Integrated surveillance approaches for malaria elimination: findings from the ENSURE programme in the Philippines

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As malaria transmission declines, surveillance systems must adapt to detect residual infections, monitor parasite susceptibility, and identify areas of ongoing transmission. The ENSURE programme evaluated complementary surveillance approaches in three Philippine provinces representing varying transmission intensities: Bataan (near-elimination), Occidental Mindoro (sporadic transmission), and Palawan, the province accounting for the majority of remaining malaria cases nationally.

Enhanced health facility surveys were conducted to improve detection beyond symptomatic case reporting. Across 6,572 participants screened in Palawan, 801 malaria infections were identified, of which 38% were subpatent and detectable only by molecular diagnostics. Enhanced surveillance detected infections across more than three times as many household locations as passive surveillance, demonstrating a substantial hidden reservoir capable of sustaining transmission.

To assess parasite susceptibility, over 300 *Plasmodium falciparum* isolates were genotyped for resistance-associated polymorphisms. No kelch-13 mutations linked to artemisinin resistance were detected, and temporal analyses indicated a decline in resistance markers consistent with national treatment policy changes, supporting the continued effectiveness of first-line therapies.

Multiplex serology was applied to 9,132 samples from the 3 sites Bataan, Occidental Mindoro, and Palawan, to characterise malaria exposure. Machine learning models achieved high accuracy for identifying recent *P. falciparum* infection (AUC = 0.96), and correctly predicted the absence of recent falciparum malaria exposure and infection in Bataan and Occidental Mindoro, where no cases had been reported for years prior to the survey. These findings confirm the utility of serological markers for reconstructing transmission patterns in near-elimination settings.

Spatial modelling further demonstrated strong associations between infection risk and forest proximity. Risk-based surveillance strategies nearly halved the cost per infected location detected while maintaining high detection probability.

Collectively, these findings highlight the value of integrated surveillance approaches for improving detection sensitivity, characterising transmission dynamics, and guiding targeted interventions. As countries approach malaria elimination, combining epidemiological, molecular, serological, and spatial tools will be critical for identifying residual transmission and supporting evidence-based elimination strategies.