Supplementary materials for “A school-based serology study to validate use of routine data for targeting malaria interventions in the Central Highlands of Madagascar“

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# Data Collection

## Data quality assessments

Four months [two higher-transmission (March and April 2014) and two lower-transmission (September and November 2013)] from the previous transmission season were purposively sampled, and health facility register data were abstracted to assess completeness of selected fields (name, age, symptoms, and treatment) as well as accuracy of selected data elements (total consultations, RDTs done, and positive RDTs) for these four months. Completeness of facility data was assessed by calculating the mean percentage of missing register fields for the four selected months. Accuracy of the data elements was assessed by comparing the tallied malaria indicators abstracted from registers with data reported in the routine health management information system (HMIS) and calculating the mean percentage discordance. Summary data completeness and data accuracy scores were created for each commune using the average register completeness and reported data accuracy scores for all facilities in the commune.

Additionally, at district health offices, teams reviewed facility monthly data reports (which get entered electronically in to the HMIS) from the previous 12 months to assess the mean number of missing fields on selected indicators: number of consultations, number of RDTs done, number of positive RDTs, and number of artemisinin-based combination therapy (ACTs) used. An overall quality score was created for each district by combining the average data accuracy and completeness measures (from both register abstraction and the monthly reports) for all facilities in the district. Districts were then divided into three “lower-quality” and four “higher-quality” districts.

# Lab Analyses

## Antigen preparation

Production and purification of PF13, the NTS-DBL1α1 domain of the PfEMP1 (*P. falciparum* Erythrocyte Membrane Protein-1) adhesin encoded by the 3D7/PF13-0003 *var* gene followed previously described methods. The C-terminal Merozoite Surface Protein-1 of *P. falciparum* (PfMSP1-p19) was produced in the baculovirus/Insect cells system as described.[2] The Apical Membrane Antigen 1 of *P. falciparum* (PfAMA1), 3D7 sequence was produced in *E. coli* as described. All proteins coupled to the Luminex beads were estimated to be at or above 80% purity. For the 3 recombinant proteins, all expression products were at the predicted molecular mass and were pure as judged by absence of major contaminants in Coomassie blue-stained SDS-PAGE gels (data not shown). For the two peptides included in this study (PfCSP: NANPNANPNANPNANPNANPNANPNANPNANPNANPNVDPNVDPC and PfGLURP: EDKNEKGQHEIVEVEEILC), a C-terminal cysteine residue was added to allow a unidirectional coupling to BSA by the manufacturer (GenScript HK *Inc.*,Hong Kong, China, or Genecust, France). Selection of peptides specific for *P. falciparum*, representing different life stages of the parasite, was based on previous work. Purity of each BSA-peptide was estimated to be >85% by high performance liquid chromatography and mass spectrometry.

## Multiplex bead-based immunoassay

After Ag-coupled bead count, 1000 beads/region/Ag were distributed in each well of a 96-well microtiter plate and 100 μL of plasma or serum samples diluted 1:100 were added in duplicate wells. Plasma or serum dilutions were done in PBS 1x supplemented with 0.05 % Tween 20 and 1% of BSA (PTB buffer). After 45 min of incubation under constant shaking and three washes in PTB buffer, 100 μL of secondary antibody (R-phycoerythrin conjugated goat F(ab’)2 anti-human IgG, Molecular Probes/Life Technologies, H10104) diluted at 1:500 in PTB buffer was added in each well. After 45-minutes incubation and washing steps, beads were re-suspended in 120 μL PTB.

# Data Analyses

## Seropositivity methods

Finite mixture models, assuming two underlying distributions of “negative” (unexposed) and “positive” (exposed) individuals, were created from log-transformed MFI values to determine seropositivity cut-offs for each antigen, a statistical approach that has been used on samples from other low-endemicity settings and that does not require antibody responses from a reference population. Finite mixture models were fit with the flexmix package in R version 3.5.1 (Comprehensive R Archive Network, Vienna, Austria). In addition, latent class analysis using the mclust package was applied to the MFI data for all *Pf* antigens to define an overall *Pf* seropositivity variable.[15] Mean seropositivity for each *Pf* antigen and for the latent *Pf* variable were calculated for each commune. In addition, reversible catalytic models were used to generate seroconversion rates (SCRs) for each commune. Bootstrap resampling was used to estimate confidence intervals for SCRs.[17]

## Regression modeling

Serological measures at the commune level were used as a “gold standard” for comparison to the other methods for estimating malaria transmission. The relationships between commune-level SCRs and APIs were explored graphically to determine potential data transformations, and relationships were then characterized through various regression models. Models were fit both with and without a commune-level weight for data accuracy (equal to 1/[1+mean proportion discordance]) and with and without accounting for spatial autocorrelation, using GPS coordinates from the schools. Regression models with various forms, including linear, piecewise linear, B-spline with knots, [18] second-degree polynomial, and third-degree polynomial, were fit in R to express the relationship between SCRs and APIs. Given the right-skewed distributions of both API and SCR, values of each variable were fit after performing log10-transformations. Final models were selected based on Akaike information criterion (AIC) [19]and Bayesian information criterion (BIC).[20]

## ROC analyses

These analyses treated the commune-level SCRs as a gold standard. We created cutoffs at the 50th, 60th, 70th, 80th, and 90th percentiles of the SCR distribution. Utilizing those cutoffs, we estimated the sensitivity, specificity, and area under the ROC curve (AUC) for each cutoff. This was done using the pROC package in R.[21] Bootstrap confidence intervals were created for AUC, sensitivity, and specificity. Youden’s J statistic [22]was used to determine the optimal sensitivity and specificity.

# Supplementary Figures

[See .tiff]

## Figure S1: Flow diagram showing the number of communes, health facilities and schools surveyed, and the number of individuals (students, parents, and teachers) sampled.

## Figure S2: Relationship between seroconversion rates and API from routine health facility data in four “higher-quality” district (A), three “lower-quality (B) districts, and six districts excluding Mandoto district which had outlying data quality scores (C)

[See .tiff]

(A)

(B)

(C)

# Supplementary Tables

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S1: RDT, Pf antibody positivity, seroconversion rate, and API by commune | | | | | | | | | | |  |
| Districts | **Communes** | **N** | **RDT** | **PF13** | **PfMSP1** | **PfAMA1** | **PfCSP** | **PfGLURP** | **Pf latent antigen** | **λ Pf latent antigen** | **2013 API** |
| c | Ambatofinandrahana | 141 | 0% | 62.4% | 17.7% | 30.5% | 23.4% | 59.6% | 27.0% | 0.01445 | 3.3 |
| Ambatomifanongoa | 153 | 0% | 60.1% | 5.9% | 22.2% | 20.3% | 49.0% | 17.0% | 0.00919 | 1.2 |
| Ambondromisotra | 147 | 0% | 51.0% | 8.8% | 17.7% | 19.7% | 41.5% | 15.0% | 0.00640 | 3.2 |
| Fenoarivo | 143 | 0% | 60.1% | 7.7% | 12.6% | 20.3% | 46.9% | 10.5% | 0.00529 | 0.8 |
| Itremo | 141 | 0% | 70.9% | 24.1% | 41.1% | 33.3% | 59.6% | 36.2% | 0.02401 | 12.2 |
| Soavina-Amba | 154 | 0% | 55.2% | 4.5% | 11.7% | 18.2% | 46.8% | 10.4% | 0.00526 | 4.9 |
| Ambohimahasoa | Ambalakindresy | 133 | 0% | 58.6% | 13.5% | 19.5% | 32.3% | 53.4% | 21.1% | 0.01026 | 3.8 |
| Ambatosoa | 132 | 0% | 48.5% | 19.7% | 17.4% | 30.3% | 45.5% | 16.7% | 0.00792 | 6.3 |
| Ambohimahasoa | 143 | 0% | 64.3% | 13.3% | 13.3% | 28.7% | 49.7% | 11.9% | 0.00529 | 11.4 |
| Ambohinamboarina | 127 | 2% | 58.3% | 15.7% | 22.8% | 22.8% | 49.6% | 21.3% | 0.01182 | 5.6 |
| Ampitana | 142 | 0% | 45.8% | 11.3% | 5.6% | 22.5% | 31.7% | 5.6% | 0.00255 | 2.1 |
| Ankafina Tsarafidy | 135 | 0% | 58.5% | 10.4% | 14.8% | 23.7% | 75.6% | 14.8% | 0.00695 | 0.2 |
| Ankerana | 135 | 0% | 51.1% | 3.0% | 3.7% | 17.0% | 96.3% | 5.2% | 0.00234 | 3.5 |
| Befeta | 139 | 0% | 71.2% | 8.6% | 21.6% | 27.3% | 61.2% | 15.8% | 0.00741 | 2.1 |
| Camp Robin | 131 | 0% | 46.6% | 3.1% | 5.3% | 16.8% | 33.6% | 6.1% | 0.00254 | 1.7 |
| Fiadanana | 126 | 0% | 57.9% | 8.7% | 5.6% | 22.2% | 25.4% | 5.6% | 0.00240 | 6.0 |
| Ikalalao | 132 | 0% | 46.2% | 7.6% | 9.1% | 14.4% | 43.2% | 7.6% | 0.00298 | 3.1 |
| Isaka | 133 | 2% | 65.4% | 13.5% | 29.3% | 24.1% | 50.4% | 24.1% | 0.01220 | 1.0 |
| Manandroy | 142 | 0% | 48.6% | 9.2% | 10.6% | 21.8% | 62.0% | 12.7% | 0.00603 | 4.8 |
| Morafeno | 136 | 1% | 62.5% | 19.9% | 16.2% | 33.1% | 42.6% | 16.9% | 0.00766 | 1.1 |
| Sahatona | 141 | 0% | 55.3% | 9.9% | 9.2% | 19.9% | 36.9% | 5.7% | 0.00244 | 0.9 |
| Sahave | 144 | 0% | 56.9% | 4.9% | 11.1% | 24.3% | 57.6% | 7.6% | 0.00330 | 1.1 |
| Vohiposa | 128 | 0% | 62.5% | 6.3% | 7.8% | 20.3% | 32.0% | 5.5% | 0.00222 | 0.9 |
| Vohitrarivo | 126 | 1% | 75.4% | 23.8% | 28.6% | 34.9% | 54.0% | 26.2% | 0.02139 | 0.0 |
| Ambositra | Alakamisy Ambohijato | 133 | 0% | 62.4% | 9.0% | 15.8% | 32.3% | 40.6% | 13.5% | 0.00635 | 3.4 |
| Ambalamanakana | 151 | 0% | 57.6% | 6.6% | 12.6% | 22.5% | 96.7% | 10.6% | 0.00435 | 0.0 |
| Ambatofitorahana | 136 | 0% | 45.6% | 2.9% | 4.4% | 25.0% | 97.8% | 4.4% | 0.00183 | 4.9 |
| Ambohimanjaka | 144 | 0% | 46.5% | 5.6% | 6.3% | 21.5% | 32.6% | 3.5% | 0.00138 | 2.7 |
| Ambohimitombo I | 130 | 1% | 70.0% | 34.6% | 44.6% | 43.8% | 59.2% | 41.5% | 0.02390 | 2.5 |
| Ambohimitombo II | 130 | 0% | 63.8% | 20.0% | 30.0% | 33.8% | 46.2% | 24.6% | 0.01294 | 7.6 |
| Ambositra I | 130 | 0% | 53.1% | 11.5% | 6.9% | 23.8% | 38.5% | 6.9% | 0.00284 | 3.0 |
| Ambositra II | 131 | 0% | 48.1% | 7.6% | 9.9% | 16.8% | 41.2% | 7.6% | 0.00331 | 7.6 |
| Andina | 138 | 0% | 60.9% | 4.3% | 10.9% | 20.3% | 25.4% | 7.2% | 0.00289 | 0.9 |
| Ankazoambo | 137 | 0% | 46.7% | 5.8% | 9.5% | 22.6% | 28.5% | 8.0% | 0.00332 | 2.0 |
| Antoetra | 133 | 1% | 58.6% | 15.8% | 26.3% | 30.1% | 72.2% | 20.3% | 0.00992 | 5.2 |
| Fahizay | 132 | 0% | 53.8% | 10.6% | 12.1% | 21.2% | 35.6% | 11.4% | 0.00513 | 0.0 |
| Ihadilanana | 71 | 4% | 63.4% | 9.9% | 18.3% | 28.2% | 40.8% | 12.7% | 0.00606 | 3.9 |
| Ilaka Centre | 145 | 0% | 50.3% | 13.8% | 11.7% | 22.1% | 36.6% | 10.3% | 0.00471 | 2.3 |
| Imerina Imady | 140 | 0% | 52.9% | 12.9% | 12.9% | 27.1% | 30.0% | 10.0% | 0.00431 | 6.5 |
| Ivato | 150 | 0% | 54.7% | 4.0% | 6.7% | 21.3% | 48.0% | 3.3% | 0.00149 | 0.2 |
| Ivony Miaramiasa | 133 | 0% | 58.6% | 8.3% | 12.0% | 20.3% | 28.6% | 6.8% | 0.00290 | 1.4 |
| Kianjandrakefina | 131 | 0% | 57.3% | 16.0% | 24.4% | 26.7% | 48.1% | 20.6% | 0.00967 | 3.9 |
| Mahazina Ambohipierenana | 143 | 0% | 53.1% | 5.6% | 9.1% | 18.9% | 31.5% | 7.7% | 0.00348 | 6.0 |
| Marosoa | 134 | 0% | 53.0% | 14.2% | 19.4% | 27.6% | 44.0% | 17.2% | 0.00825 | 1.2 |
| Tsarasaotra-Ambo | 160 | 0% | 46.3% | 9.4% | 8.8% | 26.3% | 38.8% | 8.8% | 0.00387 | 2.2 |
| Anjozorobe | Alakamisy | 131 | 0% | 46.6% | 6.9% | 17.6% | 20.6% | 42.0% | 14.5% | 0.00698 | 0.2 |
| Ambatomanoina | 155 | 1% | 65.8% | 28.4% | 45.2% | 43.2% | 58.7% | 46.5% | 0.03250 | 7.1 |
| Amboasary Nord | 143 | 1% | 71.3% | 30.1% | 48.3% | 44.1% | 67.1% | 48.3% | 0.04068 | 2.0 |
| Ambohibary Vohilena | 141 | 3% | 72.3% | 37.6% | 51.1% | 47.5% | 66.0% | 51.8% | 0.04407 | 11.7 |
| Ambohimanarina Marovazaha | 164 | 0% | 73.2% | 23.2% | 34.8% | 34.1% | 57.3% | 34.8% | 0.02795 | 0.4 |
| Ambohimirary | 133 | 2% | 73.7% | 29.3% | 46.6% | 39.8% | 93.2% | 47.4% | 0.03774 | 8.6 |
| Ambongamarina | 103 | 0% | 38.8% | 12.6% | 24.3% | 21.4% | 44.7% | 24.3% | 0.01493 | 1.0 |
| Amparatanjona | 127 | 0% | 55.1% | 19.7% | 29.1% | 28.3% | 66.1% | 29.1% | 0.01790 | 0.2 |
| Analaroa | 136 | 0% | 58.8% | 19.9% | 36.8% | 30.1% | 56.6% | 36.8% | 0.02361 | 5.2 |
| Anjozorobe | 156 | 0% | 50.6% | 10.9% | 19.2% | 25.0% | 42.3% | 18.6% | 0.01113 | 0.6 |
| Antanetibe | 129 | 2% | 67.4% | 38.0% | 50.4% | 44.2% | 61.2% | 49.6% | 0.03964 | 2.1 |
| Belanitra | 134 | 4% | 72.4% | 40.3% | 50.0% | 48.5% | 64.9% | 51.5% | 0.04198 | 8.4 |
| Betatao | 143 | 0% | 48.3% | 16.8% | 28.7% | 21.7% | 61.5% | 28.0% | 0.01692 | 0.2 |
| Mangamila | 107 | 0% | 51.4% | 4.7% | 16.8% | 14.0% | 32.7% | 15.0% | 0.00754 | 0.1 |
| Marotsipoy | 158 | 0% | 74.7% | 30.4% | 50.0% | 48.1% | 98.1% | 46.2% | 0.03766 | 31.7 |
| Tsarasaotra-Anj | 153 | 0% | 50.3% | 11.1% | 15.7% | 22.9% | 36.6% | 15.7% | 0.00812 | 0.6 |
| Ankazobe | Ambohitromby | 124 | 2% | 62.9% | 20.2% | 37.9% | 27.4% | 62.9% | 33.1% | 0.02212 | 5.5 |
| Ankazobe | 138 | 1% | 66.7% | 39.1% | 42.0% | 41.3% | 64.5% | 40.6% | 0.03358 | 14.0 |
| Antakavana | 134 | 2% | 84.3% | 44.8% | 70.9% | 64.9% | 82.1% | 67.9% | 0.07509 | 13.3 |
| Antotohazo | 144 | 3% | 68.1% | 22.2% | 45.1% | 40.3% | 67.4% | 41.0% | 0.02878 | 9.2 |
| Fihaonana | 122 | 0% | 58.2% | 10.7% | 22.1% | 25.4% | 98.4% | 20.5% | 0.01209 | 10.8 |
| Kiangara | 149 | 1% | 76.5% | 40.9% | 55.0% | 49.7% | 68.5% | 51.7% | 0.04464 | 24.5 |
| Mahavelona | 139 | 0% | 59.0% | 14.4% | 33.1% | 23.7% | 61.2% | 31.7% | 0.02042 | 8.9 |
| Marondry | 122 | 0% | 72.1% | 32.0% | 50.8% | 47.5% | 81.1% | 47.5% | 0.03593 | 43.6 |
| Miantso | 149 | 0% | 69.8% | 24.8% | 40.9% | 36.2% | 87.2% | 39.6% | 0.02893 | 1.7 |
| Talata Angavo | 135 | 13% | 82.2% | 63.0% | 62.2% | 59.3% | 79.3% | 63.0% | 0.05843 | 26.8 |
| Tsaramasoandro | 130 | 0% | 63.1% | 29.2% | 31.5% | 35.4% | 59.2% | 33.1% | 0.02473 | 33.6 |
| Betafo | Alakamisy Anativato | 146 | 0% | 50.7% | 10.3% | 9.6% | 25.3% | 34.2% | 8.2% | 0.00346 | 1.1 |
| Alakamisy Marososona | 135 | 0% | 48.1% | 3.0% | 5.9% | 19.3% | 22.2% | 4.4% | 0.00192 | 8.9 |
| Ambatonikolahy | 149 | 0% | 47.7% | 4.0% | 6.0% | 22.1% | 23.5% | 2.0% | 0.00082 | 5.5 |
| Ambohimanambola | 151 | 1% | 80.1% | 35.1% | 54.3% | 45.0% | 67.5% | 50.3% | 0.03771 | 7.6 |
| Ambohimasina | 129 | 0% | 57.4% | 20.2% | 42.6% | 27.9% | 53.5% | 38.0% | 0.02401 | 0.4 |
| Andranomafana | 139 | 0% | 59.7% | 15.8% | 20.9% | 23.0% | 97.8% | 21.6% | 0.01224 | 1.9 |
| Antohobe | 151 | 0% | 56.3% | 15.9% | 33.8% | 34.4% | 49.0% | 29.1% | 0.01923 | 11.3 |
| Antsoso | 140 | 0% | 47.9% | 9.3% | 14.3% | 25.0% | 29.3% | 10.7% | 0.00489 | 8.7 |
| Betafo | 140 | 0% | 48.6% | 9.3% | 16.4% | 22.1% | 79.3% | 15.0% | 0.00697 | 4.8 |
| Inanantonana | 142 | 0% | 66.9% | 24.6% | 47.9% | 41.5% | 62.0% | 43.7% | 0.02742 | 2.5 |
| Mahaiza | 135 | 0% | 43.0% | 5.9% | 12.6% | 21.5% | 25.9% | 10.4% | 0.00445 | 3.3 |
| Mandritsara | 158 | 0% | 46.2% | 5.7% | 9.5% | 21.5% | 27.2% | 7.6% | 0.00327 | 0.1 |
| Manohisoa | 133 | 0% | 56.4% | 14.3% | 29.3% | 22.6% | 43.6% | 24.1% | 0.01360 | 5.1 |
| Soavina-Bet | 151 | 1% | 57.0% | 20.5% | 33.1% | 26.5% | 47.7% | 26.5% | 0.01370 | 5.6 |
| Tritriva | 126 | 0% | 53.2% | 3.2% | 4.8% | 22.2% | 22.2% | 4.8% | 0.00202 | 1.1 |
| Mandoto | Anjoma Ramartina | 136 | 2% | 75.7% | 45.6% | 64.7% | 59.6% | 77.9% | 61.0% | 0.05138 | 177.3 |
| Ankazomiriotra | 125 | 0% | 60.0% | 32.0% | 44.8% | 39.2% | 60.8% | 44.8% | 0.03022 | 16.0 |
| Antanambao Ambary | 143 | 1% | 83.9% | 49.0% | 67.8% | 59.4% | 89.5% | 66.4% | 0.06089 | 69.6 |
| Mandoto | 153 | 1% | 73.2% | 47.1% | 53.6% | 45.8% | 66.0% | 48.4% | 0.03928 | 7.6 |
| Vasiana | 119 | 1% | 73.9% | 49.6% | 63.0% | 52.1% | 70.6% | 59.7% | 0.05056 | 26.2 |
| Vinany | 131 | 0% | 77.1% | 43.5% | 51.9% | 48.9% | 67.9% | 51.9% | 0.04404 | 7.8 |

## Table S2: Commune-level data missingness and data accuracy

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| District | Commune | Number of consultations, 2013 | Number of positive RDTs, 2013 | 2013 API | Mean register and HMIS discordance\* | Mean missing-ness |
| Ambatofinandrahana | Ambatofinandrahana | 5796 | 108 | 3.3 | 9% | 0% |
| Ambatomifanongoa | 2366 | 24 | 1.2 | 8% | 0% |
| Ambondromisotra | 2206 | 64 | 3.2 | 32% | 4% |
| Fenoarivo | 1573 | 14 | 0.8 | 36% | 1% |
| Itremo | 2331 | 90 | 12.2 | 73% | 1% |
| Soavina | 12841 | 126 | 4.9 | 31% | 1% |
| Ambohimahasoa | Ambalakindresy | 2683 | 63 | 3.8 | 13% | 1% |
| Ambatosoa | 1713 | 109 | 6.3 | 25% | 0% |
| Ambohimahasoa | 7859 | 108 | 11.4 | 168% | 2% |
| Ambohinamboarina | 1122 | 62 | 5.6 | 7% | 0% |
| Ampitana | 2355 | 23 | 2.1 | 23% | 0% |
| Ankafina Tsarafidy | 672 | 3 | 0.2 | 9% | 0% |
| Ankerana | 1475 | 40 | 3.5 | 19% | 3% |
| Befeta | 2335 | 37 | 2.1 | 16% | 24% |
| Camp Robin | 1845 | 22 | 1.7 | 18% | 0% |
| Fiadanana | 2201 | 112 | 6.0 | 29% | 1% |
| Ikalalao | 1179 | 46 | 3.1 | 34% | 1% |
| Isaka | 1171 | 11 | 1.0 | 20% | 2% |
| Manandroy | 2184 | 68 | 4.8 | 10% | 2% |
| Morafeno | 1156 | 13 | 1.1 | 161% | 0% |
| Sahatona | 1306 | 11 | 0.9 | 7% | 0% |
| Sahave | 1532 | 20 | 1.1 | 8% | 0% |
| Vohiposa | 1688 | 18 | 0.9 | 9% | 0% |
| Vohitrarivo | 0 | 0 | 0.0 | 14% | 1% |
| Ambositra | Alakamisy Ambohijato | 1813 | 31 | 3.4 | 80% | 0% |
| Ambalamanakana | 392 | 0 | 0.0 | 0% | 0% |
| Ambatofitorahana | 1436 | 47 | 4.9 | 30% | 0% |
| Ambohimanjaka | 6072 | 23 | 2.7 | 4% | 0% |
| Ambohimitombo I | 470 | 43 | 2.5 |  | . |
| Ambohimitombo II | 931 | 54 | 7.6 | 5% | 7% |
| Ambositra I | 16340 | 133 | 3.0 | 30% | 1% |
| Ambositra II | 2478 | 52 | 7.6 | 13% | 0% |
| Andina | 1914 | 16 | 0.9 | 10% | 2% |
| Ankazoambo | 1423 | 12 | 2.0 | 42% | 1% |
| Antoetra | 910 | 77 | 5.2 | 76% | 0% |
| Fahizay | 1645 | 0 | 0.0 | 42% | 1% |
| Ihadilanana | 4102 | 46 | 3.9 | 17% | 1% |
| Ilaka Centre | 4005 | 38 | 2.3 | 31% | 2% |
| Imerina Imady | 1779 | 42 | 6.5 | 34% | 1% |
| Ivato | 2061 | 3 | 0.2 | 12% | 0% |
| Ivony Miaramiasa | 1219 | 10 | 1.4 | 27% | 0% |
| Kianjandrakefina | 1521 | 52 | 3.9 | 2% | 1% |
| Mahazina Ambohipierenana | 3649 | 37 | 6.0 | 4% | 0% |
| Marosoa | 1040 | 22 | 1.2 | 27% | 1% |
| Tsarasaotra | 5041 | 51 | 2.2 | 70% | 1% |
| Anjozorobe | Alakamisy | 1639 | 1 | 0.2 | 15% | 4% |
| Ambatomanoina | 5442 | 174 | 7.1 | 23% | 0% |
| Amboasary Nord | 2374 | 14 | 2.0 | 3% | 1% |
| Ambohibary Vohilena | 4429 | 204 | 11.7 | 10% | 1% |
| Ambohimanarina Marovazaha | 717 | 2 | 0.4 | 28% | 0% |
| Ambohimirary | 1037 | 33 | 8.6 | 41% | 0% |
| Ambongamarina | 2033 | 17 | 1.0 | 29% | 0% |
| Amparatanjona | 3585 | 1 | 0.2 | 17% | 0% |
| Analaroa | 8555 | 60 | 5.2 | 200% | 1% |
| Anjozorobe | 4250 | 12 | 0.6 | 17% | 0% |
| Antanetibe | 2532 | 42 | 2.1 | 10% | 1% |
| Belanitra | 428 | 15 | 8.4 |  | 0% |
| Betatao | 2526 | 2 | 0.2 | 16% | 22% |
| Mangamila | 3893 | 2 | 0.1 | 68% | 0% |
| Marotsipoy | 1283 | 150 | 31.7 | 45% | 2% |
| Tsarasaotra | 2820 | 4 | 0.6 | 4% | 2% |
| Ankazobe | Ambohitromby | 1167 | 50 | 5.5 | 21% | 1% |
| Ankazobe | 3551 | 243 | 14.0 | 43% | 0% |
| Antakavana | 1077 | 73 | 13.3 | 6% | 0% |
| Antotohazo | 1374 | 88 | 9.2 | 170% | 1% |
| Fihaonana | 3945 | 226 | 10.8 | 34% | 1% |
| Kiangara | 2294 | 328 | 24.5 | 55% | 7% |
| Mahavelona | 3516 | 135 | 8.9 | 16% | 0% |
| Marondry | 2716 | 502 | 43.6 | 19% | 3% |
| Miantso | 1164 | 31 | 1.7 | 7% | 2% |
| Talata Angavo | 1382 | 357 | 26.8 | 15% | 1% |
| Tsaramasoandro | 2067 | 361 | 33.6 | 17% | 1% |
| Betafo | Alakamisy Anativato | 2115 | 13 | 1.1 |  | 1% |
| Alakamisy Marososona | 2331 | 83 | 8.9 | 59% | 1% |
| Ambatonikolahy | 2494 | 75 | 5.5 | 7% | 10% |
| Ambohimanambola | 2725 | 147 | 7.6 | 52% | 0% |
| Ambohimasina | 1465 | 8 | 0.4 | 22% | 16% |
| Andranomafana | 932 | 9 | 1.9 | 52% | 1% |
| Antohobe | 3409 | 167 | 11.3 | 89% | 3% |
| Antsoso | 1399 | 66 | 8.7 |  | . |
| Betafo | 11888 | 133 | 4.8 | 37% | 0% |
| Inanantonana | 1902 | 33 | 2.5 | 14% | 1% |
| Mahaiza | 4169 | 58 | 3.3 | 29% | 3% |
| Mandritsara | 858 | 1 | 0.1 | 11% | 3% |
| Manohisoa | 2210 | 28 | 5.1 | 5% | 0% |
| Soavina | 2173 | 81 | 5.6 | 7% | 0% |
| Tritriva | 1198 | 11 | 1.1 | 22% | 1% |
| Mandoto | Anjoma Ramartina | 7409 | 1524 | 177.3 | 18% | 0% |
| Ankazomiriotra | 6930 | 491 | 16.0 | 17% | 4% |
| Antanambao Ambary | 6370 | 789 | 69.6 | 28% | 0% |
| Mandoto | 5276 | 207 | 7.6 | 275% | 1% |
| Vasiana | 3340 | 411 | 26.2 | 38% | 5% |
| Mandoto | Vinany | 3390 | 159 | 7.8 | 15% | 6% |
| AVERAGE | -- | **2877.5** | **103.2** | **8.5** | **34.4%** | **1.9%** |

Note: Data from the first three columns come from HMIS. Malaria incidence is calculated from HMIS data by dividing the number of positive RDTs in the commune in 2013 by the estimated commune population. Data in the last two columns come from register abstraction using the selected four months' of data.

**\*** For 4 selected months; Fields reviewed include: number of consultations, number of RDTs done, and number of positive RDTs.The % discordance was calculated as |(total in register for month X – total in HMIS for month x/total in register for month X|. This value was calculated for each field for each month and averaged across all 12 scores; if a commune had more than one facility, scores were averaged among facilities.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Table S3: District-level measures of quality | |  |  |  |  |
|  | Monthly reports (A) | Register fields (B) | Accuracy (% discordance) (C) | Overall quality score (D) | Higher (1) versus lower (0) quality |
|  | *Avg. % missing fields in facility reports in past 12 months\** | *Avg. % missing fields for 4 selected months\*\** | *Mean absolute % discordance between tallied register counts and HMIS data\*\*\** | *1/[(A)+(B)+(C)]* | *Based on overall quality score in (D)* |
| Ambatofinandrahana | 0.1% | 1.2% | 31.6% | 3.04 | 1 |
| Ambohimahasoa | 0.2% | 2.1% | 32.8% | 2.86 | 1 |
| Ambositra | 0.0% | 1.0% | 27.8% | 3.48 | 1 |
| Anjozorobe | 0.0% | 2.0% | 35.0% | 2.70 | 0 |
| Ankazobe | 0.1% | 1.5% | 36.6% | 2.61 | 0 |
| Betafo | 0.1% | 2.8% | 31.2% | 2.93 | 1 |
| Mandoto | 0.3% | 2.8% | 65.1% | 1.47 | 0 |
| \* Fields reviewed include: Number of consultations, Number of RDTs done, Number of positive RDTs, and Number of ACTs dispensed. | | | | | |
| \*\* Fields reviewed include: Name, age, symptoms, and treatment given. | | | | |  |
| \*\*\* For 4 selected months; Fields reviewed include: number of consultations, number of RDTs done, and number of positive RDTs. The % discordance was calculated as |(total in register for month X – total in HMIS for month x/total in register for month X|. This value was calculated for each field for each month and averaged across all 12; Scores for all facilities in the districts were averaged to create a district-level score. | | | | | |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table S4: AIC and BIC from various models of SCRs versus API | | | | | | | | |
| **Model** | **Weighting** | **Spatial** | **PF13** | **PfMSP1** | **PfAMA1** | **PfCSP** | **PfGLURP** | **Pf latent  antigen** |
| **AIC** |  |  |  |  |  |  |  |  |
| Piecewise linear | Unweighted | Spatial | 162.7 | 152.8 | 150.9 | 148.9 | 170.7 | 151.3 |
| Piecewise linear | Weighted | Spatial | 159.2 | 152.0 | 148.3 | 144.7 | 166.2 | 149.2 |
| Piecewise linear | Unweighted | Nonspatial | 160.7 | 150.8 | 148.9 | 146.9 | 168.7 | 149.3 |
| Piecewise linear | Weighted | Nonspatial | 157.2 | 150.0 | 146.3 | 142.7 | 164.2 | 147.2 |
| B-spline with knots | Unweighted | Spatial | 167.7 | 156.5 | 153.6 | 152.1 | 170.9 | 156.3 |
| B-spline with knots | Weighted | Spatial | 164.0 | 155.3 | 151.4 | 148.6 | 166.2 | 153.8 |
| B-spline with knots | Unweighted | Nonspatial | 165.7 | 154.5 | 151.6 | 150.1 | 168.9 | 154.3 |
| B-spline with knots | Weighted | Nonspatial | 162.0 | 153.3 | 149.4 | 146.6 | 164.2 | 151.8 |
| Linear | Unweighted | Spatial | 165.1 | 157.1 | 162.9 | 149.9 | 173.7 | 163.1 |
| Linear | Weighted | Spatial | 161.3 | 154.1 | 159.5 | 145.2 | 170.0 | 159.9 |
| Linear | Unweighted | Nonspatial | 163.1 | 155.1 | 160.9 | 147.9 | 171.7 | 161.1 |
| Linear | Weighted | Nonspatial | 159.3 | 152.1 | 157.5 | 143.2 | 168.0 | 157.9 |
| 2nd deg poly | Unweighted | Spatial | 165.4 | 152.7 | 149.9 | 149.9 | 174.3 | 153.2 |
| 2nd deg poly | Weighted | Spatial | 161.9 | 151.5 | 147.7 | 145.8 | 169.8 | 150.8 |
| 2nd deg poly | Unweighted | Nonspatial | 163.4 | 150.7 | 147.9 | 147.9 | 172.3 | 151.2 |
| 2nd deg poly | Weighted | Nonspatial | 159.9 | 149.5 | 145.7 | 143.8 | 167.8 | 148.8 |
| 3rd deg poly | Unweighted | Spatial | 166.0 | 154.6 | 151.6 | 151.6 | 172.3 | 154.4 |
| 3rd deg poly | Weighted | Spatial | 162.2 | 153.3 | 149.4 | 147.6 | 168.0 | 151.8 |
| 3rd deg poly | Unweighted | Nonspatial | 164.0 | 152.6 | 149.6 | 149.6 | 170.3 | 152.4 |
| 3rd deg poly | Weighted | Nonspatial | 160.2 | 151.3 | 147.4 | 145.6 | 166.0 | 149.8 |
| **BIC** |  |  |  |  |  |  |  |  |
| Piecewise linear | Unweighted | Spatial | 177.6 | 167.7 | 165.9 | 163.8 | 185.7 | 166.3 |
| Piecewise linear | Weighted | Spatial | 174.1 | 167.0 | 163.2 | 159.6 | 181.1 | 164.2 |
| Piecewise linear | Unweighted | Nonspatial | 173.2 | 163.2 | 161.4 | 159.3 | 181.2 | 161.8 |
| Piecewise linear | Weighted | Nonspatial | 169.6 | 162.5 | 158.7 | 155.1 | 176.6 | 159.7 |
| B-spline with knots | Unweighted | Spatial | 187.6 | 176.4 | 173.5 | 172.0 | 190.8 | 176.2 |
| B-spline with knots | Weighted | Spatial | 183.9 | 175.2 | 171.3 | 168.5 | 186.2 | 173.7 |
| B-spline with knots | Unweighted | Nonspatial | 183.1 | 171.9 | 169.0 | 167.6 | 186.3 | 171.8 |
| B-spline with knots | Weighted | Nonspatial | 179.4 | 170.7 | 166.8 | 164.0 | 181.7 | 169.2 |
| Linear | Unweighted | Spatial | 177.5 | 169.6 | 175.4 | 162.4 | 186.1 | 175.6 |
| Linear | Weighted | Spatial | 173.7 | 166.5 | 172.0 | 157.7 | 182.4 | 172.3 |
| Linear | Unweighted | Nonspatial | 173.0 | 165.1 | 170.9 | 157.9 | 181.6 | 171.1 |
| Linear | Weighted | Nonspatial | 169.2 | 162.0 | 167.5 | 153.2 | 177.9 | 167.8 |
| 2nd deg poly | Unweighted | Spatial | 180.4 | 167.6 | 164.8 | 164.8 | 189.2 | 168.2 |
| 2nd deg poly | Weighted | Spatial | 176.9 | 166.4 | 162.6 | 160.7 | 184.7 | 165.7 |
| 2nd deg poly | Unweighted | Nonspatial | 175.9 | 163.1 | 160.3 | 160.4 | 184.7 | 163.7 |
| 2nd deg poly | Weighted | Nonspatial | 172.4 | 161.9 | 158.1 | 156.2 | 180.3 | 161.2 |
| 3rd deg poly | Unweighted | Spatial | 183.4 | 172.0 | 169.1 | 169.0 | 189.7 | 171.8 |
| 3rd deg poly | Weighted | Spatial | 179.6 | 170.7 | 166.8 | 165.1 | 185.4 | 169.2 |
| 3rd deg poly | Unweighted | Nonspatial | 178.9 | 167.6 | 164.6 | 164.5 | 185.2 | 167.3 |
| 3rd deg poly | Weighted | Nonspatial | 175.1 | 166.2 | 162.3 | 160.6 | 180.9 | 164.7 |
| Note: LCA = latent class antigen | |  |  |  |  |  |  |  |

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