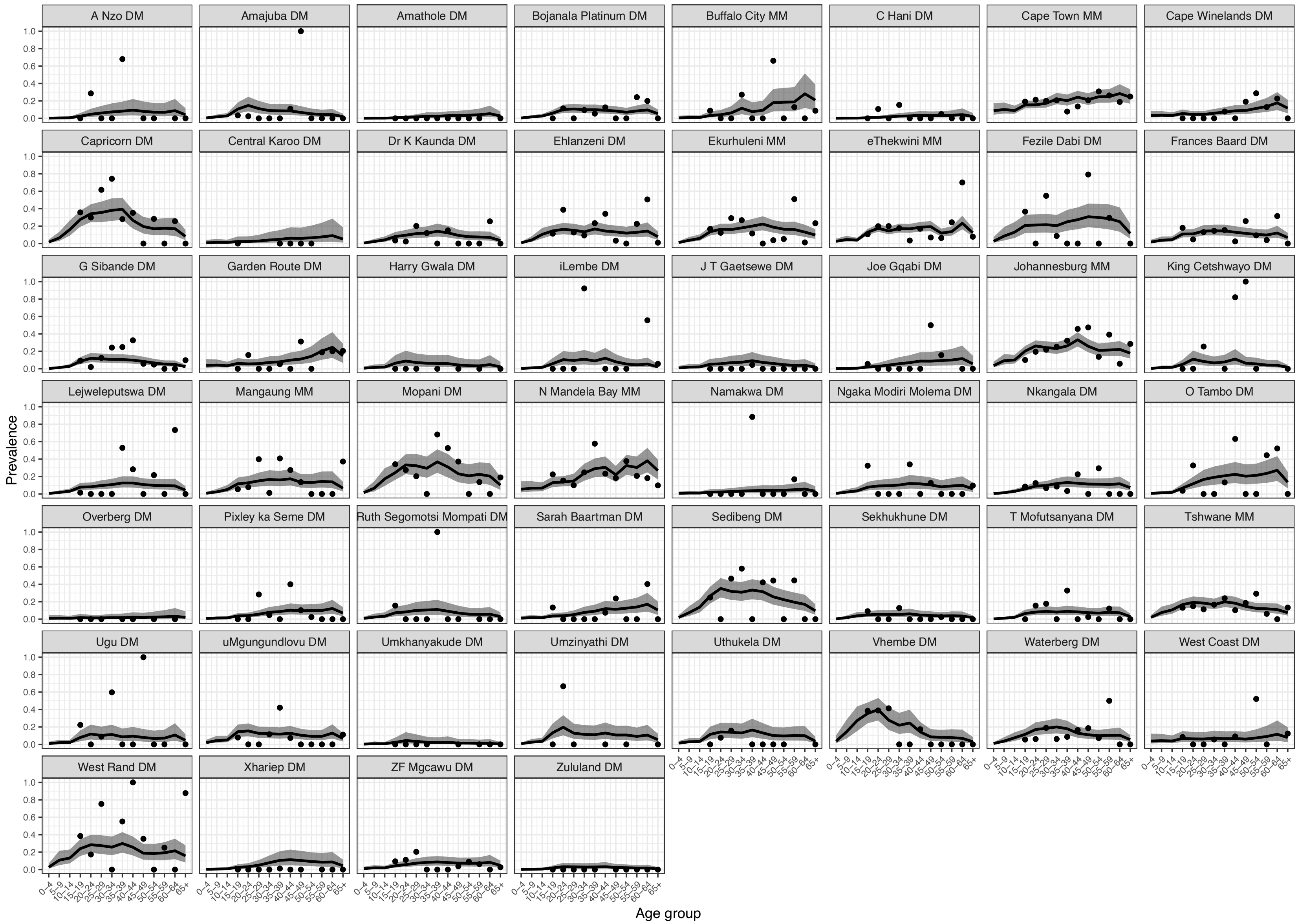

Figure C.11: Medical male circumcision prevalence in 5-year age groups in 2008 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2008 SABSSM survey.

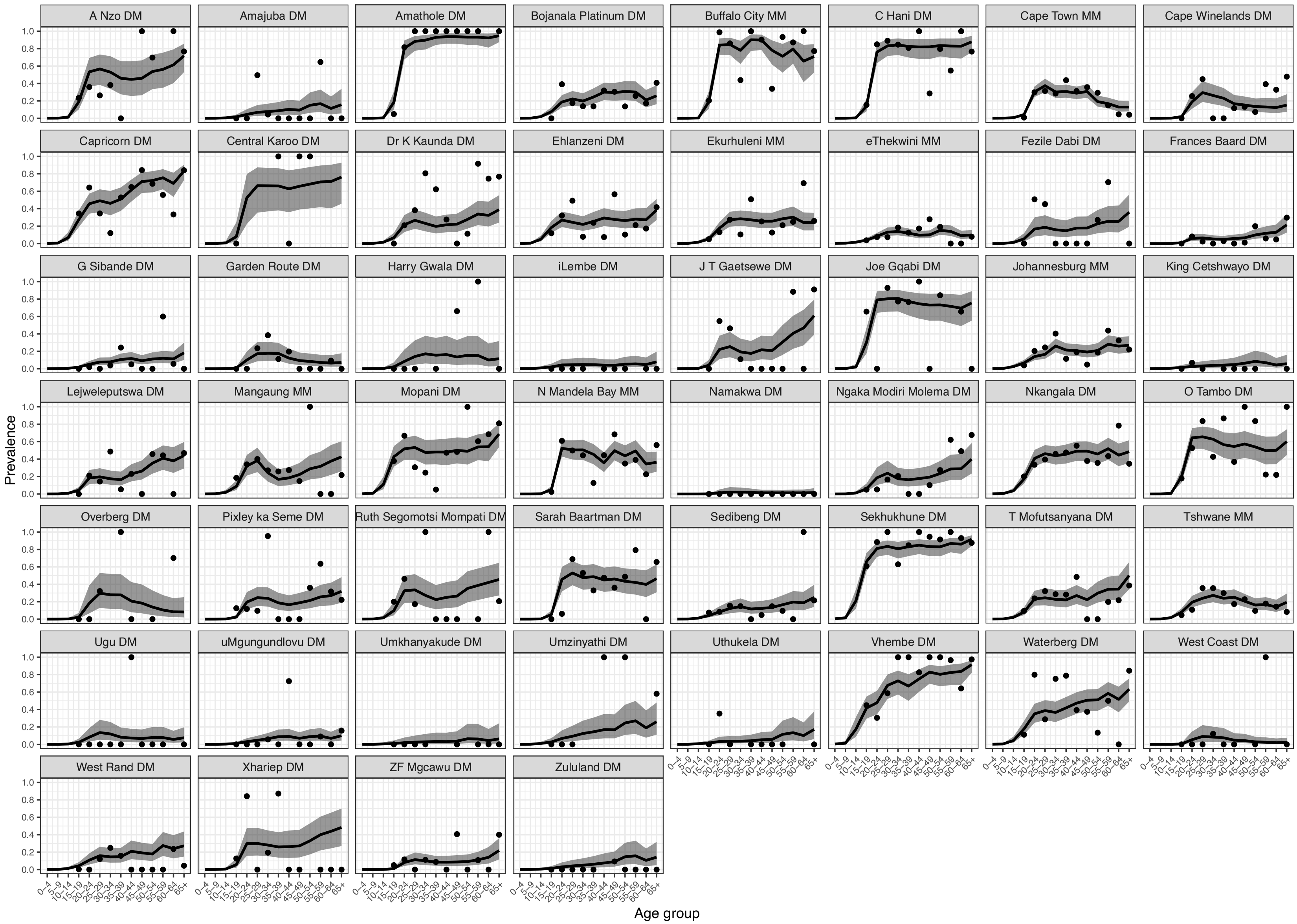

Figure C.12: Traditional male circumcision prevalence in 5-year age groups in 2008 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2008 SABSSM survey.

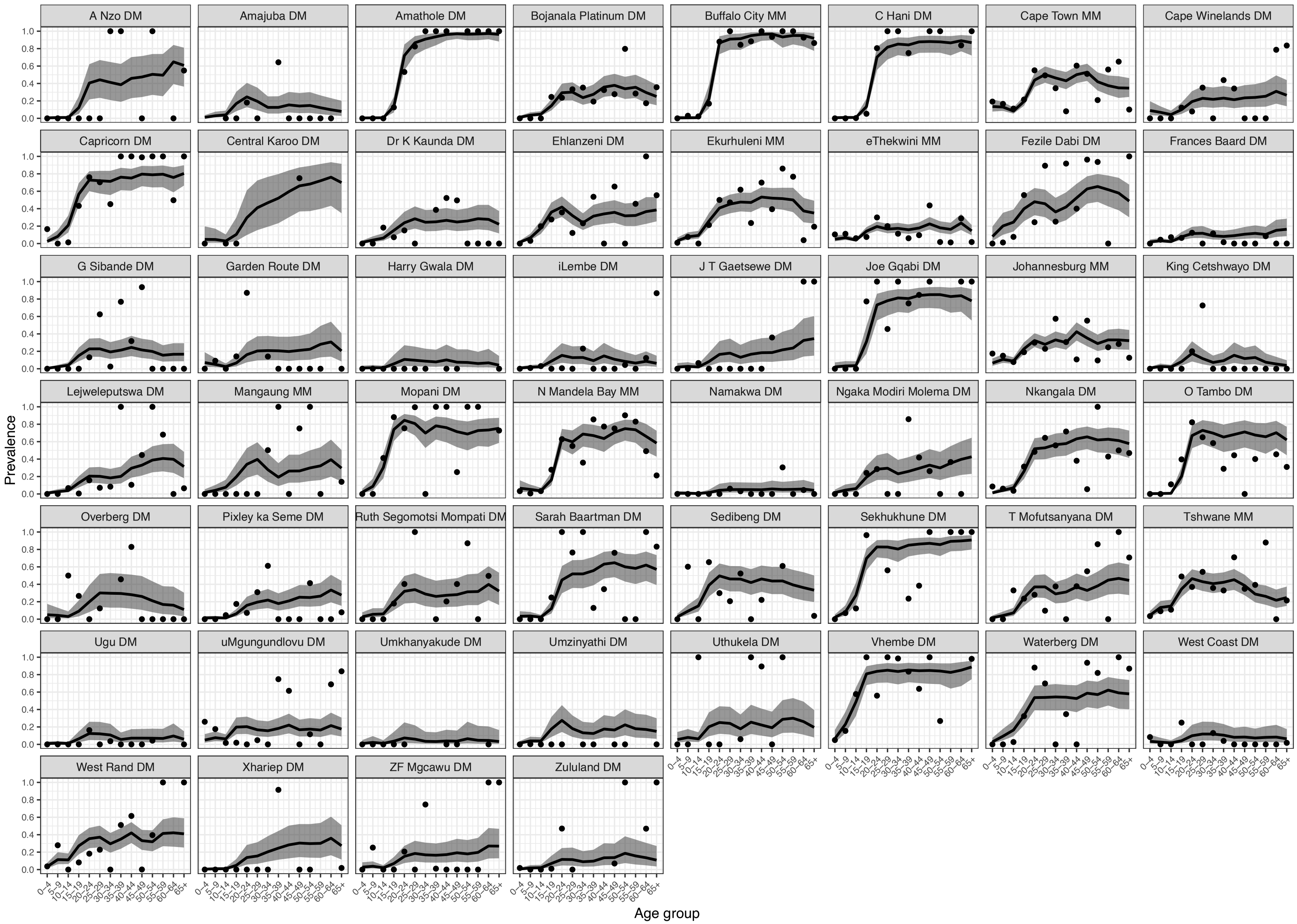

Figure C.13: Total male circumcision prevalence in 5-year age groups in 2002 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2002 SABSSM survey.

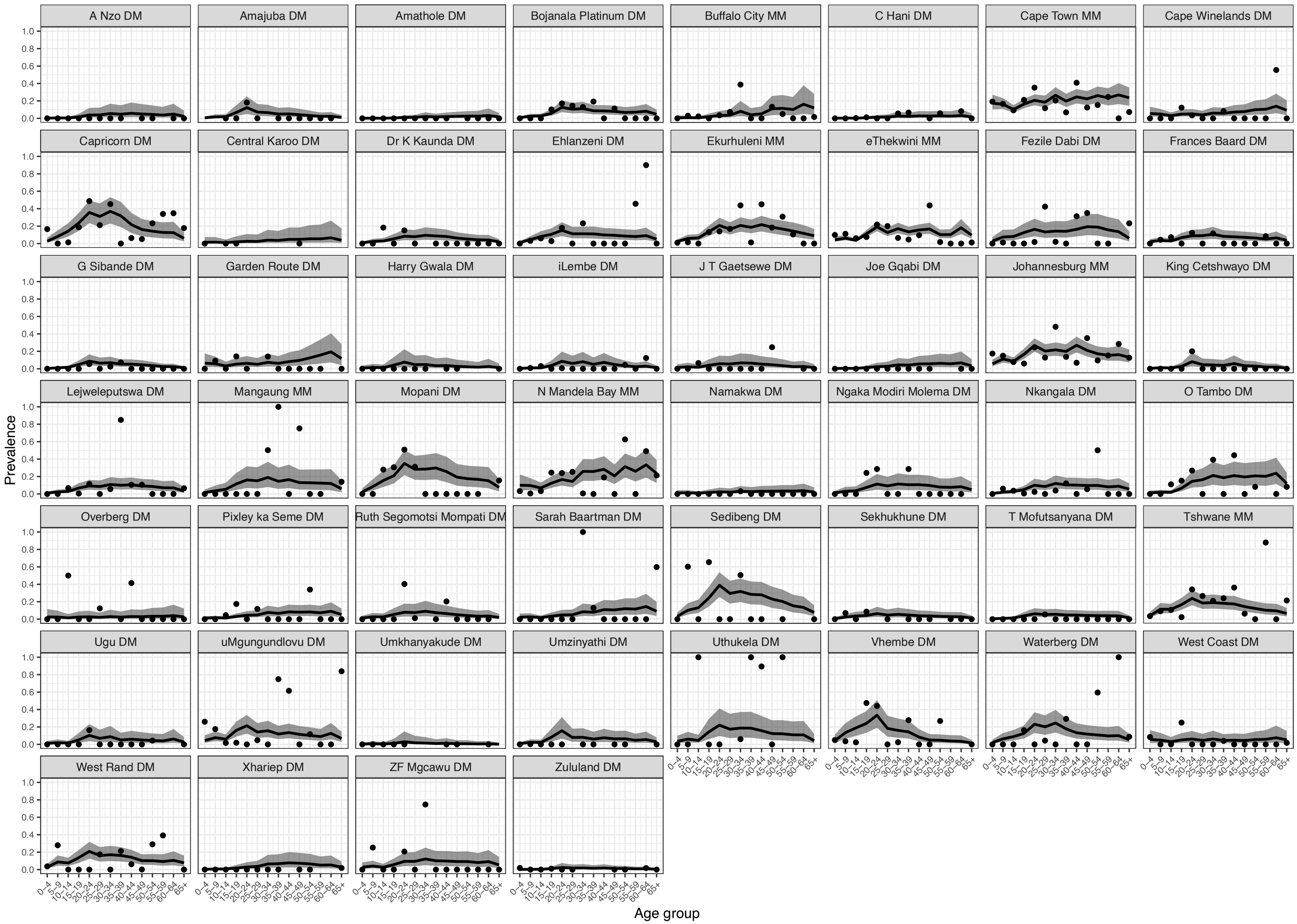

Figure C.14: Medical male circumcision prevalence in 5-year age groups in 2002 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2002 SABSSM survey.

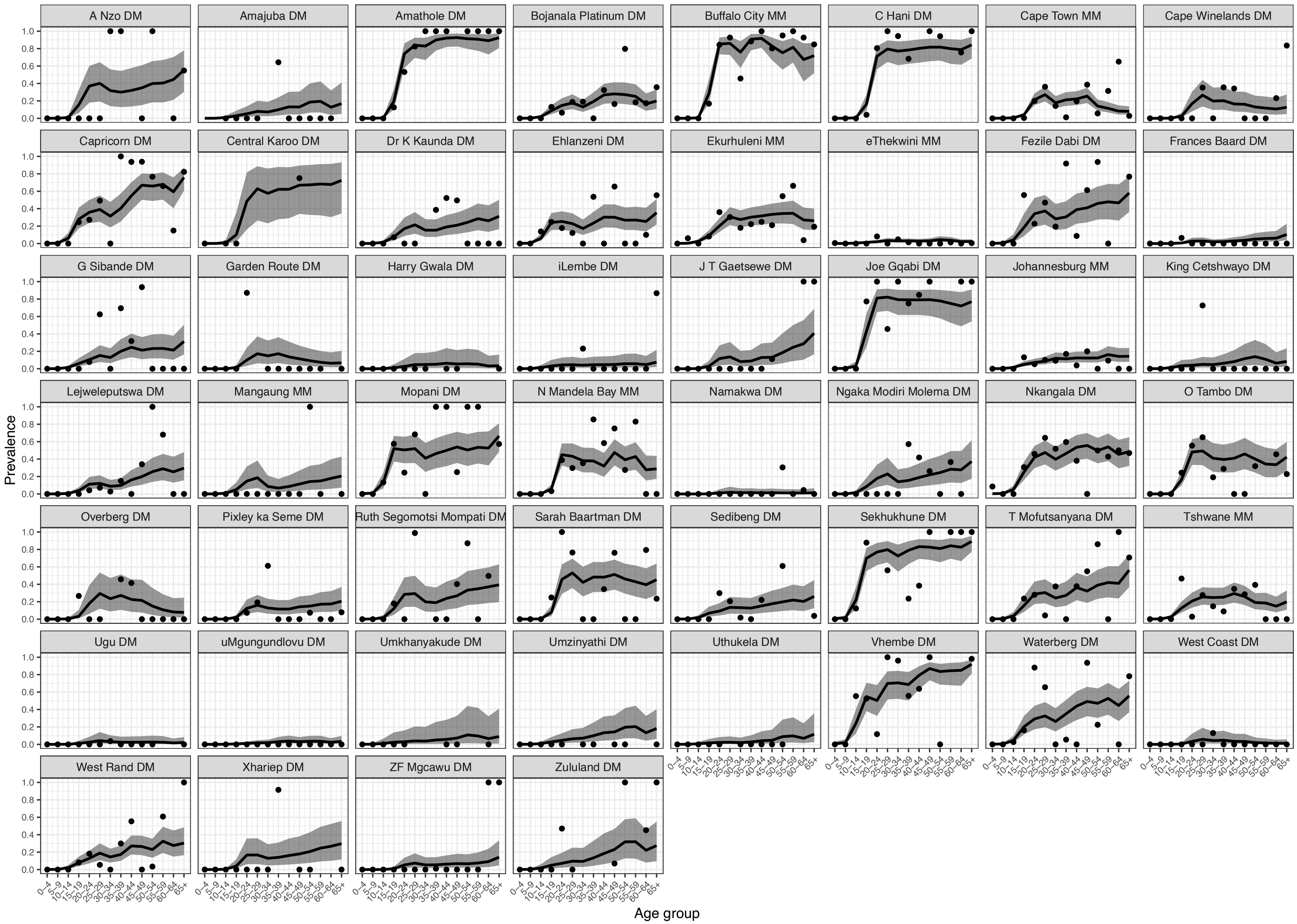

Figure C.15: Traditional male circumcision prevalence in 5-year age groups in 2002 at a district level. Black line denotes the estimated median prevalence, with the grey band denoting the 95% uncertainty interval. Black dots denote the circumcision prevalence sampled from the 2002 SABSSM survey.

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Simpson, D., Rue, H., Riebler, A., Martins, T. G. & Sørbye, S. H. 2017. Penalising model component complexity: A principled, practical approach to constructing priors. *Statistical Science*, **32**, 1–28.