Modelling of the Infectious Syphilis Outbreak in Indigenous Australians — Update

Guidance for Multi-jurisdictional Syphilis Outbreak Working Group

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Multi-Jurisdictional Syphilis Outbreak Working Group

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1. Introduction and Key Findings

This report summarises key findings from mathematical modelling undertaken in 2018-2019 to provide insight into the infectious syphilis outbreak in Indigenous Australians occurring in regional and remote areas of Queensland, Northern Territory, South Australia and Western Australia. The research was undertaken by the Kirby Institute, UNSW Sydney, for the Multi-jurisdictional Syphilis Outbreak (MJSO) Working Group with funding from the Australian Department of Health. The main aim of the modelling was to evaluate the previous and future impact of the outbreak response and to assess the potential impact of expanded testing programs on the epidemic. A key outcome is to estimate what is required to turn around the increasing trajectory of the syphilis outbreak and return to the low level of infectious syphilis occurring prior to the outbreak in 2011. This report is intended to provide guidance, without specifying specific targets, to assist in the roll out of the enhanced response nationally and developing activity work plans in Aboriginal Community Controlled Health Services and other settings.

We extended a previously developed model of STI transmission in Australian Aboriginal and Torres Strait Islander peoples (here after respectfully referred to as Indigenous Australians) [1] to include syphilis transmission, and calibrated the model to syphilis notifications in outbreak-affected areas using testing data reported to the MJSO. The modelled population represents Indigenous Australians living in regional and remote areas affected by the outbreak and provides an overall picture of the epidemic across the affected areas in northern and central Australia. All available and relevant demographic, epidemiological, sexual behaviour, and clinical data were included in the model. We calibrated the model to match the 6-monthly overall infectious syphilis notification rate across the outbreak areas from 2013 to mid-2019 assuming a similar notification rate in regional and remote locations in line with national data [2].

A key input of the model is the percentage of individuals tested in the previous 12 months. The MJSO reports testing coverage using the total number of tests and the estimated resident population (ERP) across all regions for each six-month period. This testing coverage is highly variable across the outbreak affected areas and does not accurately reflect the percentage of individuals tested in the previous 12 months. For these reasons we ran multiple testing coverage assumptions based on the reported MJSO testing coverage in the model. For each assumed testing coverage, we re-calibrated the model and simulated several modelling scenarios to assess the impact of the response since the start of the outbreak, and the potential impact of future increases in testing rates and the introduction of population-wide testing. Further details of the modelling evaluation are provided below, and in the appendices to this report.

While our model has the capacity to consider remote and regional populations separately, in this report we present results showing the effect of testing interventions on the overall syphilis outbreak (in remote and regional areas combined) up to the year 2030. In the main body of the report we present results for key scenarios describing an increase in the testing coverage each year over two years under two different assumptions for the level of testing prior to mid-2019. Results are presented as median and interquartile range (IQR) from the model runs for each of the respective scenarios. We also estimate the date when the prevalence of infectious syphilis returns to pre-outbreak levels and when elimination could be achieved.

Key findings for areas affected by the infectious syphilis outbreak

- The outbreak response has contributed to a likely stabilisation of the outbreak and averted a substantially worse epidemic in regional and remote areas.
- The MJSO testing coverage data suggests that the percentage of people tested annually has almost doubled since 2013 overall and continued efforts will be required to maintain or increase this level of testing.
- To stabilize the outbreak requires at least 40% of the population to be tested annually for infectious syphilis.
- Testing more than 50% of the population would see declines in the epidemic but it would take more than 5 years to reduce infectious syphilis to pre-outbreak levels.
- Increasing annual testing coverage to at least 60% could reduce infectious syphilis to pre-outbreak levels within 3–5 years.
- If in addition to increasing annual testing coverage to at least 60%, annual population-wide testing reached more than 30% of the remote population over a 6-week period then infectious syphilis prevalence would return to pre-outbreak levels within the 2–4years.

Further details of this work can be obtained by contacting Dr. Richard Gray (Rgray@kirby.unsw.edu.au).

2. Summary of Modelling Methods and Syphilis Testing Scenarios

Model description

We extended a previously developed individual-based simulation model of sexually transmitted infections (STIs) in Indigenous Australians to capture the syphilis outbreak across the regions affected by the outbreak. The model tracks the sexual transmission of syphilis among a population of 10,550 males and females aged 15-34 years in one large regional centre (of 5,550 people) and 10 small remote communities (of 500 people each) with a sex and age distribution based on demographic data from the Australian Bureau of Statistics (which gives a sex ratio of approximately 50:50). The model population comprises only heterosexual Indigenous Australians living outside of major cities as this is where the outbreak has been concentrated. Individuals in the model have a designated home location but can move between the regional centre and remote locations. We used this population structure to reflect available demographic data and to represent the overall Indigenous population living in the syphilis outbreak areas. While this model population structure may not reflect specific jurisdictional or regional populations, we are confident our results and key messages are broadly applicable.

For this study we did not consider Indigenous men who have sex with men and assumed males and females in the model form heterosexual partnerships only. Individuals in the model can be sexually active while travelling or away from home, forming casual partnerships, even if they have a partner at their home location. While there is an ongoing rollout of communication and education materials across the outbreak regions, we have no data on the effects of this rollout on sexual behaviour. For this analysis, we therefore assumed sexual behaviour did not change in our model over the time period considered. This assumption should be considered when interpreting our results as a greater impact could occur if risk behaviours fall in conjunction with increases in testing. Further detail of how sexual behaviour is captured in the model is provided in the appendix A1 Syphilis Model Description.

Syphilis testing

We assume ongoing syphilis testing of individuals is carried out in the model population. A key variable in the model is the percentage of males and females aged 15-34 years who are tested for syphilis in the previous 12 months (which we refer to as the testing coverage). To estimate this modelling input we first used the raw data provided by the MJSO for the total number of tests and the estimated resident population (ERP) across all affected regions in QLD, NT, SA, and WA for 15-24-year-olds for each six-month period over 2013 to mid-2019 to estimate a crude annual testing coverage. We then made assumed adjustments to this crude testing coverage (described in the following paragraphs) to reflect the possibility that the MJSO testing coverage could under- or over-estimate the actual testing coverage in the previous 12 months. Finally, we adjusted the resulting testing coverage for 15–24-year-olds to reflect the likely testing coverage in the 15–34-year-old model population. Our model assumes a varying testing coverage across the population based on sex (male, female), region (remote, regional) and age (15–19, 20–24, 25–29, 30–34 years old). We adjusted the annual testing coverage for each sex and age group using data from the STRIVE study [3,4] (as described in appendix A1 Syphilis Model Description) so that the testing coverage for all

15-34-year-olds matched the assumed testing coverage obtained from the MJSO data up to mid-2019. Prior to 2013, we assumed the overall testing coverage was constant and equalled the testing coverage of 16.9% reported in the STRIVE study [3].

Using the unadjusted MJSO data, the overall testing coverage increased from 35% in 2013 to 56% by mid-2019 (76,086 tests/155,607 ERP) for 15–24-year-olds, with variation by region. This unadjusted testing coverage may not accurately reflect the actual testing coverage achieved in the previous 12 months due to variations in the testing data reported to the MJSO from each region (e.g. numbers of tests versus individuals tested), potential under reporting of tests from private laboratories or over counting due to tests in visitors (a proportion of whom are likely to be from outside the outbreak affected areas) or multiple tests in individuals (such as pregnant women). It is likely this unadjusted testing coverage is an overestimate, but we had no specific data to inform the adjustment required.

We conducted a review of the reported MJSO testing coverage and sought input from stakeholders and the MJSO working group to inform the testing coverage to be used in the mathematical model. Based on the various factors affecting the number of tests and ERP reported for each affected region, we conducted exploratory calculations which suggest the unadjusted testing coverage could overestimate the actual testing coverage each year by ~30% (details provided in appendix A3 MJSO Testing Coverage). Given this uncertainty we ran the model under different assumptions regarding the testing coverage achieved in the previous 12 months to mid-2019. For the main report we generated results with the testing coverage for 15–24-year-olds equalling the unadjusted MJSO testing coverage and being 0.75 times the MJSO testing coverage (thus the actual testing coverage in the previous 12 months by mid-2019 would be 39%). Under each assumption we performed the same adjustments to convert the testing coverage for 15–24-year-olds to a testing coverage for the 15–34-year-old model population. For ease of description we simply refer to these testing coverage assumptions by stating the *testing coverage equals the MJSO testing coverage* and *testing coverage equals 0.75 times the MJSO testing coverage*, respectively. To test the robustness of our results and conclusions we also produced results with the testing coverage each year equal to 0.5 and 1.25 times the MJSO testing coverage (see appendix A5 Additional results).

Syphilis treatment

We assumed that syphilis is detected, through testing, with a sensitivity of 98%. Following diagnosis, almost all people are treated within 7 days in regional areas and 85% of people are treated within 4 months in remote areas. These treatment rates are based on the gonorrhoea and chlamydia treatment rates from the TTANGO study [5] and are likely to be conservative as syphilis treatment is thought to be provided in more timely manner in the outbreak affected areas. In the model we assume there is no treatment failure and that people become susceptible to re-infection immediately following treatment and resolution of infection. The model does not incorporate post-diagnosis re-testing (as per clinical guidelines) but previously infected people continue to be tested in line with the specified testing coverage.

Model calibration

Model calibration is the process of ensuring output from the model matches the available epidemiological data and ensures the model accurately reproduces the key features of the epidemic. We calibrated the syphilis outbreak model so that diagnoses per 100,000 people for each six month period produced by the model matched the infectious syphilis notification rate from 2013 (when the outbreak started spreading to multiple jurisdictions) to June 2019 for the outbreak affected areas (calculated using the 6-monthly notifications and ERP data provided by the MJSO; Figure 1A). While we were not provided with regional and remote breakdowns in the data, we assumed the notification rates in remote areas were similar to or greater than the rates in the regional centre. This assumption is based on national data for syphilis notifications in the Bloodborne Viral and Sexually Transmissible Infections in Aboriginal and Torres Strait Islander People Annual Surveillance Report [2].

Model calibration was performed for each of the testing coverage assumptions by running the model 1000 times after a single infected person was introduced into the model at the start of 2008. The infectious syphilis notification rate for each model run was then calculated, and the 100 runs with the closest match to the MJSO reported 6-monthly notification rate over 2013-2018 were selected to produce the results.

Syphilis testing scenarios

We used the model to evaluate a range of scenarios involving increased annual testing and population-wide testing. These scenarios were developed in consultation with the MJSO Working Group to reflect what we consider to be a feasible expansion of current intervention efforts to combat the syphilis outbreak in the affected areas. The first two scenarios capture the current response and the counterfactual of no outbreak response since 2013, and show the impact of the outbreak response by the jurisdictions and the enhanced response so far. For the other scenarios, targets for testing and treatment were reached within 5 years (corresponding to mid-2024) or more ambitiously within 2 years (corresponding to mid-2021). For the main report we focus on eight key scenarios listed in Table 1, which reflect more likely testing uptake patterns and the short-term targets of the response. Each scenario captures increases in annual testing to a specified testing coverage and/or population-wide testing within the population. A full list and description of all scenarios run in the model is provided in appendix A4 Full Scenario List.

The testing coverage and population-wide testing proposed in these scenarios reflect what is currently being reached or targeted in some locations already and what could be achieved if this occurred across all syphilis outbreak areas. For example, the Nganampa Health Council achieves a participation rate of approximately 70% of people in the area tested during a six-week period each year (information provided through the MJSO working group).

These scenarios are implemented in the model (for each assumption regarding annual testing coverage) in order to predict the epidemic trajectories and to estimate the impact of increases in testing from the level achieved in mid-2019 (representing current conditions or the status-quo in our analysis). We report the median and IQR for the prevalence of infectious syphilis, the annual number of new infections, and the annual number of notifications from the model runs for each of the scenarios and annual testing coverage assumptions. For the main report we focus on the results when testing coverage equals the MJSO testing coverage and when it equals 0.75 times the MJSO testing coverage, with results for the other assumptions presented in appendix A5 Additional Results. If the annual

testing coverage equals the MJSO testing coverage, the status-quo scenario assumes 33% of all regional males, 63% of all regional females, 36% of all remote males, and 68% of all remote females were tested corresponding to an overall testing coverage of 52% of the population in the previous 12 months from mid-2019. If the annual testing coverage equals 0.75 times MJSO testing coverage, the status-quo scenario assumes 24.8% of all regional males, 47.3% of all regional females, 27% of all remote males, and 51% of all remote females, corresponding to an overall testing coverage of 39% of the population in the previous 12 months from mid-2019.

Table 1: Key syphilis testing scenarios simulated in the model. We use the scenario number to refer to a specific scenario in the main text and figure legends. The full list of scenarios run in the model is provided in the appendix A4 Full Scenario List.

#	Scenario	Description
1	Outbreak response	Assume annual testing coverage remains at mid-2019 levels across all populations and regions
2	Counterfactual no outbreak response with annual proportion tested remaining at 2013 levels	Assume there was no increase in annual testing coverage since 2013 when the outbreak started spreading to multiple jurisdictions.
3	Increase annual testing coverage to 50%	Increase annual testing coverage from current levels (at mid-2019) to 50% across all populations and regions over 2 years. **Only run in the model when the assumed testing coverage mid-2019 is less than 50% (e.g. for the testing coverage equals 0.75 times the MJSO testing coverage).**
4	Increase annual testing coverage to 60%	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions over 2 years.
5	Increase annual testing coverage to 70%	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions over 2 years.
6	Increase annual testing coverage to 60% and undertake annual population-wide testing of 30% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 2 years (as in scenario 4). In addition, undertake population-wide testing in remote areas each year for 2 years (where 30% of the population is tested in 6 weeks).
7	Increase annual testing coverage to 60% and undertake annual population-wide testing	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 2 years (as in scenario 4. In addition, undertake population-wide testing in remote areas each year for 2

	of 60% of the population in remote locations	years (where 60% of the population is tested in 6 weeks).
8	Increase annual testing coverage to 70% and undertake annual population-wide testing of 30% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 2 years (as in scenario 5. In addition, undertake population-wide testing in remote areas each year for 2 years (where 30% of the population is tested in 6 weeks).
9	Increase annual testing coverage to 70% and undertake annual population-wide testing of 60% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 2 years (as in scenario 5. In addition, undertake population-wide testing in remote areas each year for 2 years (where 60% of the population is tested in 6 weeks).

3. Results

Impact of the outbreak response

Since the start of the outbreak the unadjusted testing coverage for syphilis in outbreak affected areas reported by the MJSO increased from 31.0% in the previous 12 months in 2011 to 56% in the previous 12 months for 15–24-year-olds by mid-2019. This corresponds to a 1.8 times relative increase in the annual testing coverage (which is reflected in all of the testing coverage assumptions used in the modelling).

Assuming the annual testing coverage equals the MJSO testing coverage and remains at the mid-2019 level of 52% overall (when adjusted for age, sex and region), we project the syphilis outbreak will stabilise and start to slowly decline with the number of diagnoses for the previous 6 months decreasing from 303.3 (IQR: 227.5–379.2) per 100,000 people at mid-2019 to 113.7 (IQR: 28.4–255.9) per 100,000 people at the end of 2025 (Figure 1B). This corresponds to a decrease in prevalence from 0.36% (IQR: 0.25–0.53%) to 0.10% (IQR: 0.01–0.27%) over this period (Figure 2A, Scenario 1 results; Table 2). If the annual testing coverage equals 0.75 times the MJSO testing coverage and remains at the mid-2019 level of 39% overall, then we project the syphilis outbreak will stabilize but not decline with the number of diagnoses for the previous 6 months changing from 341.2 (IQR: 246.5–398.1) per 100,000 people at mid-2019 to 360.2 (IQR: 189.6–597.2) per 100,000 people at end of 2025 (Figure 1B). This corresponds to a decrease in prevalence from 0.51% (0.44–0.65%) to 0.77% (IQR: 0.60–0.93%) over this period (Figure 2A, Scenario 1 results; Table 2).

Under both assumptions, the response since 2013 appears to have stabilised the outbreak and has prevented a substantially worse syphilis outbreak. If there was no outbreak response and the annual testing coverage remained at 2013 levels and did not increase, the estimated diagnosis rate for the previous 6 months would be 265.4 (IQR: 170.6–417.1) per 100,000 people at mid-2019 and would increase to 587.7 (IQR: 360.2–710.9) per 100,000 people by end of 2025 (Figure 1C). Without a response, infectious syphilis prevalence would potentially increase to 3.20% (IQR: 2.50–3.92%) by the end of 2025 rather than decreasing to 0.10% (IQR: 0.01–0.27%). Under the assumption that the testing coverage equals the MJSO testing coverage, we estimate the increase in testing coverage since 2013 has reduced the potential number of new syphilis infections by 44.7% (IQR: 27.2–59.7%) over 2013–2020 and predict a further reduction in new infections of 93.3% (IQR: 86.7–97.4%) over 2020–2030 (Table 2).

It is also important to be aware that the increase in testing since 2013 resulted in a higher number of notifications to mid-2019 than would have been found if testing remained at 2013 levels (see Figure 1C). However, we expect to see a decline in notifications after 2020 rather than a continual increase, as the future increase in testing (followed by treatment) leads to a reduction in infectious syphilis prevalence. Running the alternative testing coverage assumptions in our model provides results consistent with the ones described in the previous paragraphs (see appendix A5 Additional Results).

These results suggest that to stabilize the outbreak and prevent further increases the annual testing coverage should reach at least 40% and should be greater than 50% to produce declines in the number of people infected. If the testing coverage prior to mid-2019 was as low as 0.5 times the MJSO testing coverage, then we would expect to see a continuing increase in notifications. In contrast, if the MJSO testing coverage underestimates the

percentage of people tested each year then the model predicts an immediate and potentially rapid decline in notifications from mid-2019 if such testing levels were maintained (see appendix A5 Additional Results).

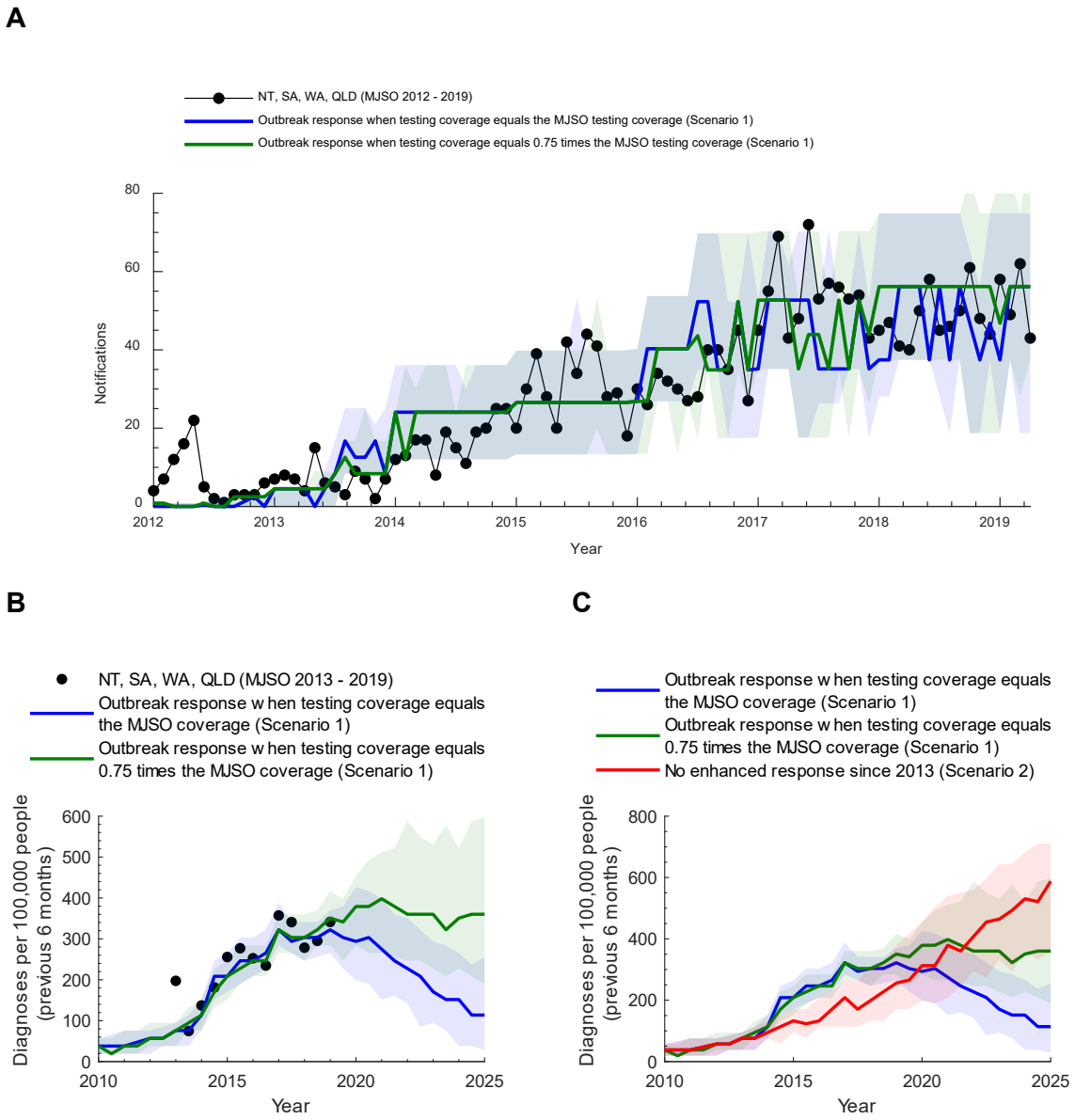

Figure 1: Estimated diagnoses from the model for the two main testing coverage assumptions compared to notifications data. (A) Estimated number of diagnoses under the current response (status-quo) scenario from the model (adjusted for population size) compared to the number of notifications in the outbreak affected areas (black points). (B) Diagnoses per 100,000 people from 2010 to 2025 under the current response (status-quo) scenario compared to the total notification rate in the outbreak affected areas (black points). The solid line and the shaded region are the median and interquartile range, respectively, from the 100 selected model runs that best fit the data. (C) Comparison of diagnoses per 100,000 people from 2010 to 2025 for the outbreak response scenario (Scenario 1) and the counterfactual (no response) scenario (Scenario 2; where the testing coverage remains at 2013 levels). The solid lines and shading are the median and interquartile range from the selected model runs, respectively.

Future impact of increases in annual syphilis testing coverage

Our modelling predicts that further increases in annual syphilis testing have the potential to rapidly reduce or possibly even eliminate infectious syphilis in the affected Indigenous populations by the 4th quarter of 2021 (Table 3).

The predicted decline in prevalence when testing coverage increases to 50% by mid-2021 (Scenario 3), under the assumption that the actual testing coverage equals 0.75 times the MJSO testing coverage, is very similar to the predicted decline in prevalence for the status-quo scenario (Scenario 1) when the testing coverage is assumed to equal the MJSO testing coverage (52% overall). Prevalence decreases from 0.77% (IQR: 0.60–0.93%) at mid-2019 to 0.14% (IQR: 0.01–0.36%) at the end of 2030. If the overall testing coverage increased from the mid-2019 value to 60% by mid-2021 (Scenario 4) then we would see similar declines in the population prevalence of infectious syphilis under each testing coverage assumption, though with slower rates of decline for lower testing coverage values at mid-2019 . Under the assumption that the MJSO testing coverage accurately reflects the actual testing coverage, the prevalence of infectious syphilis would decline to 0.01% (IQR: 0.00–0.12%) in 2025 (which is below the prevalence in 2011) and leading to virtual elimination by 2030. Similarly, if we assume the testing coverage equals 0.75 times the MJSO testing coverage the prevalence would decline to 0.14% (IQR: 0.03–0.25%) in 2025 (which is below the prevalence in 2011) also leading to virtual elimination by 2030.

Increasing testing further so that 70% of the population overall are tested each year by mid-2021 (51% regional males, 81% regional females, 54% remote males, 86% remote females; Scenario 5) is predicted to result in a large decline in syphilis prevalence by 2025 (ranging from 0.0% to 0.05%) under both testing coverage assumptions (Figure 2). Such increases in annual testing would virtually eliminate new syphilis infections by 2030 under both testing coverage assumptions (Table 2).

Slower increases in the testing coverage each year would result in similar but slower declines in prevalence. For example, under the assumption that the MJSO testing coverage reflects the actual testing coverage, increasing the testing coverage to 60% and 70% by mid-2024 is predicted to result in a decline in prevalence to 0.06% (IQR: 0.00–0.16%) and 0.01% (IQR: 0.00–0.07%), respectively, by 2025 with the potential elimination of syphilis by the end of 2026 (see appendix A5 Additional Results). Running the alternative testing coverage assumptions in our model for these scenarios produces similar results to those presented here (see appendix A5 Additional Results).

These results suggest that to achieve rapid declines in infectious syphilis across the outbreak regions, the level of testing needs to increase and be sustained at a level where greater than 60% of the overall population are tested at least once per year.

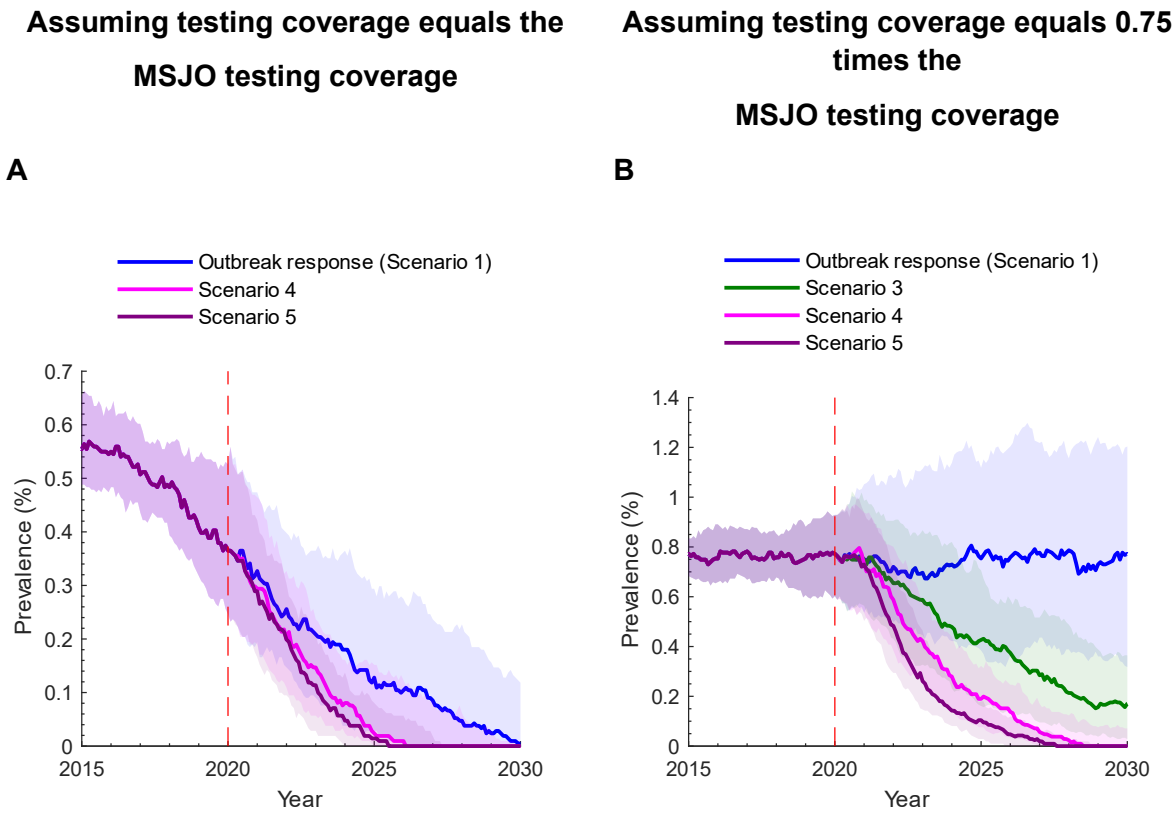

Figure 2: Change in infectious syphilis prevalence over 2015–2030 following increases in the Testing coverage each year. (A) Change in prevalence if the overall testing coverage reaches 60% and 70% by mid-2021 from a level matching the MJSO testing coverage (Scenarios 4–5). (B) Change in prevalence if the overall testing coverage reaches 50%, 60% and 70% by mid-2021 from a level equal to 0.75 times the MJSO testing coverage (Scenarios 3–5). The red dashed vertical line indicates the point in mid-2019 when each scenario begins in the model. Further results related to future increases in the testing coverage are available in appendix A5 Additional results.

Future impact of population-wide testing

The results shown in Figure 2 suggest increases in annual testing coverage can lead to a rapid decline in infectious syphilis prevalence and new infections. If annual population-wide syphilis testing over a short period was adopted in addition to increased testing, then we estimate that even quicker reductions in infectious syphilis prevalence and incidence would occur with the elimination of infectious syphilis potentially being achieved as early as 2024 (Figure 3; Table 3).

Assuming the testing coverage equals the MJSO testing coverage, if 30% of people in remote areas undergo population-wide testing once every year over a 2-year period, in addition to testing 60% of the population each year (Scenario 6), then overall syphilis prevalence would decrease to 0.01% (IQR: 0.00 – 0.12%) by 2025 (Figure 3A; Table 2). Increasing the testing coverage to 70% and reaching 60% of the remote population during annual population-wide testing (Scenario 9) would result in the elimination of infectious syphilis by 2025 (Figure 3A; Table 2). Similar results were obtained when the assumed testing coverage equals 0.75 times the MJSO testing coverage (Figure 3B; Table 3).

In all remote area population-wide testing scenarios there is an almost immediate fall in overall syphilis prevalence. Achieving these annual testing and population-wide testing

targets in remote areas over 5 years would result in only slightly slower reductions in the epidemic (as the time taken to achieve the corresponding increase in annual testing coverage is five years rather than only two; see appendix A5 Additional Results).

If population-wide testing is implemented in regional as well as remote communities, a more rapid elimination of infectious syphilis could be achieved (see appendix A5 Additional Results). However, such an intervention is likely to be less feasible than remote only population-wide testing.

When implementing population-wide testing it is important to maintain the high levels of ongoing annual syphilis testing otherwise there is a risk of a rebound in prevalence. It is also important to note that population-wide testing periods will produce a spike in diagnoses due to the detection of large numbers of infections in a short period.

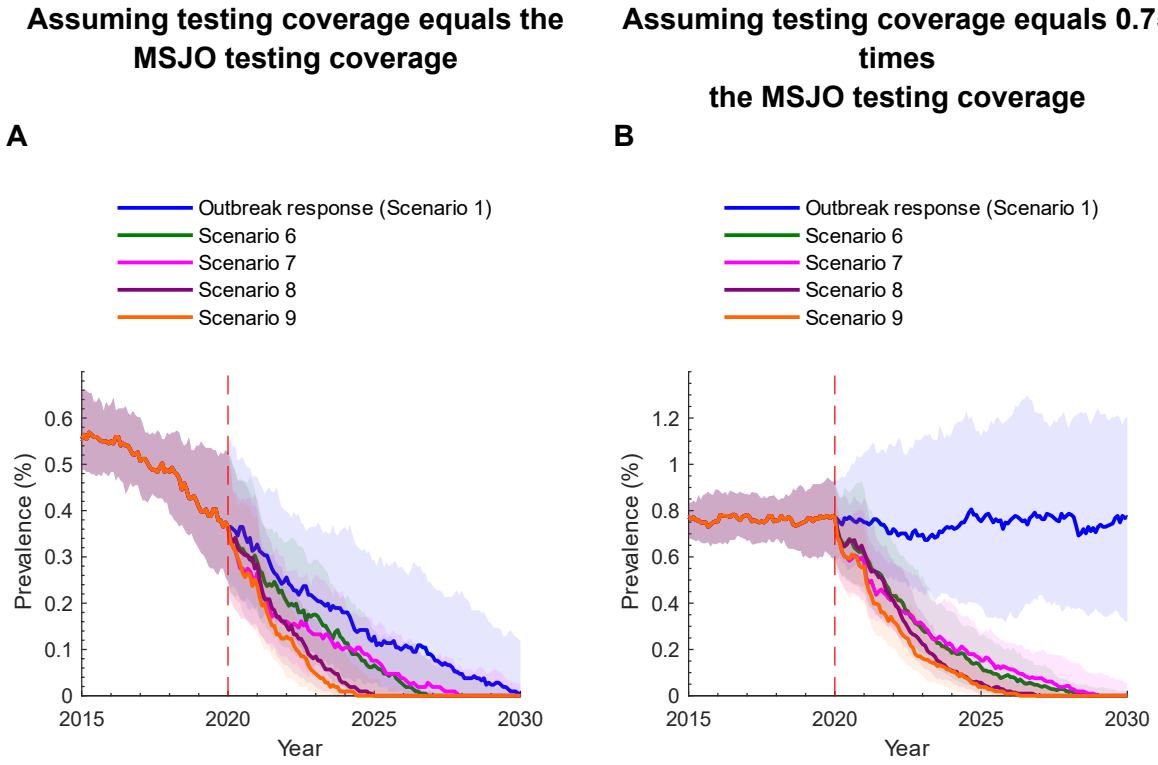

Figure 3: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 and the implementation of annual population-wide testing. Change in prevalence if overall testing coverage each year increases to 60% and 70% by mid-2021 and remote areas implement population-wide testing reaching 30% and 60% of the remote population over a six week period (Scenarios 6–9) under the assumptions the actual testing coverage equals the MJSO testing coverage prior (A) and equals 0.75 times the MJSO testing coverage (B) prior to 2019. The red dashed vertical line shows the point in mid-2019 when each scenario begins in the model. Further results related to population wide testing are available in appendix A5 Additional results.

Table 2: Change in infectious syphilis indicators over 2020–2030 for the key modelling scenarios and testing coverage assumptions. Results show the median (in bold) and the IQR for the selected model runs. The infections averted (final) column reports the difference between each scenario and the outbreak response scenario (Scenario 1; note negative percentages correspond to an increase).

Scenario	Prevalence			Annual new infections per 100,000 people			Reduction in infections over 2020–2030
	2020	2025	2030	2020	2025	2030	
Assuming testing coverage equals the MJSO Testing Coverage							
Current outbreak response and no outbreak response							
1	**0.33%** (0.24–0.45%)	**0.10%** (0.01–0.27%)	**0.00%** (0.00–0.10%)	**355** (213–502)	**104** (0–299)	**0** (0–104)	Reference scenario
2	**2.09%** (1.29–2.85%)	**3.20%** (2.50–3.92%)	**3.40%** (2.71–4.05%)	**1,678** (1,047–2,351)	**2,592** (2,019–3,152)	**2,664** (2,171–3,175)	**-93.3%** (-97.4, -86.7%)
2-year increase in annual testing coverage scenarios							
3	Not applicable						
4	**0.29%** (0.19–0.46%)	**0.01%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**327** (194–483)	**9** (0–133)	**0** (0–0)	**29.8%** (-12.4–61.2%)
5	**0.29%** (0.17–0.42%)	**0.00%** (0.00–0.06%)	**0.00%** (0.00–0.00%)	**336** (190–502)	**0** (0–76)	**0** (0–0)	**41.8%** (10.3–66.4%)
2-year population-wide testing scenarios – Remote only							
6	**0.29%** (0.18–0.41%)	**0.02%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**341** (190–488)	**24** (0–147)	**0** (0–0)	**26.9%** (-1.9–56.4%)
7	**0.27%** (0.15–0.40%)	**0.04%** (0.00–0.12%)	**0.00%** (0.00–0.01%)	**294** (161–474)	**43** (0–133)	**0** (0–5)	**33.8%** (-18.2–68.8%)
8	**0.28%** (0.15–0.43%)	**0.00%** (0.00–0.03%)	**0.00%** (0.00–0.00%)	**313** (161–488)	**0** (0–47)	**0** (0–0)	**49.9%** (13.2–73.5%)
9	**0.24%** (0.13–0.39%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**289** (166–455)	**0** (0–19)	**0** (0–0)	**57.6%** (27.7–78.4%)
Assuming testing coverage equals 0.75 times the MJSO Testing Coverage							
Current outbreak response and no outbreak response							
1	**0.75%** (0.54–1.05%)	**0.76%** (0.36–1.20%)	**0.69%** (0.33–1.22%)	**720** (517–1,028)	**716** (318–1,180)	**659** (327–1,166)	Reference scenario
2	**2.07%** (1.50–2.97%)	**3.29%** (2.76–3.93%)	**3.49%** (3.08–4.01%)	**1,692** (1,223–2,408)	**2701** (2,161–3,090)	**2,801** (2,498–3,156)	**-68.0%** (-81.6, -54.8%)

2-year increase in annual testing coverage scenarios							
3	**1.70%** (1.25 - 2.07%)	**0.74%** (0.47 - 0.97%)	**0.32%** (0.14 - 0.50%)	**1545** (1152 - 1886)	**777** (464 - 1028)	**332** (142 - 526)	**57.3%** (46.6 - 64.0%)
4	**0.73%** (0.54–0.94%)	**0.14%** (0.03–0.25%)	**0.00%** (0.00–0.04%)	**754** (526–943)	**147** (33–294)	**0** (0–33)	**60.8%** (42.9 - 73.4%)
5	**0.73%** (0.50–0.94%)	**0.05%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**749** (521–1005)	**66** (9–152)	**0** (0–0)	**69.3%** (57.1 - 78.5%)
2-year population-wide testing scenarios – Remote only							
6	**0.61%** (0.47–0.90%)	**0.08%** (0.01–0.19%)	**0.00%** (0.00–0.00%)	**645** (464–957)	**100** (0–223)	**0** (0–0)	**67.4%** (51.4–81.0%)
7	**0.58%** (0.42–0.80%)	**0.11%** (0.02–0.23%)	**0.00%** (0.00–0.02%)	**602** (455–829)	**133** (19–275)	**0** (0–19)	**68.6%** (48.6–79.0%)
8	**0.62%** (0.45–0.86%)	**0.02%** (0.00–0.07%)	**0.00%** (0.00–0.00%)	**654** (460–919)	**24** (0–100)	**0** (0–0)	**72.4%** (58.8–83.5%)
9	**0.56%** (0.40–0.73%)	**0.01%** (0.00–0.08%)	**0.00%** (0.00–0.00%)	**607** (417–853)	14 (0–90)	**0** (0–0)	**79.6%** (66.0–86.6%)

Table 3: Date when infectious syphilis prevalence returns to the level in 2011 (pre-outbreak; 0.24%) and when syphilis prevalence reaches zero (elimination) for each modelling scenario. Dates are provided by year and quarter (Q1, Q2, Q3, Q4) when median prevalence for each model scenario first achieves these levels.

	Assuming testing coverage equals the MJSO testing coverage		**Assuming testing coverage equals 0.75 times the MJSO testing coverage**	
Scenario	**Date when overall prevalence returns to pre-2011 level**	**Date when syphilis is eliminated**	**Date when overall prevalence returns to pre-2011 level**	**Date when syphilis is eliminated**
Current enhanced response and no enhanced response				
1	2022 – Q1	2030 – Q2	Not applicable	Not applicable
2	Not applicable	Not applicable	Not applicable	Not applicable
2-year increase in annual testing coverage scenarios				
3	Not applicable	Not applicable	2027– Q4	2036 – Q2
4	2021 – Q4	2028 – Q3	2024 – Q1	2028 – Q3
5	2021 – Q3	2026 – Q2	2023 – Q1	2027 – Q3
2-year population-wide testing scenarios – Remote only				
6	2021 – Q2	2026 – Q4	2023 – Q3	2028 – Q3
7	2021 – Q1	2027 – Q4	2023 – Q4	2029 – Q1
8	2021 – Q1	2025 – Q1	2022 – Q4	2026 – Q4
9	2020 – Q4	2024 – Q2	2022 – Q3	2026 – Q2

4. Comments regarding the modelling analysis

There are several aspects of the modelling, including methodological limitations, that need to be considered when interpreting our results:

1) A key variable in the model describing the response to the syphilis outbreak is the percentage of individuals who are tested for syphilis in the previous 12 months. We used the raw data provided by the MJSO for the total number of tests and the estimated resident population (ERP) for 15-24-year-olds across all regions for each six-month period prior to mid-2019 to inform this input. However, as acknowledged in the MJSO data reports, there are number of caveats and limitations which could affect the completeness and accuracy of the MJSO testing data (as described in appendix A3 MJSO Testing Coverage). To account for this uncertainty, we ran the modelling and scenario analysis multiple times under different testing assumptions to assess the robustness of our results to the assumed testing coverage used in the model. We found our results were consistent for the different assumptions with the stabilization and decline in the epidemic occurring at a similar annual testing coverage of 40% and 50%, respectively. Starting from a lower coverage in mid-2019 to reach these levels over the next two years results in a slower decline in the epidemic.
2) We calibrated the model to match the infectious syphilis notification rate since 2013 in the outbreak affected areas provided by the MJSO Working Group. These data show a rising trend to mid-2019 and then an apparent stabilisation in notifications (though there are fluctuations). Our model captures this trend up to mid-2019 under all testing assumptions but the predicted trajectory then depends on the testing coverage in mid-2019. For the two testing coverage assumptions used in this analysis the number of diagnoses either stabilises or slowly declines if testing coverage remains at the mid-2019 level. We believe these projections are reasonable for the current epidemic when considering the monthly notifications by jurisdiction. In particular, the infectious syphilis notifications in QLD peaked in June 2017 and have declined since, in line with our model projections for the overall outbreak.
3) The model assumes people are treated for syphilis within the same timeframes after diagnosis as reported for gonorrhoea and chlamydia (based on data from the TTANGO study) and that treatment is100% effective. The MJSO working group has informed us that it is likely that syphilis treatment is initiated sooner after diagnosis than for gonorrhoea and chlamydia in the outbreak affected areas, but we have no data to quantify this. We have taken a conservative approach and used the data we have available for treatment of other STIs.
4) Our scenarios only consider increases in testing for infectious syphilis and do not consider corresponding changes in risk behaviours which could occur with the parallel rollout of communication and education materials across the outbreak regions. This assumption should be considered when interpreting our results as a greater impact could occur if risk behaviours fall in conjunction with increases in testing.
5) We want to emphasize that there is uncertainty in our results, as indicated in the inter-quartile ranges and the shading in the figures, which needs to be considered.
6) There is limited information on the level of movement between communities and across remote and regional areas. The level of population movement can have an impact on our results as the prevalence of syphilis (particularly in the remote communities) is sensitive to population movement. Given the limited data, we adjusted the rate of population

movement during the calibration process to ensure the notification rate overall, and in regional and remote areas separately, reflected available data.

7) The population size and structure we used in the model reflected available data for Indigenous people living in regional and remote areas across QLD, NT, WA and SA (the jurisdictions experiencing the outbreak). The model was designed to capture the overall population characteristics and to describe the overall syphilis outbreak. We acknowledge the variation in population characteristics and epidemics across the individual affected jurisdictions, but our aims were to provide general guidance for the response and location specific factors would need to be considered when interpreting our results.
8) Our modelling evaluation was not designed to investigate the cause of the outbreak. Infectious syphilis outbreaks in Indigenous Australians have occurred in the past but have not reached the level of the current outbreak. For the purposes of our evaluation we selected simulations which matched the current outbreak but note that our modelling shows there is no guarantee the outbreak always occurs given the same conditions. Exploring this was outside the remit for the current work but could be explored in future extensions of this study.
9) Finally, the feasibility of the scenarios we ran in the model needs to be considered. Some of these scenarios represent aspirational increases in annual syphilis testing and population-wide testing. These scenarios were used to determine what is required to rapidly turn around the trajectory of the outbreak and may not be feasible in all outbreak affected areas. However, we believe some health services have already set targets of 80-90% annual testing coverage and the Nganampa Health Council has been conducting population-wide age-based testing, reaching 70% of people in the area over a six-week period, suggesting these scenarios are plausible.

5. Conclusions

We have undertaken mathematical modelling to provide insight into the infectious syphilis outbreak in Indigenous Australians. Our results suggest that the response so far has contributed to a stabilization of the outbreak and prevented a much worse epidemic but is not enough to rapidly reduce the epidemic to pre-outbreak levels. Further increases in annual syphilis testing coverage, and population-wide testing where a proportion of the population in an area is tested for syphilis during a short period once a year, are required to quickly return to pre-outbreak levels of infectious syphilis. While this may be difficult to achieve in regional settings and some remote areas, such strategies are in place in some regions and any expansion or uptake of population-wide testing would be beneficial. It is important that efforts continue to ensure current testing levels are sustained and can continue to increase.

Our results can be summarized in the following key findings:

- The outbreak response has contributed to a likely stabilisation of the outbreak and averted a substantially worse epidemic in regional and remote areas.
- The MJSO testing coverage data suggests that the percentage of people tested annually has almost doubled since 2013 overall (ranging between X and Y times across the outbreak affected region) and continued efforts will be required to maintain or increase this level of testing.

- To stabilize the outbreak requires at least 40% of the population to be tested annually for infectious syphilis.
- Testing more than 50% of the population would see declines in the epidemic but it would take more than 5 years to reduce infectious syphilis to pre-outbreak levels.
- Increasing annual testing coverage to at least 60% could reduce infectious syphilis to pre-outbreak levels within 3–5 years.
- If in addition to increasing annual testing coverage to at least 60%, annual population-wide testing reached more than 30% of the remote population over a 6-week period then infectious syphilis prevalence would return to pre-outbreak levels within the 2–4years.

6. References

1 Hui BB, Gray RT, Wilson DP, *et al.* Population movement can sustain STI prevalence in remote Australian indigenous communities. *BMC Infect Dis* 2013;**13**:188.

2 The Kirby Institute. Bloodborne viral and sexually transmissible infections in Aboriginal and Torres Strait Islander people annual surveillance Report 2018. Kirby Institute, UNSW Sydney 2018.

3 Ward J, McGregor S, Guy RJ, *et al.* STI in remote communities: improved and enhanced primary health care (STRIVE) study protocol: a cluster randomised controlled trial comparing 'usual practice' STI care to enhanced care in remote primary health care services in Australia. *BMC Infect Dis* 2013;**13**:425. doi:10.1186/1471-2334-13-425

4 Ward J, Guy RJ, Rumbold AR, *et al.* Strategies to improve control of sexually transmissible infections in remote Australian Aboriginal communities: a stepped-wedge, cluster-randomised trial. *Lancet Glob Health* 2019;**7**:e1553–63. doi:10.1016/S2214-109X(19)30411-5

5 Guy RJ, Ward J, Causer LM, *et al.* Molecular point-of-care testing for chlamydia and gonorrhoea in Indigenous Australians attending remote primary health services (TTANGO): a cluster-randomised, controlled, crossover trial. *Lancet Infect Dis* 2018;**18**:1117–26. doi:10.1016/S1473-3099(18)30429-8

7. Appendices

A1 Syphilis Model Description

Summary

An individual-based model of syphilis transmission was developed for this study. The model population consists of 10,550 heterosexual individuals spanning over 11 hypothetical locations. The first location constitutes the home for 5,550 individuals and is denoted as the regional centre. The remaining 10 locations are home to 500 individuals each and denote the remote locations for the population.

The locations are linked as a complete graph such that residents at each location are free to move away for a short period before returning home. See the sub-section “Population Mobility” below for details on how mobility is implemented in the model.

The model population includes individuals of both genders of age 16-34, with the age, infection status, physical location, sexual partner history and sexual behaviour of individuals tracked and updated daily. A detailed description of the modelled population demographics is provided in the appendix A2 Population Size and Distribution below.

Individuals can form sexual partnership while they are at the same physical location. Partnership are maintained even if one or both partners have moved away, but sexual contact can only occur if both partners are at the same location at the same time. The frequency of partner change and duration of partnership is determined by the partner acquisition rate calculated based on the number of partners an individual can have in last 12 months. See the sub-section “Sexual behaviour” below for the descriptions and parameters on how partnerships are formed in the model.

Transmission of infection can occur if a sexual act occurs between an infectious individual and a susceptible individual. Infected individuals are considered as infectious if they are in the exposed, primary, secondary, early latent or recurrent stages of syphilis. If left untreated, individuals will eventually reach tertiary syphilis and remain there until they receive treatment. See the sub-section “Syphilis Infection” below for a description of how syphilis transmission defined in this model.

Individual can be tested through annual STI testing, and treatment is scheduled if infection is found. The model allowed some time delays between testing and treatment or could missed treatment entirely. See the sub-section “Annual STI Testing” below for descriptions and parameters governing the testing and treatments of individuals in this model.

The model is calibrated against the reported syphilis notification rate from 2013 to mid-2019 [2] (as described in the main section of the report). Each simulation run starts with burn-in period of 55 years (consisting of 50 years with no infection, followed by the introduction of syphilis and then continuing for another 10 years). Five thousand simulations are then run and 100 simulations with the notification rate (define as the diagnostic rate from screening and testing from the model) with the closest match to the reported notification rate from 2013 to mid-2019 (as determined by smallest sum of squares difference) are selected as the fitted simulations for the modelling analysis. As an example Figure 4 shows a summary of the infectious syphilis notification rate from selected simulation runs against the notification rate from the surveillance report under the assumption the testing coverage prior to mid-2019 equals the MJSO coverage.

The model is programmed using Java and is available at GitHub at the following address https://github.com/bbcbh/Package_RMP.

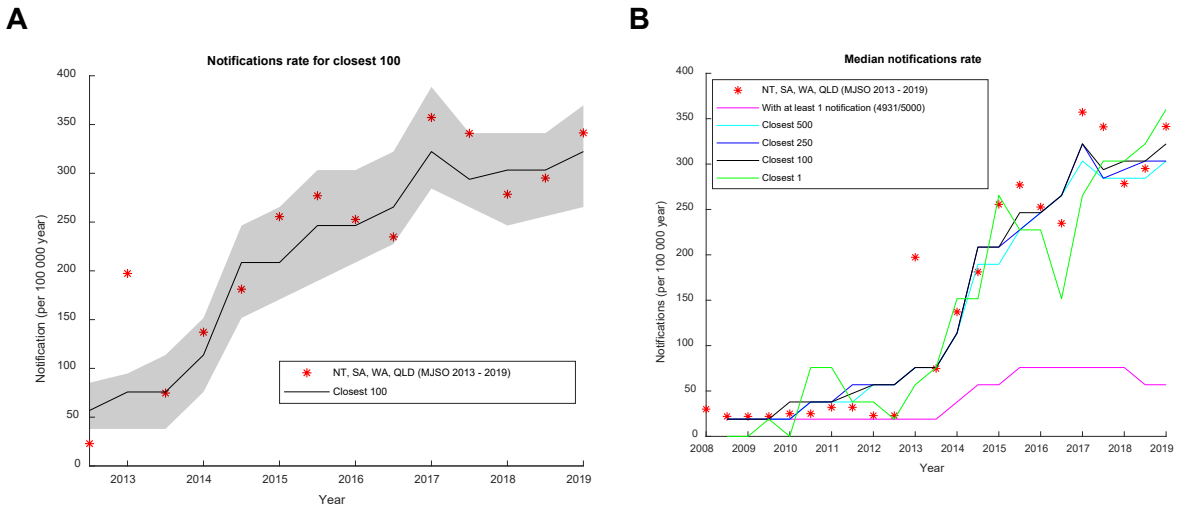

Figure 1: Example of calibrated model assuming testing coverage prior to 2019 equals the MJSO testing coverage. (A) Infectious syphilis notification rate from 2010 – 2018 (red asterisk), against the infectious syphilis notification rate from 100 model simulations (selected from 5000 separate simulations) that have the closest match with notification rate from 2013 to mid-2019. The solid black line and the shaded region are the median and the 25th-75th percentile of those 100 simulation results respectively. (B) Infectious syphilis notification rate from 2010 – 2018 (red asterisk), against the median notification rate of infectious syphilis generated by the model by selecting: all simulation runs with at least 1 notification (pink), closest 500 (cyan), closest 250 (blue) and closest 100 (black).

Population Mobility

The model includes the effects of on temporary mobility between multiple small populations. Mobility entails the movement of individuals away from their home location to a new location. Individuals stay at the new location for a predetermined period before returning to their home location. We assume individual stays away from home 2 weeks to 6 months, based on the findings from Prout [A3].

The proportion of the population away from home is based on the findings reported in the study by Biddle and Prout [A4] and is shown in Table 4. At each time step, the proportion of individuals away from home is calculated for each of the sex-age group defined in Table 4. If, for a particular sex-age group, the proportion away is less than the corresponding value listed in Table 2, then some individuals at home will be randomly selected and move away from home in the next time step, with their destination randomly selected from the 10 non-home locations. The number of individuals to move is calculated as the product of the differences between the proportion away and values listed in Table 4, and the total number of individuals within the particular gender-age group. This ensures the proportion of individuals away in the model to match closely with the data at every time step as Figure 5 shows. Note that there are more variations (i.e. more outliers, wider box etc) for the remote location due to smaller population size.

Table 4: Percentage of individual away from home, in term of gender and home location.

Location	Male Age Group				Female Age Group			
	16-19	20-24	25-29	30-34	16-19	20-24	25-29	30-34
Regional	8%	10%	9%	8%	8%	7%	6%	5%
Remote	11%	10%	9%	9%	11%	10%	9%	8%

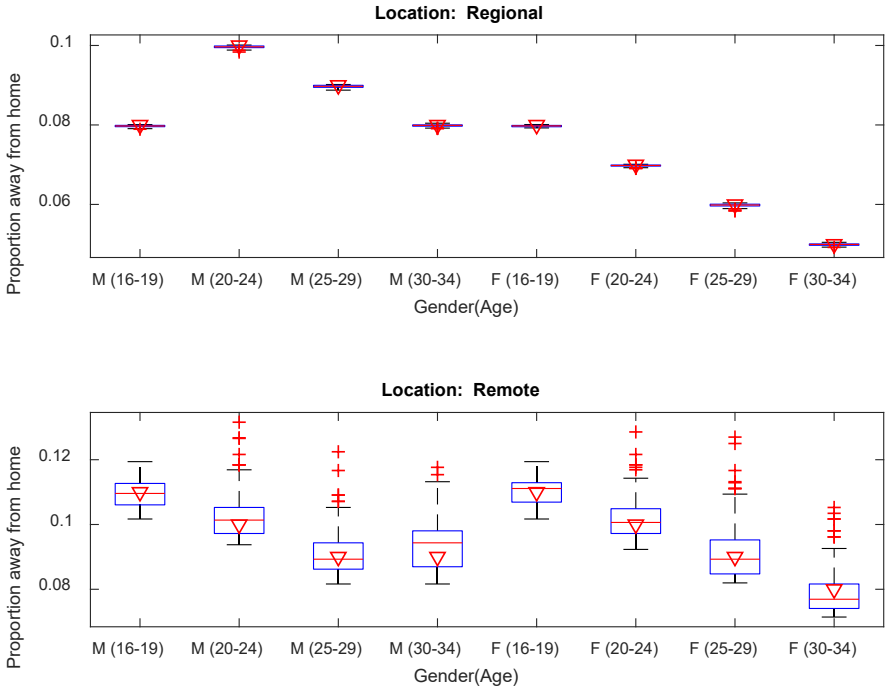

Figure 2: Proportion of population away from home. The boxplot is the result from 5000 simulation runs of the baseline model. The triangles are the age, gender and location specific proportion of population away from home from Biddle and Prout [A4] (i.e. Table 4)

Sexual behaviour

The formation and dissolution of partnership is governed by the number of partners in last 12 months report from GOANNA [5] and is listed in Table 5. The partnership status of all individuals in the modelled population is updated daily. During each one-day cycle, the number of partners in the last 12 months for each individual is calculated. The number of individuals that seek or break partnership is then calculated by comparing the differences between value from the model and from the Table 5.

For example, if we assume at a time-step, the percentage of 16-19-year-olds that have 0, 1, 2-4, and 5+ partner in last 12 months are 8%, 43%, 40%, 9%, respectively. Then there is an excess of individuals aged 16-19 years who had 1 partner in last 12 months. In order to ensure the model matches with data, some of them need to seek another partner (at a

probability of $\frac{(42-40)+(9-9)}{3} = \frac{2}{3}$) while the rest need to break-up from a current partner (at probability $\frac{9-8}{3} = \frac{1}{3}$). In this example, the number of individuals that seek or break-up a partnership will be 3% of the total number of individuals aged 16-19 years. That number of individuals is then randomly selected from those who had 1 partner in last 12 months, and the selected individuals then seek another partner or break-up a partnership according to probability calculated above. This ensures the partner seeking behaviour in the model closely matches the data in Figure 6.

Sexual acts (required for transmission of infection) occur between two individuals within an existing partnership at the same physical location. In the model, the frequency of acts is 1.4 per week, based on the number of sexual acts per week reported in the Australian Study of Health and Relationships [A6]. The condom usage is 0.54 per acts as reported in GONNA [A5].

Table 5: The relationship between age and the number of partners an individual has in last 12 months. The percentage represents the proportion of individuals within age group (i.e. columns) that have specified number of partners in last 12 months.

Number of partners in last 12 months	**Age**			
	16-19	**20-24**	**25-29**	**30-34***
0	9%	7%	9%	9%
1	40%	47%	55%	62%
2-4	42%	38%	32%	27%
5+	9%	8%	4%	2%

* Since the upper age limit for GOANNA is 30, we estimate the number of partners from last 12 months for the 30-34 age group by extrapolating a linear curve across the three age groups.

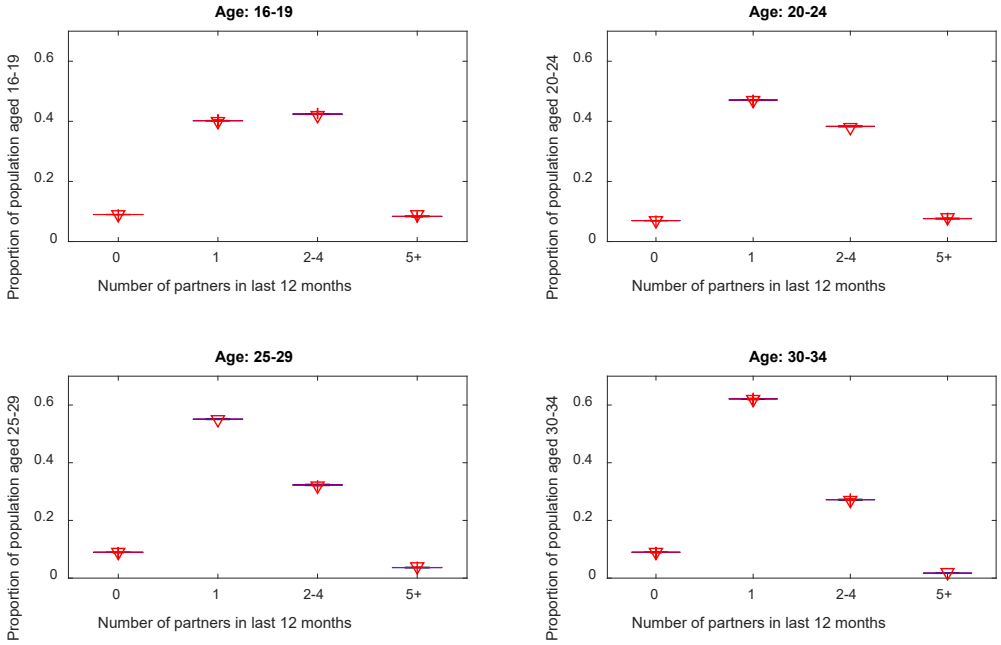

Figure 3: The age specific distribution on the number of partners an individual has in last 12 months. The boxplot is the result from 100 simulation runs of the baseline model. The triangles are the data from GOANNA (see Table 3).

Sexual behaviour of travellers

The model assumes some travellers with an existing partnership in their home location can have sexual contact with non-partners while away from home. While this is a fair assumption, reliable data on this factor is unavailable (and possibly never available). In the model we assume that, on top of the normal partner seeking pathway described above, some travellers can seek one-off sexual contacts (i.e. no partnership formed and only engage sex acts for one day) while away from home, but only with individuals at the same location who are also travellers or are also seeking partners at the same time. Previous modelling calibrations of the model to gonorrhoea and chlamydia data suggests that if 53%, 18%, 5% and 2% of travellers of age 16-19, 20-24, 25-29 and 30-34 respectively engage in sex outside their primary partnership, then the prevalence of chlamydia and gonorrhoea is around the same level as those found in the STRIVE baseline prevalence survey [7]. These same percentages are used in the current syphilis model.

Syphilis Infection

The natural history of syphilis is assumed to be same as a previous model on syphilis in MSM population [A8]. Infected individuals are considered as infectious if they are in the exposed, primary, secondary, early latent or recurrent stages of syphilis. If left untreated, individuals will eventually reach tertiary syphilis and remain there until they receive treatment. Figure 7 is the schematic diagram showing the stages and disease progression of syphilis as described in the model, and the infection parameters used in the model is listed in Table 9.

When a sexual act occurs between an infectious individual and a susceptible individual, a uniform random number (range [0,1]) is generated, and transmission of infection to the susceptible individual will occur if that number is less than the transmission probability

assigned for the simulation. The probability of developing symptoms is assigned by similar process. The duration of infection stages is sample from the uniform distributions with range as specified in Table 9, and is assigned on a per-infection basis.

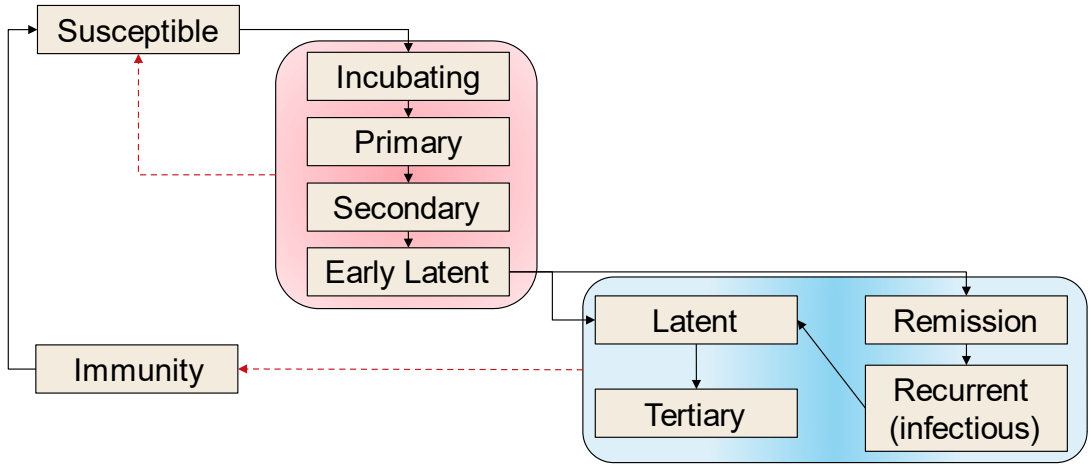

Figure 4: Schematic diagram of stages and disease progression of syphilis in the model. (based on [A8], figure 1).

Table 6: Parameters related to syphilis infection

Parameters	**Values**	**Source**
Duration of incubation period	21 – 28 days	[A8]
Duration of primary syphilis	45 – 60 days	
Duration of secondary syphilis	100 - 140 days	
Duration of early latent period*	132 - 554 days	
Duration of latent period	15 years	
Duration of remission	6 months	
Duration of recurrent infection (infectious)	90 days	
Duration of immunity from treatment	5 years	
Transmission probability per act**		
Male to female	0.0525	Calibrated
Female to male	0.0430	Assume to be 82% of transmission probability from male to female, based on the ratio from Johnson et al. [A9]

Percentage of syphilis cases that recur after infectious syphilis	25%	[A8]

* Total duration of infectiousness, which comprise of incubation, primary, secondary and early latent period, is believed to be 1-2 years.
** It is assumed the transmission probability is halved if the infected.

Annual Syphilis Testing

Prior enhanced response (prior to mid-2013)

Annual testing coverage – remote

For remote communities, it is assumed assume annual STI testing of individuals of age 16-34 are carried out in the population. The STI testing coverage varies according to gender and age and are based on baseline testing coverage from the STRIVE study and are listed in Table 10.

Table 7: Annual STI testing coverage for remote locations prior to outbreak response at mid-2013.

Male Age Group Testing Coverage		**Female Age Group Testing Coverage**	
16-19	13%	16-19	26%
20-24	14%	20-24	24%
25-30	23%	25-30	11%
30-34	11%	30-34	19%

Annual testing coverage – regional

Age and sex specific testing coverage data is not available from the GOANNA study or other sources. In this model, STI testing coverage in regional areas is assumed to have the same pattern as remote, but the values are adjusted by the overall testing coverage in GOANNA. In GOANNA, 44% surveyed in regional centres are tested in the last 12 months, compared to 48% surveyed in remote communities. Therefore, in this model we assumed the testing coverage for the regional centre is $\frac{0.44}{0.48} = 0.917$ of the coverage of residents in the remote communities. E.g. the testing coverage of 16-19-year-old males who reside in the regional centre will have a testing coverage of $0.13 \times \frac{0.44}{0.48} = 0.12$.

Post enhance response (after mid-2013)

As described in the main report we calculated an unadjusted annual testing coverage using the testing and estimated resident population (ERP) reported by the MJSO. As described in appendix A3 MJSO Testing Coverage below this unadjusted testing coverage for 15–24-year-olds in the outbreak affected regions could be an under- or over-estimate of the percentage of individuals tested each year. Due to this uncertainty we conducted our modelling analysis with different levels of testing coverage over 2013–2019. We also adjusted the coverage in 15–24-year-olds to reflect the likely testing coverage in 15–34-year-

olds used in the model. In this section we describe the adjustments to the 15–24-year-old testing coverage under the assumption the MJSO testing coverage data accurately reflects the percentage of people in this age group tested each year. The other testing coverage assumptions run in the model are obtained by multiplying the testing coverages described below by the same factor.

Since the start of the unadjusted annual testing coverage areas has increased substantially from 30.1% in the previous 12 months in 2011 to 56.0% in the previous 12 months by mid-2019 in 15-24-year-olds as shown Table 11.

Table 8: Syphilis testing coverage for 15-24-year-olds from mid-2013 to mid-2019, as supplied by MJSO.

Year	**End-2013**	**2014**		**2015**		**2016**		**2017**		**2018**		**Mid-2019**
Testing coverage	35%	34%	36%	40%	41%	47%	46%	48%	49%	52%	52%	56%

As the annual testing coverage reported by the MSJO working group is for 15–24-year-olds, we set the sex-age specific coverage used in the model such that the coverage for all 15–24-year-olds in the remote communities in the model is the same as Table 11, while the coverage for the other sex, age, and location specific groups was assumed to have the same relative difference in testing coverage as the assumed coverage prior to 2013 from the STRIVE study. The testing coverage use in the model prior to mid-2019 is shown in Table 12.

Table 9: Syphilis testing coverage used in the model from mid-2013 to 2018

Year	**End-2013**	**2014**		**2015**		**2016**		**2017**		**2018**		**Mid-2019**
Annual testing coverage for remote communities (%)												
Male 16-19	24	23	25	27	28	32	31	33	33	35	34	38
Male 20-24	26	25	27	29	30	35	34	35	36	38	38	41
Male 25-30	20	20	21	23	24	27	26	28	28	30	30	32
Male 30-34	20	20	21	23	24	27	26	28	28	30	30	32
Female 16-19	48	46	49	55	56	64	62	66	66	71	70	76

Female 20-24	44	43	45	51	52	59	58	61	61	65	65	70
Female 25-30	42	41	44	48	50	57	55	58	59	63	62	67
Female 30-34	35	34	36	40	41	47	46	48	48	52	51	56
Annual testing coverage for regional centre (%)												
Male 16-19	22	21	23	25	26	29	29	30	30	32	32	35
Male 20-24	23	23	24	27	28	32	31	32	33	35	35	38
Male 25-30	18	18	19	21	22	25	24	25	26	27	27	29
Male 30-34	18	18	19	21	22	25	24	25	26	27	27	29
Female 16-19	44	42	45	50	51	59	57	60	61	65	64	70
Female 20-24	40	39	42	46	47	54	53	55	56	60	59	64
Female 25-30	39	37	40	44	46	52	51	53	54	57	57	62
Female 30-34	32	31	33	37	38	43	42	44	44	47	47	51

Treatment sensitivity and delay

Table 13 listed other input parameters related to the sexual behaviour in the modelled population. It is assumed that treatment will be dictated by the location where the test is carried out. For example, if an individual tested positive at home location and is scheduled to be treated 7 days later but was not at home at that time, then treatment will not occur for that individual.

Table 10: Parameters related to testing

Parameters	Value	Source
Test sensitivity	0.98	Assumption
Treatment delay* (Remote)		
None	27.4%	TTANGO**
2 days or less	30.1%	
7 days or less	47.2%	
4 months or less	85.7%	
Treatment delay (Regional)	90% treated within 7 days	Assumption

* It is assumed the patient will not be treated if that patient has not received treatment after 4 months.
** Personal communication with Louise Causer (investigator on the TTANGO study).

Additional References

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A5. Ward, J., et al., Sexual Health and relationships in young Aboriginal and Torres Strait Islander people: Results from the fi rst national study assessing knowledge, risk practices and health service use in relation to sexually transmitted infections and blood borne viruses. 2014.

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A8. National Centre in HIV Epidemiology and Clinical Research, Phase A of the National Gay Men's Syphilis Action Plan: Modelling evidence and research on acceptability of interventions for controlling syphilis in Australia. 2009, National Centre in HIV Epidemiology and Clinical Research: Sydney.

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A2 Population Demographics

The model aims to represent the overall Indigenous population across the regions affected by the syphilis epidemic. From the Australian Bureau of Statistics (ABS) we obtained the population size estimates for Indigenous Australians living in NT, QLD, SA, and WA by region (Series 3238.0 - Estimates and Projections, Aboriginal and Torres Strait Islander Australians, 2001 to 2026 which is available from: https://www.abs.gov.au/ausstats/abs@.nsf/mf/3238.0.55.001). From these estimates we calculated the percentages in each region in each jurisdiction and overall for the four states as shown in Table 4.

Based on this data we have modified the population composition in our model so the regional to remote and very remote population proportion matches the 1.11 to 1 ratio for the population across NT, QLD, SA, and WA (as shown in Table 1). Specifically, the model population will change to consist of one regional centre with 5500 Indigenous people and 10 remote communities with 500 people each giving a total population of 10,500. This population is substantially smaller than our previous model, but the updated model still reproduces the syphilis outbreak and the smaller population size allows us to more efficiently generate results.

We acknowledge the variation in the regional to remote ratio across the four jurisdictions but to capture this change in demographics would require a model with jurisdictional level population groupings. Such a model would be a substantial extension of the current model and we would not be able to produce results for several months. We propose this update to the current model to better represent the Indigenous population affected by the syphilis epidemic to produce results in the next few weeks. In future we can further refine the population structure to better capture jurisdictional variations if request by the MJSO working group.

Table 11: Percentage of Indigenous population in jurisdictions experiencing the syphilis outbreak by regional classification. Calculated from ABS data for 2016.

Percentage of population in …	NT	QLD	SA	WA	NT, QLD, SA, WA only	Australia overall
Major Cities	0	36.51	54.73	42.46	33.18	39.55
Regional	22.63	47.72	30.18	20.27	35.16	41.65
Remote	20.98	5.61	3.95	12.63	9.81	6.32
Very Remote	56.40	10.17	11.14	24.64	21.85	12.49
K = Regional / (Remote + Very Remote)	0.29	3.02	2.00	0.54	1.11	2.21

The population distribution for each sex and age group is based on the estimated population size of Aboriginal and Torres Strait Islander Australians living in remote regions at 2010 from the ABS and is shown in Table 5. This population distribution is maintained throughout the

simulation runs, with aged-out individuals replaced by a new individual of the same sex and aged 15 years.

Table 12: The population age distribution used in the model.

Gender/age group	Percentage of population (%)
Male, 15-19	14.3
Male, 20-24	13.6
Male, 25-29	12.0
Male, 30-34	10.0
Female, 15-19	13.5
Female, 20-24	13.7
Female, 25-29	12.4
Female, 30-34	10.4

A3 MJSO Testing Coverage

To conduct our modelling analysis, we initially used the raw data provided by the MJSO for the total number of tests and the estimated resident population (ERP) for 15-24-year-olds across all regions for each six-month period over 2013-2018 to estimate a crude annual testing coverage.

The annualised testing coverage at the end of 2018 from the data provided to us by the MJSO was 50% (obtained by dividing the number of tests by 6-monthly ERP for the final 6 months of 2018) for 15-24-year-olds, with variation by region. However, feedback from the MJSO working group and other stakeholders suggested that this crude testing coverage could overestimate the proportion of individuals tested for syphilis each year in the outbreak affected areas. For example, for two outbreak regions in the MJSO report, testing coverage produced from other sources (an individual clinic, TTANGO2) shows large differences.

As our scenarios and results are based on this testing coverage, we were concerned this could affect any recommendations based on the modelling. We conducted a review of the reported MJSO data to assess the potential for the reported MJSO testing coverage to over- or under-estimation of the percentage of individuals tested each year.

The 6-monthly testing coverage reported by the MJSO uses routinely available data every 6 months, and thus is very useful and valuable as it provides a consistent measure for highlighting the trends and variations in syphilis testing across the outbreak regions. However, as acknowledged in the MJSO data reports, there are number of caveats and limitations which could affect the completeness and accuracy of the data. Below we explore the potential effects of these caveats and limitations, to determine what level of testing coverage should be included in the mathematical model for this analysis.

Potential factors affecting testing coverage

<u>Factors affecting total number of individuals tested (numerator)</u>

- The MSJO data report states that tests for QLD are under reported because only tests from public laboratory data are included. When adjusting the reported tests to account for the contribution of public laboratories in each region we estimate the number of tests in QLD is underestimated by around 30%. In 2018, QLD contributed 36% of all tests this could contribute to an approximate 10% underestimate in tests overall.
- A proportion of individuals would have 2 tests in a year. In the STRIVE study, it was reported that of 10,559 individuals aged ≥16 years with an initial negative CT/NG test (median age=25 years), 20.3% had a re-test in 9-15 months. If we assume that syphilis testing occurs concurrently with CT/NG testing, then this could contribute to an 20% overestimation in tests.
- According to syphilis testing guidelines pregnant women in outbreak areas should now be tested 5 times during pregnancy and after birth (though this has changed from 3 tests in earlier guidelines). Using data from the ABS for the year 2017 we estimate 8.56% of all Indigenous women aged 15-24 years gave birth. While adherence to guidelines is unlikely to be 100% and the national birth percentage might not represent women in outbreak affected years, this could contribute to an approximate 13% overestimation in tests in females and 8% overall.
- At most Indigenous health services, a substantial proportion of clients are transient and not residents. In some clinics in the STRIVE study, about 25-35% of tests were conducted in people outside of the region. From personal communication some clinics in affected areas report even higher percentages of transient clients being tested for

syphilis. As we summed all tests conducted in the outbreak regions, tests conducted in visitors from other outbreak areas do not affect our calculations. An unknown but potentially significant proportion of visitors could come from outside the outbreak regions (contributing to its spread) resulting in an overestimate in the number of tests within the outbreak areas. On the other hand, people resident in the outbreak areas could have been tested for syphilis in clinics outside the outbreak areas counteracting this effect.

Factors affecting the total number of individuals in an area (denominator)

- The ERP estimates for QLD and WA are from ABS data. However, as acknowledged by the ABS, estimates from census data result in an undercount of Indigenous people living in an area. While the ABS adjusts for undercounting using a Post Enumeration Survey, "The extent of undercoverage of Aboriginal and Torres Strait Islander Australians in the 2016 Census and the relatively small sample size of the Post Enumeration Survey to adjust for that undercoverage means the estimates should be interpreted with a degree of caution". This could contribute to an underestimate of the resident population and hence an overestimate of the proportion of individuals tested each year.
- Conversely, in the MJSO data report the ERP denominator used in WA includes both the estimated Aboriginal and Torres Strait Islander and non-Aboriginal and Torres Strait Islander Resident Population, which could contribute to an overestimate of the resident population and hence an underestimate of the proportion of individuals tested each year.

Calculations quantifying the potential effects these factors

- Effect of repeat tests during pregnancy:
    - From the ABS, total number of Indigenous women aged 15 to 24 living in Australia (2017) = 76,990 and total number of Indigenous women aged 15 to 24 who gave birth living in Australia (2017) = 6,591
        - 8.56% of Indigenous women aged 15-24 years gave birth living in Australia in 2017.
    - Syphilis testing guidelines for pregnant women recommend 5 tests during pregnancy, as adherence will not be 100%, we assume each pregnant woman receives 2.5 syphilis tests on average during pregnancy.
    - This means the total number of tests in females overestimates the number of females tested by a factor of (0.086*2.5 + 0.914) = 1.129
    - From the STRIVE study the testing coverage for women was 1.9 times that of men aged 15-24 years old.
    - Total tests = tests in males + test in females = males tested + 1.129*females tested = tests in males + 1.9* tests in males = males tested + 1.129*1.9*males tested = p*Total people tested
        - Here we are assuming no duplicate tests which are accounted for below
    - Rearranging these equations gives p = (1.9 + 1)/ (1.129*1.9+1) = 0.922
    - This suggests overall number of tests reported is inflated by around 7-8% due to repeat testing in pregnant women.
- Effect of under reporting of tests in QLD:
    - 36.5% of all syphilis tests in outbreak areas occurred in QLD.
    - In the four regions number of tests and percentage reported through public labs (from the MJSO data report):
        - Cairns and Hinterland: 272 tests, 44% reported
        - Townsville HHSs: 717 tests, 63% reported
        - North West: 480 tests, 84% reported
        - Torres and Cape HHS: 1352 tests, 99% reported

    - Overall this means the number of tests in QLD was underreported by a factor:
        - (272/0.44 + 717/0.63 + 480/0.84 + 1352/0.99)/ (272 + 717 + 480 + 1352) = 1.309
        - A 30.9% underestimate
    - The overall effect of this on the overall number of tests is then given by a factor:
        - 1.309*0.365+0.645 = 1.123
        - A 12.3% underestimate
- Effect of repeat testing:
    - Based on the STRIVE study described above repeat testing could contribute to a 20% overestimate in tests
    - A factor of 0.8
- Effect of non-resident or transient visitors:
    - Based on the STRIVE study were 25-35% of tests were conducted in people outside of the region, we assume around half of these or 15% overall of tests are in non-visitors.
    - A factor of 0.85
- Combining all these together means that number of individuals tested less than the total number of tests conducted the number of tests could overestimate the number of individuals tested by a factor of 1/0.704 = 1.42:
    - 0.922*1.123*0.8*0.85 = 0.704
    - This effectively reduces the coverage (assuming no change in ERP) at the end of 2018 to 48.79%*0.704 = 34.4%.

Potential effect on the overall testing coverage estimates

By taking all these potential caveats into consideration, we have tried to calculate what difference these caveats/limitations in testing could potentially make. We were unable to determine the potential changes in the ERP denominator, so we have assumed it is unchanged. From our very preliminary calculations, we conservatively estimate that the number of unique individuals tested is approximately 70% of the total number of tests in relative terms), see calculations below.

This means the percentage of people tested for syphilis each year in outbreak affected areas may in fact be about 35% in 15-24-year-olds in the final 6-months of 2018, compared to the 50% calculated using total tests and the 6-monthly ERP estimates.

Summary data from a specific region affected by the outbreak showing the number of individuals tested in each 6-month period is ~25% less than the number of tests overall (which is similar to the estimate from our preliminary calculations).

Assume testing coverage for the modelling analysis

Given this discrepancy between the reported MJSO testing coverage and the actual testing coverage used in the modelling, the uncertainty in the size of this discrepancy, and the variation in the reported MJSO testing coverage across the outbreak affected regions we ran complete modelling analyses under four testing coverage assumptions:

1. Actual testing coverage equals the reported MJSO testing coverage
2. Actual testing coverage is equal to 0.75 times the reported MJSO testing coverage
3. Actual testing coverage is equal to 0.5 times the reported MJSO testing coverage
4. Actual testing coverage is equal to 1.25 times the reported MJSO testing coverage

We re-calibrated the model and ran the scenarios listed in the appendix A4 Full scenario list under each of these testing coverage assumptions.

A4 Full Scenario List

This appendix provides a table consisting of a full list of all the scenarios run in the model under each of the testing coverage assumptions. Each scenario was run from mid-2019 starting from the assumed testing coverage mid-2019.

Scenario Table

#	Scenario	Description
1	Outbreak response	Assume annual testing coverage remains at mid-2019 levels across all populations and regions
2	Counterfactual no outbreak response with annual proportion tested remaining at 2013 levels	Assume there was no increase in annual testing coverage since 2013 when the outbreak started spreading to multiple jurisdictions.
Key scenarios		
3	Increase annual testing coverage to 50%	Increase annual testing coverage from current levels (at mid-2019) to 50% across all populations and regions over 2 years. **Only run in the model when the assumed testing coverage mid-2019 is less than 50% (e.g. for the testing coverage equals 0.75 times the MJSO testing coverage).**
4	Increase annual testing coverage to 60%	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions over 2 years.
5	Increase annual testing coverage to 70%	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions over 2 years.
6	Increase annual testing coverage to 60% and undertake annual population-wide testing of 30% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 2 years (as in scenario 4). In addition, undertake population-wide testing in remote areas each year for 2 years (where 30% of the population is tested in 6 weeks).
7	Increase annual testing coverage to 60% and undertake annual population-wide testing of 60% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 2 years (as in scenario 4. In addition, undertake population-wide testing in remote areas each year for 2 years (where 60% of the population is tested in 6 weeks).
8	Increase annual testing coverage to 70% and	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 2

	undertake annual population-wide testing of 30% of the population in remote locations	years (as in scenario 5. In addition, undertake population-wide testing in remote areas each year for 2 years (where 30% of the population is tested in 6 weeks).
9	Increase annual testing coverage to 70% and undertake annual population-wide testing of 60% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 2 years (as in scenario 5. In addition, undertake population-wide testing in remote areas each year for 2 years (where 60% of the population is tested in 6 weeks).
Additional scenarios with 2-year scale-up		
10	Increase annual testing coverage in males to equal females and increase to 60%	Increase annual testing coverage in males from current levels (at mid-2019) to match the female testing coverage and increase to 60% across all regions over 2 years.
11	Increase annual testing coverage in males to equal females and increase to 70%	Increase annual testing coverage in males from current levels (at mid-2019) to match the female testing coverage and increase to 70% across all regions over 2 years.
12	Increase annual testing coverage to 60% and undertake annual population-wide testing of 30% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 2 years (as in scenario 4). In addition, undertake population-wide testing in all areas for each year 2 years (where 30% of the population is tested in 6 weeks).
13	Increase annual testing coverage to 60% and undertake annual population-wide testing of 60% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 2 years (as in scenario 4). In addition, undertake population-wide testing in all areas each year for 2 years (where 60% of the population is tested in 6 weeks).
14	Increase annual testing coverage to 70% and undertake annual population-wide testing of 30% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 2 years (as in scenario 5). In addition, undertake population-wide testing in all areas each year for 2 years (where 30% of the population is tested in 6 weeks).
15	Increase annual testing coverage to 70% and	Increase annual percentage tested from current levels (at mid-2019) to 70% across all populations and regions in 2

	undertake annual population-wide testing of 60% of the whole population	years (as in scenario 5). In addition, undertake population-wide testing in all areas each year for 2 years (where 60% of the population is tested in 6 weeks).
Scenarios with 5-year scale up		
16	Increase annual testing coverage to 60%	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions over 5 years.
17	Increase annual testing coverage to 70%	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions over 5 years.
18	Increase annual testing coverage in males to equal females and increase to 60%	Increase annual testing coverage in males from current levels (at mid-2019) to match the female testing coverage and increase to 60% across all regions over 5 years.
19	Increase annual testing coverage in males to equal females and increase to 70%	Increase annual testing coverage in males from current levels (at mid-2019) to match the female testing coverage and increase to 70% across all regions over 5 years.
20	Increase annual testing coverage to 60% and undertake annual population-wide testing of 30% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 5 years (as in scenario 3). In addition, undertake population-wide testing in remote areas each year for 5 years (where 30% of the population is tested in 6 weeks).
21	Increase annual testing coverage to 60% and undertake annual population-wide testing of 60% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 5 years (as in scenario 3). In addition, undertake population-wide testing in remote areas each year for 5 years (where 60% of the population is tested in 6 weeks).
22	Increase annual testing coverage to 70% and undertake annual population-wide testing of 30% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 5 years (as in scenario 4). In addition, undertake population-wide testing in remote areas each year for 5 years (where 30% of the population is tested in 6 weeks).

23	Increase annual testing coverage to 70% and undertake annual population-wide testing of 60% of the population in remote locations	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 5 years (as in scenario 16). In addition, undertake population-wide testing in remote areas each year for 5 years (where 60% of the population is tested in 6 weeks).
24	Increase annual testing coverage to 60% and undertake annual population-wide testing of 30% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 5 years (as in scenario 16). In addition, undertake population-wide testing in all areas for each year 5 years (where 30% of the population is tested in 6 weeks).
25	Increase annual testing coverage to 60% and undertake annual population-wide testing of 60% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 60% across all populations and regions in 5 years (as in scenario 17). In addition, undertake population-wide testing in all areas each year for 5 years (where 60% of the population is tested in 6 weeks).
26	Increase annual testing coverage to 70% and undertake annual population-wide testing of 30% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 5 years (as in scenario 17). In addition, undertake population-wide testing in all areas each year for 5 years (where 30% of the population is tested in 6 weeks).
27	Increase annual testing coverage to 70% and undertake annual population-wide testing of 60% of the whole population	Increase annual testing coverage from current levels (at mid-2019) to 70% across all populations and regions in 5 years (as in scenario 4). In addition, undertake population-wide testing in all areas each year for 5 years (where 60% of the population is tested in 6 weeks).

A5 Additional Results

This appendix provides additional results to the those presented in the main report. Summary figures and tables of the results are provided for each of the testing coverage assumptions listed at the end of appendix A3 MJSO Testing Coverage for the scenarios listed in appendix A4 Full Scenario List.

Additional results for the assumption testing coverage equals the MJSO testing coverage

Results for the key scenarios presented in the main report are presented here for comparison purposes.

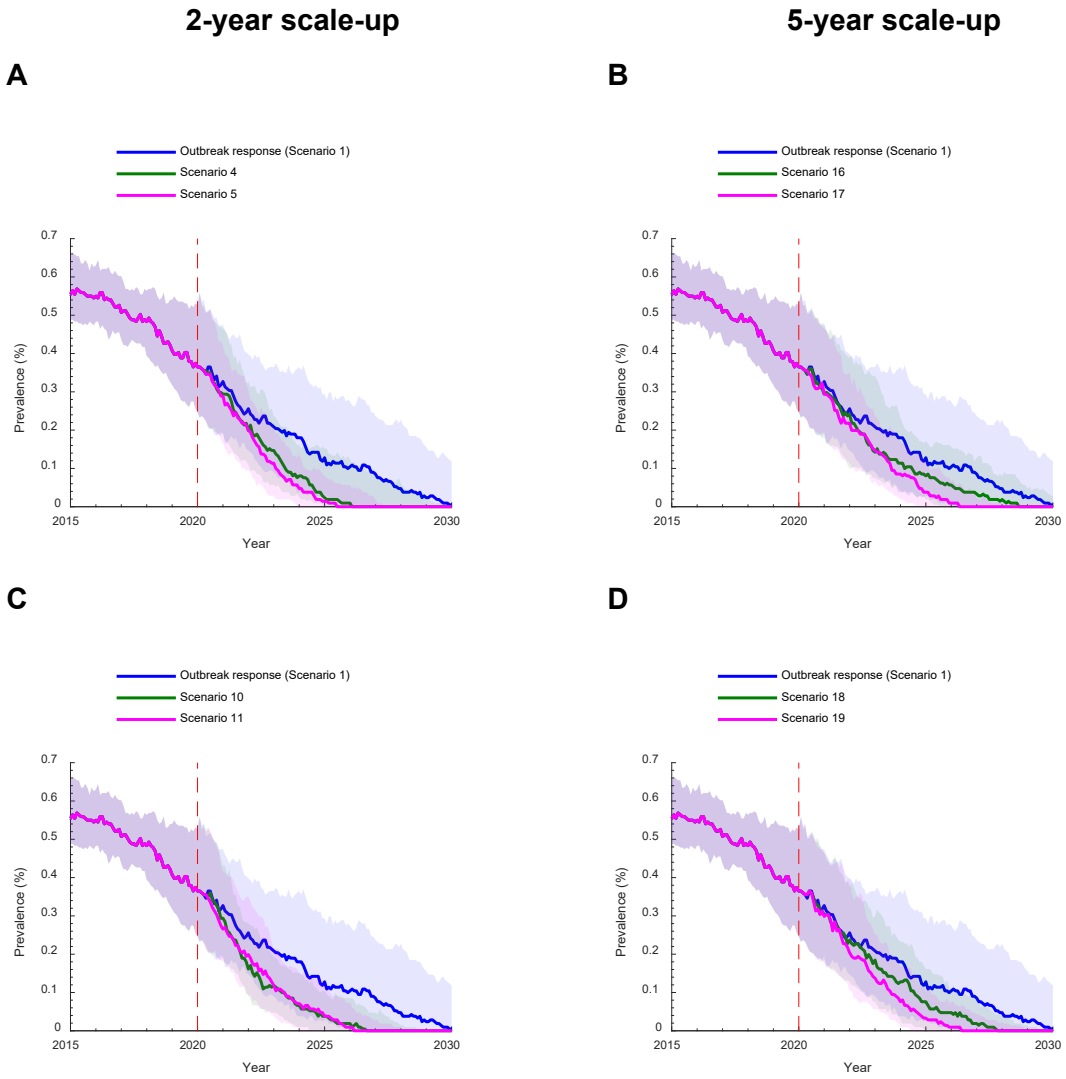

Figure 5: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 assuming testing coverage equals MJSO testing coverage. (A) and (B) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively (Scenarios 4–5 and 16–17). (C) and (D) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively, with testing coverage for males increasing to match the female testing coverage over the same period (Scenarios 10-11 and 18–19). The red dashed vertical line indicates the point in mid-2019 when each scenario begins in the model.

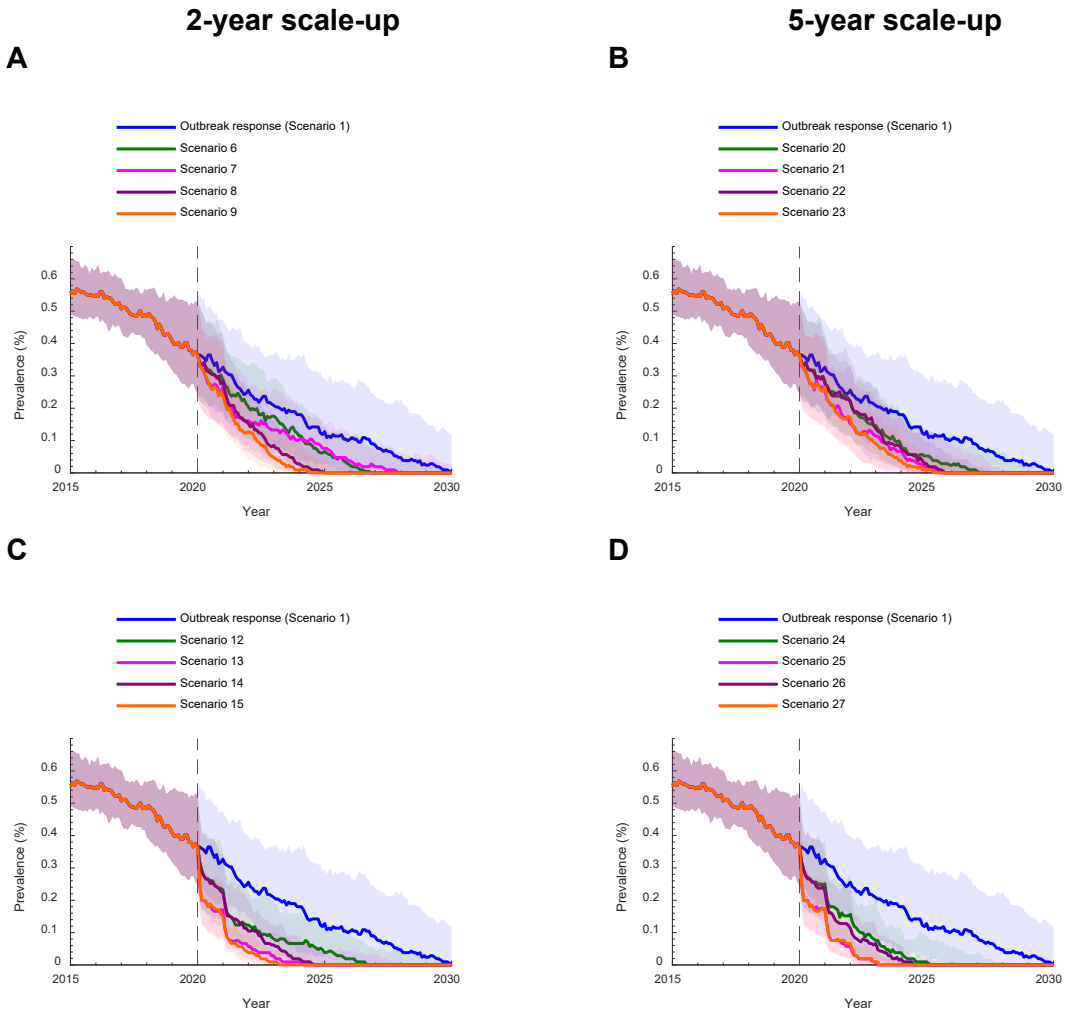

Figure 6: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 and the implementation of annual population-wide testing assuming testing coverage equals MJSO testing coverage. (A) and (B) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively, and remote areas implement population-wide testing reaching 30% and 60% of the remote population over a six week period (Scenarios 6–9 and 20–23). (C) and (D) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2024 and mid-2021, respectively, and population-wide testing is implemented across the population reaching 30% and 60% of the overall population over a six week period (Scenarios 12–15 and 24–27). The red dashed vertical line shows the point in mid-2019 when each scenario begins in the model.

Table 13: Change in infectious syphilis indicators over 2020–2030 for each modelling scenario assuming testing coverage equals the MJSO testing coverage. Results show the median (in bold) and the IQR for the selected model runs. The infections averted (final) column reports the difference between each scenario and the enhanced response scenario (Scenario 1; note negative percentages correspond to an increase).

Scenario	Prevalence			Annual new infections per 100,000 people			Reduction in infections over 2019–2030
	2020	2025	2030	2020	2025	2030	
Current outbreak response and no outbreak response							
1	**0.33%** (0.24–0.45%)	**0.10%** (0.01–0.27%)	**0.00%** (0.00–0.10%)	**355** (213–502)	**104** (0–299)	**0** (0–104)	Reference scenario
2	**2.09%** (1.29–2.85%)	**3.20%** (2.50–3.92%)	**3.40%** (2.71–4.05%)	**1,678** (1,047–2,351)	**2,592** (2,019–3,152)	**2,664** (2,171–3,175)	**-93.3%** (-97.4, -86.7%)
2-year increase in annual testing coverage scenarios							
3	Not applicable						
4	**0.29%** (0.19–0.46%)	**0.01%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**327** (194–483)	**9** (0–133)	**0** (0–0)	**29.8%** (-12.4–61.2%)
5	**0.29%** (0.17–0.42%)	**0.00%** (0.00–0.06%)	**0.00%** (0.00–0.00%)	**336** (190–502)	**0** (0–76)	**0** (0–0)	**41.8%** (10.3–66.4%)
2-year population-wide testing scenarios – Remote only							
6	**0.29%** (0.18–0.41%)	**0.02%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**341** (190–488)	**24** (0–147)	**0** (0–0)	**26.9%** (-1.9–56.4%)
7	**0.27%** (0.15–0.40%)	**0.04%** (0.00–0.12%)	**0.00%** (0.00–0.01%)	**294** (161–474)	**43** (0–133)	**0** (0–5)	**33.8%** (-18.2–68.8%)
8	**0.28%** (0.15–0.43%)	**0.00%** (0.00–0.03%)	**0.00%** (0.00–0.00%)	**313** (161–488)	**0** (0–47)	**0** (0–0)	**49.9%** (13.2–73.5%)
9	**0.24%** (0.13–0.39%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**289** (166–455)	**0** (0–19)	**0** (0–0)	**57.6%** (27.7–78.4%)
2-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)							
10	**0.29%** (0.19–0.43%)	**0.02%** (0.00–0.09%)	**0.00%** (0.00–0.00%)	**308** (218–498)	**19** (0–114)	**0** (0–0)	**33.7%** (3.5–63.2%)
11	**0.27%** (0.18–0.42%)	**0.01%** (0.00–0.08%)	**0.00%** (0.00–0.00%)	**299** (204–498)	**9** (0–90)	**0** (0–0)	**32.2%** (3.8–64.2%)
2-year population-wide testing scenarios – Regional and remote							
12	**0.23%** (0.13–0.34%)	**0.02%** (0.00–0.09%)	**0.00%** (0.00–0.00%)	**284** (142–431)	**14** (0–95)	**0** (0–0)	**45.5%** (6.1–69.6%)

13	**0.17%** (0.09–0.26%)	**0.00%** (0.00–0.04%)	**0.00%** (0.00–0.00%)	**218** (90–327)	**0** (0–47)	**0** (0–0)	**68.1%** (43.2–87.6%)
14	**0.22%** (0.11–0.35%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**284** (133–403)	**0** (0–5)	**0** (0–0)	**60.4%** (33.2–77.2%)
15	**0.15%** (0.08–0.25%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**218** (95–332)	**0** (0–0)	**0** (0–0)	**76.9%** (63.8–88.4%)
5-year increase in annual testing coverage scenarios							
16	**0.36%** (0.25–0.53%)	**0.06%** (0.00–0.16%)	**0.00%** (0.00–0.00%)	**327** (185–483)	**66** (0–199)	**0** (0–0)	**10.1%** (-27.3–46.7%)
17	**0.29%** (0.19–0.46%)	**0.01%** (0.00–0.07%)	**0.00%** (0.00–0.00%)	**327** (194–488)	**14** (0–114)	**0** (0–0)	**29.2%** (5.3–57.5%)
5-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)							
18	**0.30%** (0.18–0.46%)	**0.05%** (0.00–0.10%)	**0.00%** (0.00–0.00%)	**346** (204–502)	**57** (0–161)	**0** (0–0)	**12.1%** (-15.1–54.4%)
19	**0.30%** (0.18–0.46%)	**0.01%** (0.00–0.08%)	**0.00%** (0.00–0.00%)	**336** (199–498)	**14** (0–95)	**0** (0–0)	**33.2%** (-5.8–60.0%)
5-year population-wide testing scenarios – Remote only							
20	**0.28%** (0.18–0.43%)	**0.02%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**318** (180–479)	**19** (0–114)	**0** (0–0)	**40.3%** (-17.2–62.9%)
21	**0.26%** (0.16–0.42%)	**0.00%** (0.00–0.09%)	**0.00%** (0.00–0.00%)	**299** (161–469)	**0** (0–118)	**0** (0–0)	**46.8%** (13.7–69.1%)
22	**0.27%** (0.18–0.42%)	**0.00%** (0.00–0.05%)	**0.00%** (0.00–0.00%)	**341** (190–474)	**0** (0–66)	**0** (0–0)	**38.1%** (0.2–63.6%)
23	**0.27%** (0.14–0.39%)	**0.00%** (0.00–0.03%)	**0.00%** (0.00–0.00%)	**299** (161–455)	**0** (0–43)	**0** (0–0)	**53.8%** (7.0–71.7%)
5-year population-wide testing scenarios – Regional and remote							
24	**0.25%** (0.15–0.38%)	**0.00%** (0.00–0.06%)	**0.00%** (0.00–0.00%)	**265** (166–417)	**0** (0–71)	**0** (0–0)	**48.9%** (17.4–70.5%)
25	**0.17%** (0.09–0.26%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**213** (90–322)	**0** (0–0)	**0** (0–0)	**80.0%** (59.3–88.6%)
26	**0.23%** (0.14–0.35%)	**0.00%** (0.00–0.01%)	**0.00%** (0.00–0.00%)	**275** (142–431)	**0** (0–9)	**0** (0–0)	**61.1%** (35.7–77.2%)
27	**0.18%** (0.09–0.27%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**218** (90–336)	**0** (0–0)	**0** (0–0)	**80.3%** (60.0–89.0%)

Table 14: Date when infectious syphilis prevalence returns to the level in 2011 (pre-outbreak; 0.24%) and when syphilis prevalence reaches zero (elimination) for each modelling scenario assuming testing coverage equals the MJSO testing coverage. Dates are provided by year and quarter (Q1, Q2, Q3, Q4) when median prevalence for each model scenario first achieves these levels.

Scenario	Date when overall prevalence returns to pre-2011 level	Date when syphilis is eliminated
Current outbreak response and no outbreak response		
1	2022 – Q1	2030 – Q2
2	Not applicable	Not applicable
2-year increase in annual testing coverage scenarios		
3	Not applicable	Not applicable
4	2021 – Q4	2028 – Q3
5	2021 – Q3	2026 – Q2
2-year population-wide testing scenarios – Remote only		
6	2021 – Q2	2026 – Q4
7	2021 – Q1	2027 – Q4
8	2021 – Q1	2025 – Q1
9	2020 – Q4	2024 – Q2
2-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)		
10	2021 – Q2	2026 – Q3
11	2021 – Q2	2026 – Q1
2-year population-wide testing scenarios – Regional and remote		
12	2020 – Q4	2026 – Q3
13	2020 – Q1	2024 – Q1
14	2020 – Q4	2024 – Q3
15	2020 – Q1	2023 – Q2
5-year increase in annual testing coverage scenarios		
16	2021 – Q4	2028 – Q3
17	2021 – Q3	2026 – Q2
5-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)		
18	2021 – Q4	2027 – Q4
19	2021 – Q4	2026 – Q2
5-year population-wide testing scenarios – Remote only		
20	2021 – Q2	2027 – Q1
21	2021 – Q1	2025 – Q3
22	2021 – Q2	2025 – Q4
23	2021 – Q1	2025 – Q2
5-year population-wide testing scenarios – Regional and remote		
24	2021 – Q1	2025 – Q1
25	2020 – Q1	2023 – Q1
26	2020 – Q4	2024 – Q3
27	2020 – Q1	2023 – Q1

Additional results for the assumption testing coverage equals 0.75 times the MJSO testing coverage

Results for the key scenarios presented in the main report are presented here for comparison purposes.

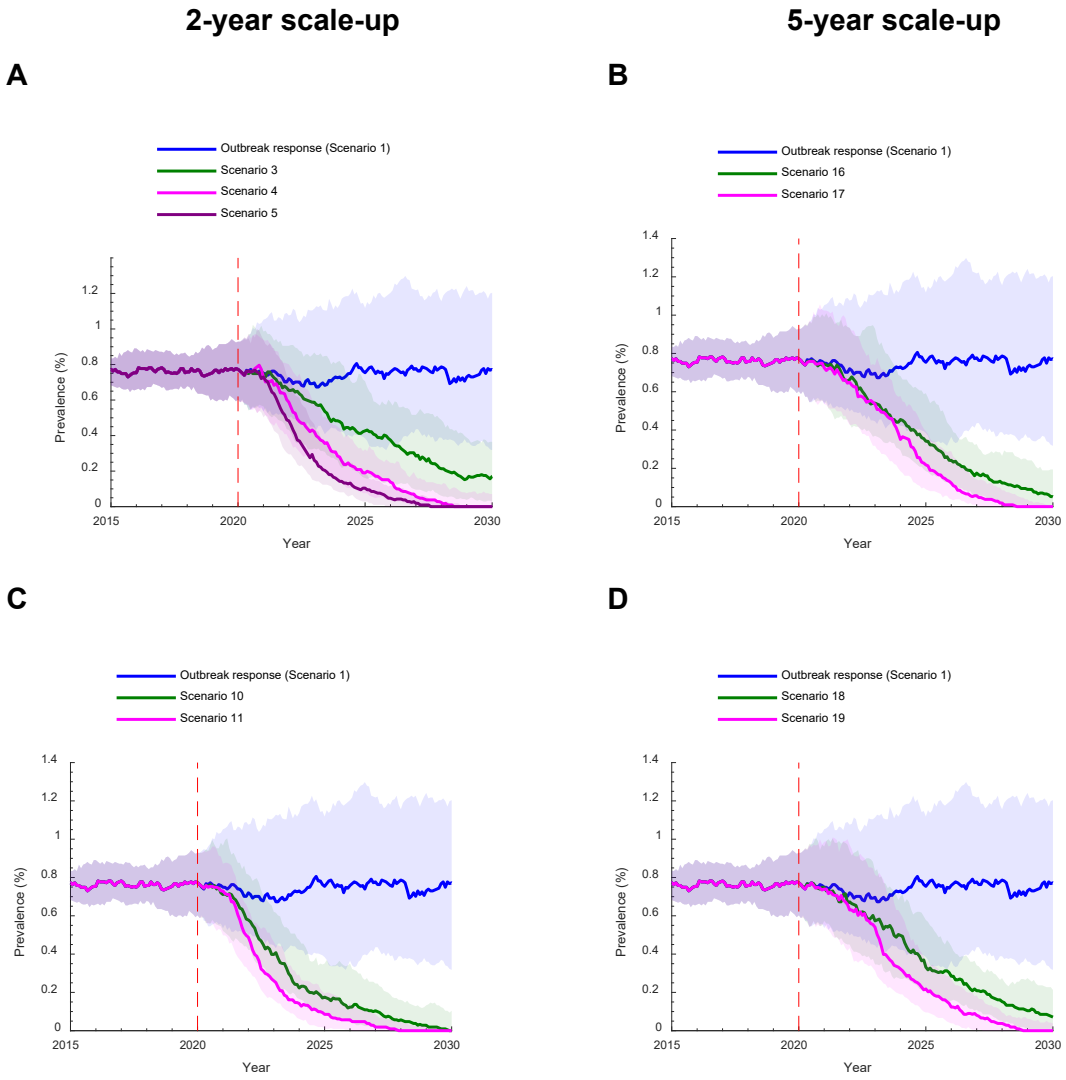

Figure 7: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 assuming testing coverage equals 0.75 times MJSO testing coverage. (A) and (B) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively (Scenarios 4–5 and 16–17). (C) and (D) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively, with testing coverage for males increasing to match the female testing coverage over the same period (Scenarios 10-11 and 18–19). The red dashed vertical line indicates the point in mid-2019 when each scenario begins in the model.

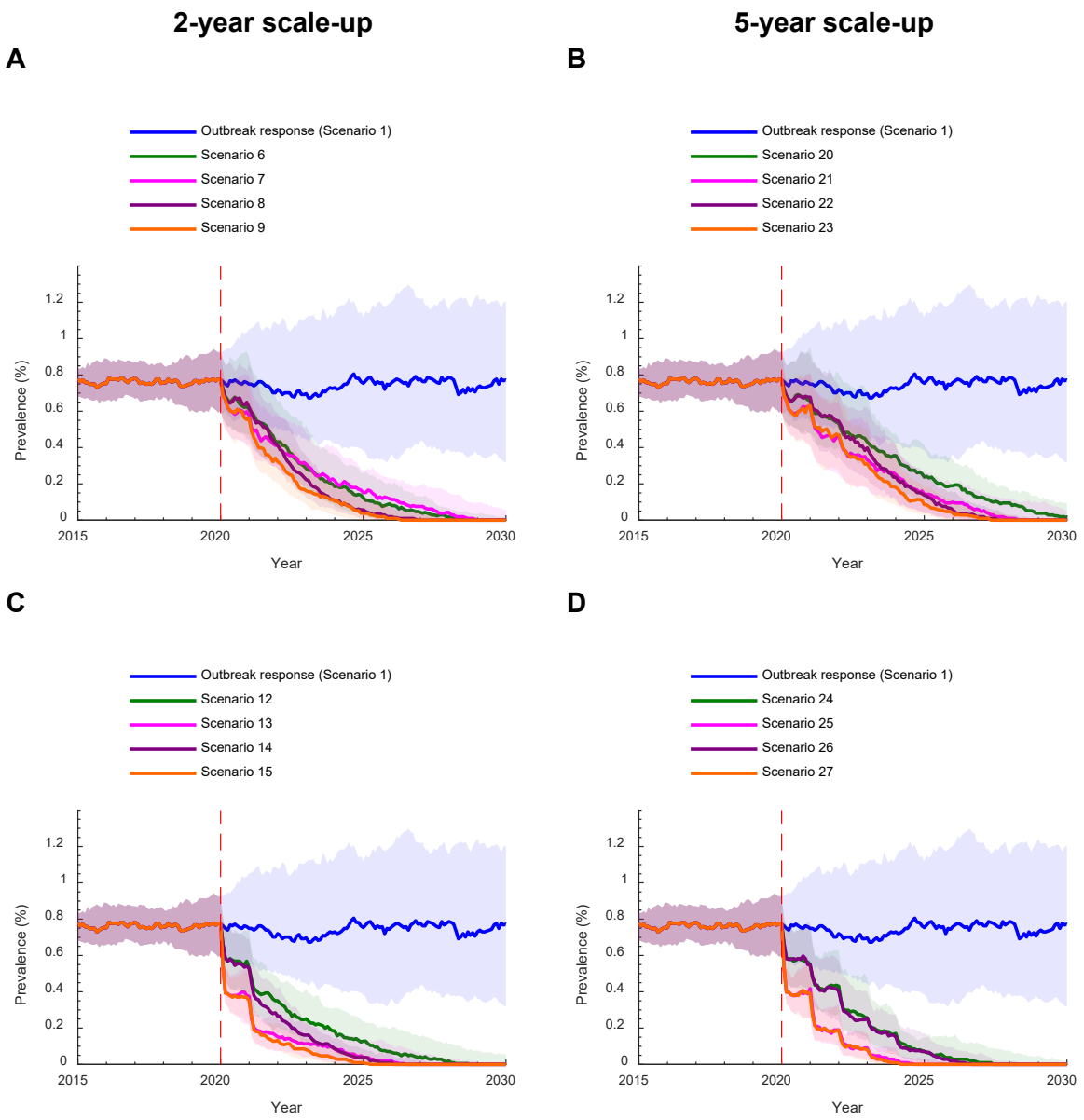

Figure 8: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 and the implementation of annual population-wide testing assuming testing coverage equals 0.75 times the MJSO testing coverage. (A) and (B) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively, and remote areas implement population-wide testing reaching 30% and 60% of the remote population over a six week period (Scenarios 6–9 and 20–23). (C) and (D) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2024 and mid-2021, respectively, and population-wide testing is implemented across the population reaching 30% and 60% of the overall population over a six week period (Scenarios 12–15 and 24–27). The red dashed vertical line shows the point in mid-2019 when each scenario begins in the model.

Table 15: Change in infectious syphilis indicators over 2020–2030 for each modelling scenario assuming testing coverage equals 0.75 times the MJSO testing coverage. Results show the median (in bold) and the IQR for the selected model runs. The infections averted (final) column reports the difference between each scenario and the enhanced response scenario (Scenario 1; note negative percentages correspond to an increase).

Scenario	Prevalence			Annual new infections per 100,000 people			Reduction in infections over 2019–2030
	2020	2025	2030	2020	2025	2030	
Current outbreak response and no outbreak response							
1	**0.75%** (0.54–1.05%)	**0.76%** (0.36–1.20%)	**0.69%** (0.33–1.22%)	**720** (517–1,028)	**716** (318–1,180)	**659** (327–1,166)	Reference scenario
2	**2.07%** (1.50–2.97%)	**3.29%** (2.76–3.93%)	**3.49%** (3.08–4.01%)	**1,692** (1,223–2,408)	**2701** (2,161–3,090)	**2,801** (2,498–3,156)	**-68.0%** (-81.6, -54.8%)
2-year increase in annual testing coverage scenarios							
3	**1.70%** (1.25 - 2.07%)	**0.74%** (0.47 - 0.97%)	**0.32%** (0.14 - 0.50%)	**1545** (1152 - 1886)	**777** (464 - 1028)	**332** (142 - 526)	**57.3%** (46.6 - 64.0%)
4	**0.73%** (0.54–0.94%)	**0.14%** (0.03–0.25%)	**0.00%** (0.00–0.04%)	**754** (526–943)	**147** (33–294)	**0** (0–33)	**60.8%** (42.9 - 73.4%)
5	**0.73%** (0.50–0.94%)	**0.05%** (0.00–0.12%)	**0.00%** (0.00–0.00%)	**749** (521–1005)	**66** (9–152)	**0** (0–0)	**69.3%** (57.1 - 78.5%)
2-year population-wide testing scenarios – Remote only							
6	**0.61%** (0.47–0.90%)	**0.08%** (0.01–0.19%)	**0.00%** (0.00–0.00%)	**645** (464–957)	**100** (0–223)	**0** (0–0)	**67.4%** (51.4–81.0%)
7	**0.58%** (0.42–0.80%)	**0.11%** (0.02–0.23%)	**0.00%** (0.00–0.02%)	**602** (455–829)	**133** (19–275)	**0** (0–19)	**68.6%** (48.6–79.0%)
8	**0.62%** (0.45–0.86%)	**0.02%** (0.00–0.07%)	**0.00%** (0.00–0.00%)	**654** (460–919)	**24** (0–100)	**0** (0–0)	**72.4%** (58.8–83.5%)
9	**0.56%** (0.40–0.73%)	**0.01%** (0.00–0.08%)	**0.00%** (0.00–0.00%)	**607** (417–853)	14 (0–90)	**0** (0–0)	**79.6%** (66.0–86.6%)
2-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)							
10	**0.71%** (0.52–0.97%)	**0.12%** (0.05–0.35%)	**0.00%** (0.00–0.07%)	**758** (521–971)	**137** (62–398)	**0** (0–66)	**60.0%** (39.8 - 69.9%)
11	**0.73%** (0.50–0.87%)	**0.06%** (0.00–0.14%)	**0.00%** (0.00–0.00%)	**739** (526–919)	**66** (0–161)	**0** (0–0)	**68.4%** (55.4 -78.7%)
2-year population-wide testing scenarios – Regional and remote							
12	**0.53%**	**0.07%**	**0.00%**	**573**	**76**	**0**	**71.0%**

	(0.39–0.73%)	(0.00–0.20%)	(0.00–0.02%)	(431–806)	(0–223)	(0–28)	(57.8 – 82.2%)
13	**0.37%** (0.22–0.56%)	**0.02%** (0.00–0.11%)	**0.00%** (0.00–0.00%)	**422** (256–616)	**9** (0–161)	**0** (0–0)	**87.2%** (70.9 – 91.4%)
14	**0.53%** (0.37–0.69%)	**0.01%** (0.00–0.05%)	**0.00%** (0.00–0.00%)	**569** (412–787)	**9** (0–66)	**0** (0–0)	**81.4%** (74.7 – 87.4%)
15	**0.35%** (0.23–0.51%)	**0.00%** (0.00–0.02%)	**0.00%** (0.00–0.00%)	**408** (261–611)	**0** (0–24)	**0** (0–0)	**87.9%** (80.8 – 93.0%)
5-year increase in annual testing coverage scenarios							
16	**0.74%** (0.55–0.99%)	**0.24%** (0.11–0.41%)	**0.02%** (0.00–0.14%)	**754** (531–976)	**289** (142–474)	**28** (0–166)	**46.9%** (18.4 –61.0%)
17	**0.73%** (0.54–1.02%)	**0.12%** (0.04–0.29%)	**0.00%** (0.00–0.00%)	**739** (536–1038)	**161** (66–355)	**0** (0–0)	**60.2%** (45.5 – 69.7%)
5-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)							
18	**0.75%** (0.57–0.96%)	**0.28%** (0.16–0.44%)	**0.03%** (0.00–0.17%)	**720** (517–953)	**318** (156–498)	**43** (0–227)	**44.8%** (28.7 – 58.4%)
19	**0.74%** (0.55–0.99%)	**0.12%** (0.04–0.27%)	**0.00%** (0.00–0.01%)	**735** (502–1005)	**190** (47–332)	**0** (0–14)	**56.7%** (36.3 – 70.9%)
5-year population-wide testing scenarios – Remote only							
20	**0.66%** (0.48–0.95%)	**0.19%** (0.05–0.34%)	**0.00%** (0.00–0.08%)	**659** (483–995)	**209** (52–374)	**0** (0–109)	**57.4%** (40.7 – 69.5%)
21	**0.63%** (0.41–0.81%)	**0.10%** (0.01–0.18%)	**0.00%** (0.00–0.01%)	**626** (398–839)	**118** (9–218)	**0** (0–9)	**69.6%** (52.0 – 80.4%)
22	**0.68%** (0.47–0.91%)	**0.06%** (0.01–0.15%)	**0.00%** (0.00–0.00%)	**664** (464–938)	**71** (9–213)	**0** (0–0)	**68.1%** (53.4 – 78.0%)
23	**0.63%** (0.41–0.81%)	**0.04%** (0.00–0.10%)	**0.00%** (0.00–0.00%)	**616** (403–834)	**62** (0–161)	**0** (0–0)	**73.4%** (57.9 – 81.5%)
5-year population-wide testing scenarios – Regional and remote							
24	**0.55%** (0.39–0.76%)	**0.03%** (0.00–0.15%)	**0.00%** (0.00–0.02%)	**569** (398–796)	**28** (0–175)	**0** (0–0)	**74.9%** (61.7 – 83.8%)
25	**0.42%** (0.25–0.58%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**412** (280–626)	**0** (0–0)	**0** (0–0)	**88.3%** (79.6 – 92.0%)
26	**0.55%** (0.41–0.78%)	**0.02%** (0.00–0.09%)	**0.00%** (0.00–0.00%)	**573** (422–829)	**33** (0–133)	**0** (0–0)	**77.1%** (67.5 – 84.4%)
27	**0.39%** (0.26–0.55%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**417** (470–621)	**0** (0–0)	**0** (0–0)	**88.0%** (82.1 – 92.7%)

Table 16: Date when infectious syphilis prevalence returns to the level in 2011 (pre-outbreak; 0.24%) and when syphilis prevalence reaches zero (elimination) for each modelling scenario assuming testing coverage equals 0.75 times the MJSO testing coverage. Dates are provided by year and quarter (Q1, Q2, Q3, Q4) when median prevalence for each model scenario first achieves these levels.

Scenario	Date when overall prevalence returns to pre-2011 level	Date when syphilis is eliminated
Current outbreak response and no outbreak response		
1	Not applicable	Not applicable
2	Not applicable	Not applicable
2-year increase in annual testing coverage scenarios		
3	2027– Q4	2036 – Q2
4	2024 – Q1	2028 – Q3
5	2023 – Q1	2027 – Q3
2-year population-wide testing scenarios – Remote only		
6	2023 – Q3	2028 – Q3
7	2023 – Q4	2029 – Q1
8	2022 – Q4	2026 – Q4
9	2022 – Q3	2026 – Q2
2-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)		
10	2024 – Q1	2029 – Q4
11	2023 – Q1	2027 – Q4
2-year population-wide testing scenarios – Regional and remote		
12	2023 – Q1	2028 – Q4
13	2021 – Q1	2026 – Q3
14	2022 – Q2	2026 – Q1
15	2021 – Q1	2025 – Q2
5-year increase in annual testing coverage scenarios		
16	2026 – Q1	2032 – Q1
17	2024 – Q4	2028 – Q3
5-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)		
18	2026 – Q3	2032 – Q4
19	2024 – Q4	2028 – Q4
5-year population-wide testing scenarios – Remote only		
20	2025 – Q1	2030 – Q3
21	2024 – Q1	2028 – Q2
22	2023 – Q4	2027 – Q3
23	2023 – Q2	2027 – Q2
5-year population-wide testing scenarios – Regional and remote		
24	2023 – Q1	2027 – Q2
25	2021 – Q1	2024 – Q3
26	2023 – Q1	2026 – Q3
27	2021 – Q1	2024 – Q1

Results for the assumption testing coverage equals 0.5 times the MJSO testing coverage

Assuming testing coverage is 0.5 times the MJSO testing coverage implies the mid-2019 testing coverage overall equals 26%. Under such an assumption we predict that the syphilis outbreak will continue to increases (see Figures 9 and 10). We predict increasing testing coverage to 50-70% will result in a decline in infectious syphilis like that seen under the other testing coverage assumptions (as described in the main report). In addition to running Scenarios 3–5 which increase coverage to 50– 70% we ran a scenario where testing coverage increases to 40% by mid-2021 and mid-2024. The results are shown in Figure 11 and Table 17. The results in Figure 11 and Table 17 suggest that reaching a testing coverage of 40% will stabilise the outbreak (potentially after a slight increase) and lead to a slow decline in the prevalence of infectious syphilis.

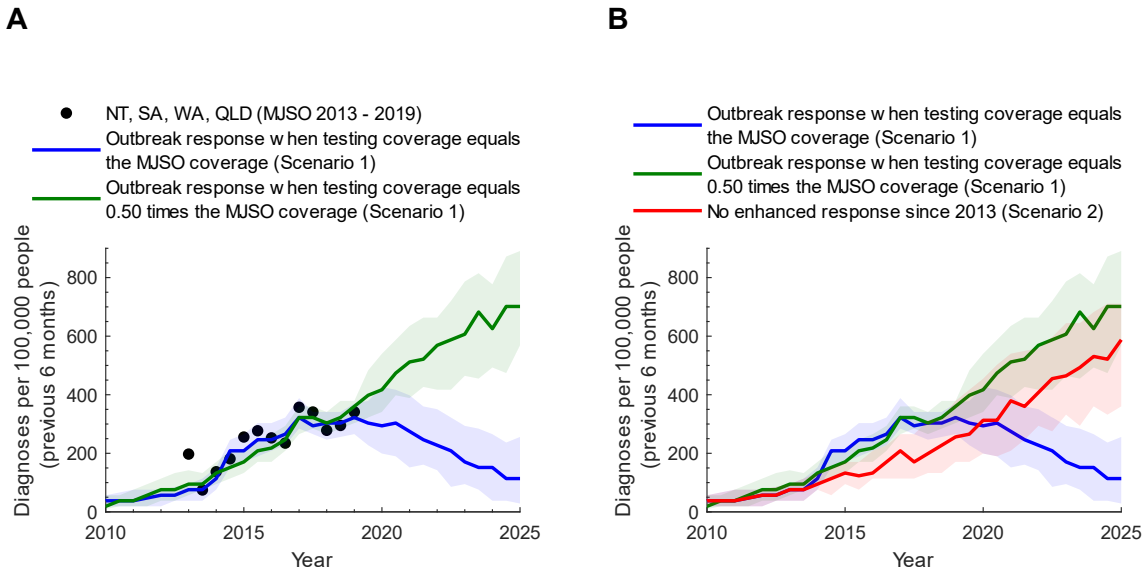

Figure 9: Estimated diagnoses from the model compared to notifications data. (A) Diagnoses per 100,000 people from 2010 to 2025 under the current response (status-quo) scenario compared to the total notification rate in the outbreak affected areas (black points) assuming testing coverage equals the MJSO testing coverage (blue line) and 0.5 times the MJSO testing coverage (green line). The solid line and the shaded region are the median and interquartile range, respectively, from the 100 selected model runs that best fit the data. (B) Comparison of diagnoses per 100,000 people from 2010 to 2025 for the outbreak response scenario (Scenario 1) and the counterfactual (no outbreak response) scenario (Scenario 2; where testing rates remain at 2013 levels) assuming testing coverage equals the MJSO testing coverage (blue line) and 0.5 times the MJSO testing coverage (green line). The solid lines and shading are the median and interquartile range from the selected model runs, respectively.

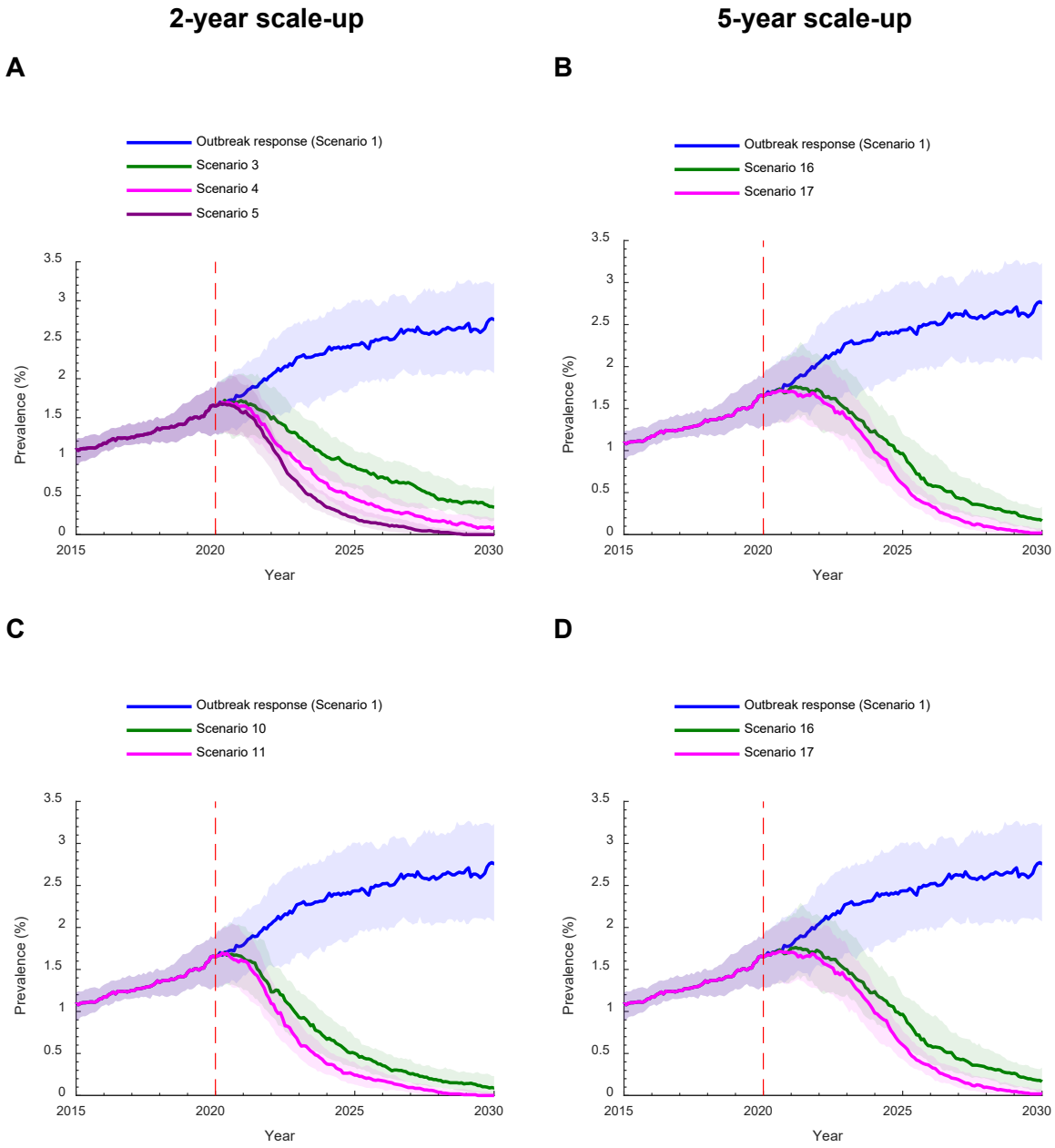

Figure 10: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 assuming testing coverage equals 0.5 times the MJSO testing coverage. (A) and (B) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively (Scenarios 4–5 and 16–17). (C) and (D) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively, with testing coverage for males increasing to match the female testing coverage over the same period (Scenarios 10-11 and 18–19). The red dashed vertical line indicates the point in mid-2019 when each scenario begins in the model.

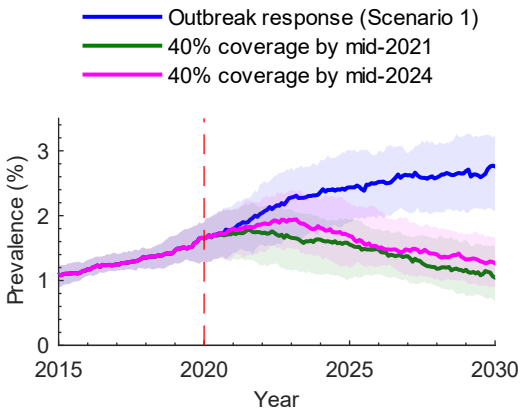

Figure 11: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 assuming testing coverage equals 0.5 times the MJSO testing coverage. Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 40% by mid-2021 and mid-2024. The red dashed vertical line indicates the point in mid-2019 when each scenario begins in the model.

Table 17: Change in infectious syphilis indicators over 2020–2030 for each modelling scenario assuming testing coverage equals 0.75 times the MJSO testing coverage. Results show the median (in bold) and the IQR for the selected model runs. The infections averted (final) column reports the difference between each scenario and the enhanced response scenario (Scenario 1; note negative percentages correspond to an increase).

Scenario	Prevalence			Annual new infections per 100,000 people			Reduction in infections over 2019–2030
	2020	2025	2030	2020	2025	2030	
Increase coverage to 40% by mid-2021	**1.73%** (1.34–2.09%)	**1.48%** (1.09–1.80%)	**1.04%** (0.70–1.48%)	**1521** (1128–1882)	**1393** (1028–1691)	**1052** (673–1445)	**33.4%** (18.6 - 47.1%)
Increase coverage to 40% by mid-2021	**1.80%** (1.36–2.10%)	**1.50%** (1.22–2.08%)	**1.18%** (0.88–1.63%)	**1550** (1161–1820)	**1455** (1175–2009)	**1194** (896–1526)	**25.3%** (12.1 – 39.6%)

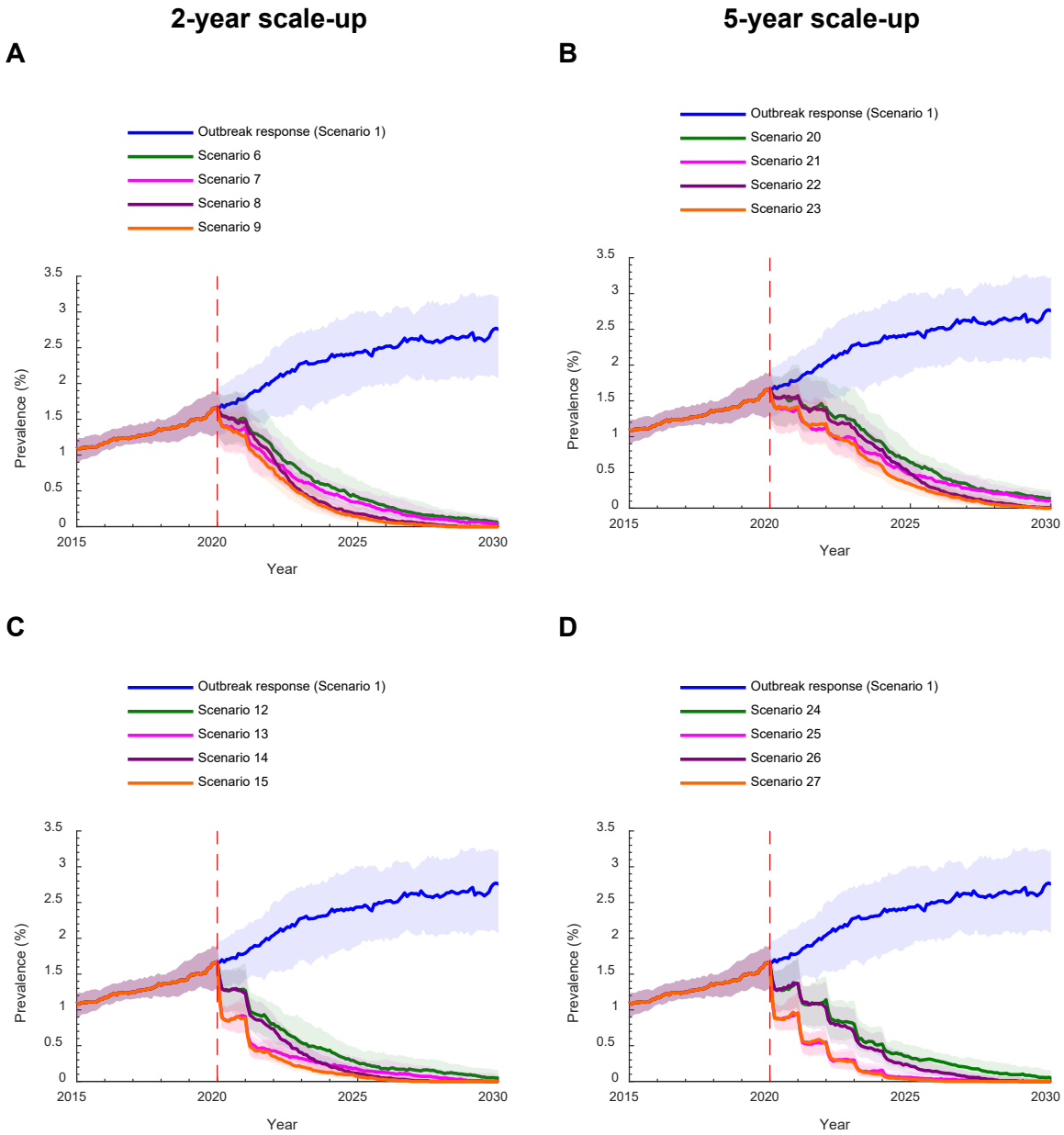

Figure 12: Change in infectious syphilis prevalence following further increases in annual syphilis testing coverage over 2015–2030 and the implementation of annual population-wide testing assuming testing coverage equals 0.5 times the MJSO testing coverage. (A) and (B) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2021 and mid-2024, respectively, and remote areas implement population-wide testing reaching 30% and 60% of the remote population over a six week period (Scenarios 6–9 and 20–23). (C) and (D) Change in prevalence if the overall testing coverage increases from mid-2019 levels to reach 60% and 70% by mid-2024 and mid-2021, respectively, and population-wide testing is implemented across the population reaching 30% and 60% of the overall population over a six week period (Scenarios 12–15 and 24–27). The red dashed vertical line shows the point in mid-2019 when each scenario begins in the model.

Table 18: Change in infectious syphilis indicators over 2020–2030 for each modelling scenario assuming testing coverage equals 0.5 times the MJSO testing coverage. Results show the median (in bold) and the IQR for the selected model runs. The infections averted (final) column reports the difference between each scenario and the enhanced response scenario (Scenario 1; note negative percentages correspond to an increase).

Scenario	Prevalence			Annual new infections per 100,000 people			Reduction in infections over 2019–2030
	2020	2025	2030	2020	2025	2030	
	Current outbreak response and no outbreak response						
1	**1.79%** (1.43–2.17%)	**2.52%** (2.01–3.00%)	**2.71%** (2.00–3.29%)	**1578** (1256–1825)	**2156** (1749–2545)	**2261** (1735–2754)	Reference scenario
2	**2.34%** (1.90–3.03%)	**3.57%** (3.05–4.07%)	**3.40%** (2.85–3.99%)	**1896** (1550–2517)	**2929** (2422–3275)	**2697** (2246–3180)	**-21.2%** (-36.2, -10.3%)
	2-year increase in annual testing coverage scenarios						
3	**1.70%** (1.25–2.07%)	**0.74%** (0.47–0.97%)	**0.32%** (0.14–0.50%)	**1545** (1152–1886)	**777** (464–1028)	**332** (142–526)	**57.3%** (46.6 – 64.0%)
4	**1.65%** (1.26–2.04%)	**0.33%** (0.19–0.52%)	**0.04%** (0.00–0.18%)	**1531** (1123–1886)	**355** (227–630)	**47** (0–190)	**69.3%** (60.8 – 77.3%)
5	**1.56%** (1.30–1.92%)	**0.13%** (0.05–0.25%)	**0.00%** (0.00–0.0%)	**1488** (1223–1858)	**175** (71–360)	**0** (0–0)	**78.0%** (70.6 – 81.8%)
	2-year population-wide testing scenarios – Remote only						
6	**1.50%** (1.12–1.86%)	**0.28%** (0.17–0.49%)	**0.03%** (0.00–0.13%)	**1403** (1038–1796)	**351** (185–559)	**38** (0–147)	**73.4%** (65.1 – 79.8%)
7	**1.39%** (1.00–1.68%)	**0.23%** (0.10–0.43%)	**0.02%** (0.00–0.09%)	**1318** (1009–1635)	**284** (104–507)	**19** (0–128)	**77.2%** (71.7 – 81.5%)
8	**1.48%** (1.12–1.79%)	**0.11%** (0.05–0.21%)	**0.00%** (0.00–0.00%)	**1427** (1104–1749)	**147** (71–308)	**0** (0–0)	**79.4%** (74.6 – 83.6%)
9	**1.27%** (1.03–1.61%)	**0.06%** (0.02–0.13%)	**0.00%** (0.00–0.00%)	**1294** (1014–1550)	**90** (28–199)	**0** (0–0)	**83.4%** (77.7 – 87.0%)
	2-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)						
10	**1.64%** (1.26–2.01%)	**0.36%** (0.22–0.53%)	**0.06%** (0.00–0.15%)	**1502** (1156–1900)	**412** (256–602)	**66** (0–190)	**68.1%** (62.1 – 76.2%)
11	**1.60%** (1.21–1.92%)	**0.18%** (0.08–0.28%)	**0.00%** (0.00–0.01%)	**1526** (1113–1915)	**223** (85–332)	**0** (0–19)	**76.3%** (72.1 – 81.7%)
	2-year population-wide testing scenarios – Regional and remote						
12	**1.27%**	**0.18%**	**0.03%**	**1275**	**190**	**24**	**78.9%**

	(0.96–1.64%)	(0.08–0.38%)	(0.00–0.15%)	(900–1607)	(81–493)	(0–180)	(70.8 – 84.1%)
13	**0.91%** (0.68–1.19%)	**0.12%** (0.05–0.31%)	**0.00%** (0.00–0.05%)	**972** (678–1280)	**156** (47–355)	**0** (0–66)	**86.3%** (80.2 – 90.3%)
14	**1.23%** (0.89–1.56%)	**0.04%** (0.01–0.14%)	**0.00%** (0.00–0.00%)	**1218** (900–1564)	**71** (9–185)	**0** (0–0)	**84.4%** (80.9 – 88.3%)
15	**0.89%** (0.66–1.09%)	**0.02%** (0.00–0.10%)	**0.00%** (0.00–0.00%)	**957** (706–1194)	**28** (0–128)	**0** (0–0)	**89.8%** (86.3 – 93.2%)
5-year increase in annual testing coverage scenarios							
16	**1.75%** (1.37–2.13%)	**0.59%** (0.37–0.96%)	**0.09%** (0.02–0.24%)	**1507** (1166–1891)	**668** (460–1137)	**104** (9–289)	**55.9%** (48.4 – 64.9%)
17	**1.71%** (1.34–2.11%)	**0.35%** (0.23–0.48%)	**0.00%** (0.00–0.02%)	**1540** (1242–1886)	**483** (299–687)	**0** (0–38)	**65.3%** (57.0 – 72.4%)
5-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)							
18	**1.75%** (1.29–2.17%)	**0.68%** (0.52–1.01%)	**0.12%** (0.02–0.26%)	**1517** (1142–1839)	**777** (592–1227)	**152** (24–308)	**53.8%** (45.8 – 64.2%)
19	**1.73%** (1.31–2.12%)	**0.36%** (0.23–0.55%)	**0.00%** (0.00–0.09%)	**1521** (1166–1844)	**479** (308–749)	**0** (0–114)	**63.2%** (54.3 – 72.3%)
5-year population-wide testing scenarios – Remote only							
20	**1.56%** (1.20–2.01%)	**0.47%** (0.25–0.64%)	**0.08%** (0.01–0.18%)	**1365** (1076–1839)	**559** (299–801)	**104** (0–227)	**66.2%** (56.7 – 73.1%)
21	**1.40%** (1.10–1.74%)	**0.37%** (0.23–0.56%)	**0.07%** (0.00–0.18%)	**1299** (995–1573)	**427** (284–673)	**76** (0–199)	**72.0%** (62.9 – 76.4%)
22	**1.57%** (1.17–1.96%)	**0.27%** (0.15–0.38%)	**0.00%** (0.00–0.02%)	**1427** (1071–1825)	**355** (209–521)	**0** (0–38)	**71.2%** (64.6 – 76.3%)
23	**1.42%** (1.08–1.75%)	**0.20%** (0.10–0.31%)	**0.00%** (0.00–0.02%)	**1365** (962–1649)	**303** (175–431)	**0** (0–19)	**75.9%** (69.4 – 80.5%)
5-year population-wide testing scenarios – Regional and remote							
24	**1.36%** (1.02–1.75%)	**0.28%** (0.09–0.41%)	**0.03%** (0.00–0.16%)	**1265** (910–1583)	**336** (118–483)	**19** (0–156)	**75.4%** (69.3 – 82.0%)
25	**0.96%** (0.71–1.28%)	**0.03%** (0.00–0.11%)	**0.00%** (0.00–0.01%)	**948** (701–1284)	**33** (0–113)	**0** (0–14)	**89.0%** (85.6 – 92.6%)
26	**1.37%** (0.99–1.71%)	**0.13%** (0.07–0.23%)	**0.00%** (0.00–0.00%)	**1318** (896–1659)	**180** (95–332)	**0** (0–0)	**80.3%** (73.6 – 85.4%)
27	**0.95%** (0.73–1.25%)	**0.01%** (0.00–0.05%)	**0.00%** (0.00–0.00%)	**967** (725–1218)	**9** (0–66)	**0** (0–0)	**89.8%** (87.0 – 92.7%)

Table 19: Date when infectious syphilis prevalence returns to the level in 2011 (pre-outbreak; 0.24%) and when syphilis prevalence reaches zero (elimination) for each modelling scenario assuming testing coverage equals 0.5 times the MJSO testing coverage. Dates are provided by year and quarter (Q1, Q2, Q3, Q4) when median prevalence for each model scenario first achieves these levels.

Scenario	Date when overall prevalence returns to pre-2011 level	Date when syphilis is eliminated
Current outbreak response and no outbreak response		
1	Not applicable	Not applicable
2	Not applicable	Not applicable
2-year increase in annual testing coverage scenarios		
3	2033 – Q2	2040 – Q4
4	2027 – Q2	2032 – Q2
5	2024 – Q4	2028 – Q4
2-year population-wide testing scenarios – Remote only		
6	2026 – Q2	2032 – Q2
7	2025 – Q4	2031 – Q3
8	2024 – Q3	2028 – Q3
9	2024 – Q1	2028 – Q1
2-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)		
10	2027 – Q2	2033 – Q1
11	2025 – Q1	2029 – Q2
2-year population-wide testing scenarios – Regional and remote		
12	2025 – Q2	2032 – Q1
13	2023 – Q4	2029 – Q3
14	2023 – Q4	2027 – Q3
15	2022 – Q3	2026 – Q4
5-year increase in annual testing coverage scenarios		
16	2029 – Q1	2034 – Q2
17	2026 – Q3	2030 – Q2
5-year increase in annual testing coverage scenarios (male coverage increasing to match female coverage)		
18	2029 – Q2	2035 – Q1
19	2026 – Q3	2030 – Q3
5-year population-wide testing scenarios – Remote only		
20	2027 – Q4	2033 – Q2
21	2027 – Q3	2033 – Q3
22	2026 – Q1	2030 – Q2
23	2025 – Q3	2029 – Q4
5-year population-wide testing scenarios – Regional and remote		
24	2026 – Q3	2032 – Q1
25	2023 – Q1	2027 – Q4
26	2024 – Q4	2028 – Q4
27	2023 – Q1	2026 – Q2

Results for the assumption testing coverage equals 1.25 times the MJSO testing coverage

When we assumed the MJSO testing coverage was an underestimate of the actual testing coverage our model predicted infectious syphilis notifications and prevalence would decline rapidly after mid-2019 (Figure 13; Table 20). We did not run all the scenarios listed in appendix A4 Full Scenario List as increasing testing coverage and introducing population-wide screening would accelerate the reduction in infectious syphilis under this assumption. Below we present the results for the status-quo (Scenario 1), no outbreak response (Scenario 2) and increasing coverage to 70% (Scenario 4) scenarios. Under this testing coverage assumption, the testing coverage is already greater than 60% in mid-2019.

Under this assumed testing coverage, we predict the epidemic would return to pre-outbreak levels before the end of 2020 if such higher testing coverage levels are current testing levels are sustained

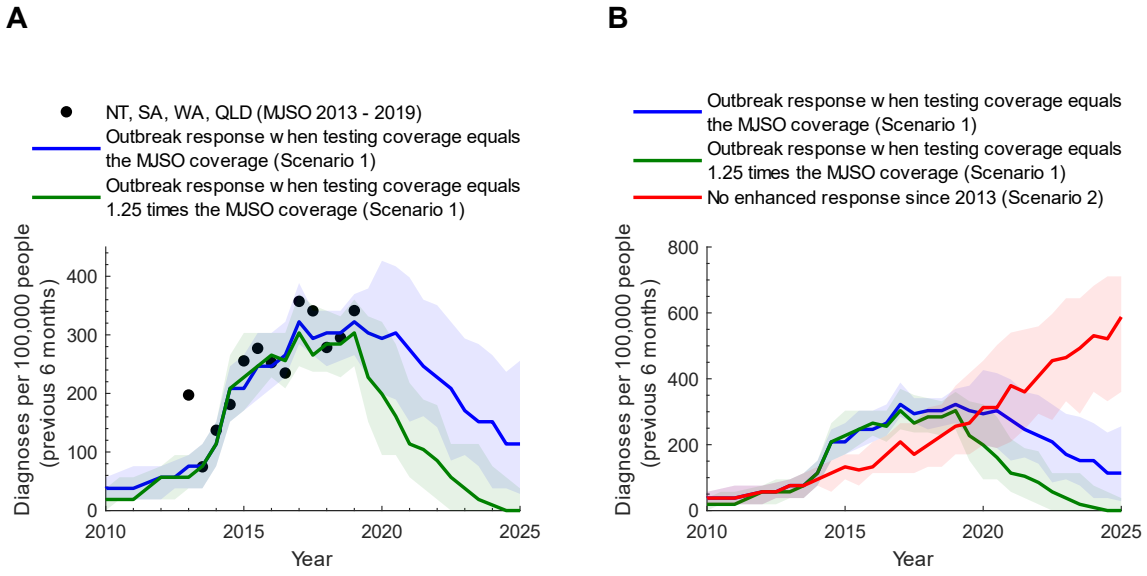

Figure 13: Estimated diagnoses from the model compared to notifications data. (A) Diagnoses per 100,000 people from 2010 to 2025 under the current response (status-quo) scenario compared to the total notification rate in the outbreak affected areas (black points) assuming testing coverage equals the MJSO testing coverage (blue line) and 1.25 times the MJSO testing coverage (green line). The solid line and the shaded region are the median and interquartile range, respectively, from the 100 selected model runs that best fit the data. (B) Comparison of diagnoses per 100,000 people from 2010 to 2025 for the outbreak response scenario (Scenario 1) and the counterfactual (no outbreak response) scenario (Scenario 2; where testing rates remain at 2013 levels) assuming testing coverage equals the MJSO testing coverage (blue line) and 1.25 times the MJSO testing coverage (green line). The solid lines and shading are the median and interquartile range from the selected model runs, respectively.

Table 20: Change in infectious syphilis indicators over 2020–2030 for each modelling scenario assuming testing coverage equals 0.5 times the MJSO testing coverage. Results show the median (in bold) and the IQR for the selected model runs. The infections averted (final) column reports the difference between each scenario and the enhanced response scenario (Scenario 1; note negative percentages correspond to an increase).

Scenario	Prevalence			Annual new infections per 100,000 people			Reduction in infections over 2019–2030
	2020	2025	2030	2020	2025	2030	
Current outbreak response and no outbreak response							
1	**0.09%** (0.03–0.15%)	**0.00%** (0.00–0.00%)	**0.00%** (0.00–0.00%)	**100** (28–204)	0 (0–0)	**0** (0–0)	Reference Scenario
2	**1.94%** (1.29–2.69%)	**3.21%** (2.42–4.00%)	**3.41%** (2.67–3.93%)	**1607** (1062–2199)	**2630** (1972–3194)	**2711** (2109–3071)	**-99.1%** (-99.8, -97.4%)
2-year increase in annual testing coverage scenarios							
3				Not applicable			
4				Not applicable			
5	**0.08%** (0.02–0.15%)	**0.00%** (0.00–0.03%)	**0.00%** (0.00–0.00%)	**100** (28–194)	**0** (0–0)	**0** (0–0)	**0.0%** (-22.6–37.4%)