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# QUANTIFYING THE IMPACT OF PROACTIVE COMMUNITY CASE MANAGEMENT ON SEVERE MALARIA CASES USING AGENT-BASED SIMULATION

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## ABSTRACT

Malaria remains a major global health threat, especially for children under five, causing hundreds of thousands of deaths annually. Proactive Community Case Management (ProCCM) is an intervention designed to enhance early malaria detection and treatment through routine household visits (sweeps), complementing existing control measures. ProCCM is crucial in areas with limited healthcare access and low treatment-seeking rates, but its effectiveness depends on transmission intensity and the coverage of existing interventions. To quantify the impact of ProCCM, we calibrated an agent-based simulation model for settings with seasonal transmission and existing interventions. We evaluated how different ProCCM scheduling strategies perform under varying treatment-seeking rates in reducing severe malaria cases. Our proposed heuristics—greedy and weighted—consistently outperformed a standardized, uniformly spaced approach, offering practical guidance for designing more effective and adaptive malaria control strategies.

## 1 INTRODUCTION

Malaria remains a major global health challenge, particularly in sub-Saharan Africa, with an estimated 263 million cases and nearly 600,000 deaths in 2023, most among children under five (WHO 2024). While interventions such as insecticide-treated nets, indoor spraying, and preventive treatment during pregnancy have reduced the burden, recent years have seen stagnation in progress.

A critical barrier is the lack of timely access to diagnosis and treatment in rural and remote regions, where distance, cost, and mistrust of health systems prevent care-seeking. Community case management was introduced to extend access by training community health workers to diagnose and treat malaria in Senegal. To improve uptake, a proactive version was introduced in 2012, known as proactive community case management. Under this model, health workers conduct regular village sweeps during the malaria season, testing symptomatic individuals and providing treatment or referral. Evidence suggested this approach reduced symptomatic prevalence and was later adopted nationally (Linn et al. 2015).

However, its impact on severe malaria outcomes has not been systematically studied, and there is limited guidance on how to best schedule sweeps in relation to local conditions. This study addresses these gaps by extending an agent-based malaria model to evaluate proactive case management for reducing severe malaria and by testing sweep scheduling strategies.

## 2 METHODS

We extend a validated agent-based malaria model to capture ProCCM interventions (Griffin et al. 2016). The human dynamics describe individuals moving through susceptible, asymptomatic, mild clinical, severe clinical, treated, and protected states. Probabilities of transition depend on immunity and superinfection. Mosquito dynamics are modeled through a compartmental framework including eggs, larvae, pupae, and adult stages, which drive transmission. Treatment-seeking behavior reflects the daily probability that a symptomatic individual seeks treatment (Wang et al. 2024). ProCCM sweeps override this behavior by diagnosing and treating all symptomatic cases encountered.

The Saraya Health District in Senegal was used as a case study. Weekly sweeps were piloted there in 2013 along with bed net distribution and seasonal chemoprevention. The model was calibrated to observed data including rainfall, prevalence, and case counts.

We evaluated three sweep scheduling heuristics. The uniform strategy spaced sweeps evenly across the season. The greedy strategy concentrated sweeps around peak symptomatic prevalence. The weighted strategy distributed sweeps proportionally to prevalence while maintaining temporal equity. Simulations explored scenarios with 5 to 20 sweeps per season and treatment-seeking rates ranging from 0.05 to 0.50.

## 3 RESULTS

Simulations show that proactive case management reduces both symptomatic prevalence and severe malaria, with stronger effects in low-access settings. At a treatment-seeking rate of 0.05, severe cases declined from over 20 with 5 sweeps to about 8 with 20 sweeps, a reduction of more than 60 percent. At 0.20, severe cases declined from about 10 to 3.5. At 0.50, reductions were smaller, from just above 2 to around 1.5. Thus, the intervention's greatest value is in settings with low treatment access.

Comparing strategies, greedy scheduling consistently outperformed others, producing the fewest severe cases under most conditions, particularly when sweep numbers were limited. Weighted scheduling performed moderately well, balancing coverage and responsiveness. Uniform spacing produced the highest case counts and was least effective. Differences between strategies narrowed as sweep numbers increased, with convergence around 20 sweeps. Prevalence patterns showed seasonal peaks in July to November, with sweeps reducing burden at intervention points. Greedy scheduling aligned sweeps with peaks, while weighted scheduling provided broader coverage.

## 4 DISCUSSION

The findings highlight three key insights. First, ProCCM sweeps robustly reduce severe malaria cases, confirming their value as a supplemental intervention. Second, the intervention is most impactful in low-access contexts, compensating for limited healthcare availability, while in higher-access areas the marginal benefit declines. Third, adaptive sweep scheduling is important for maximizing effectiveness. Greedy strategies provide the largest reduction, while weighted strategies offer more temporal equity.

Despite its effectiveness, ProCCM alone does not interrupt malaria transmission because asymptomatic carriers remain untreated. Nonetheless, its contribution to reducing severe cases, particularly among children, is substantial. Limitations include the absence of explicit modeling for high-risk groups such as pregnant women and constrained validation due to limited field data. Future work should focus on developing operationally feasible heuristics using real-time data, extending models to vulnerable groups, and strengthening empirical validation.

Overall, this study demonstrates that adaptive ProCCM strategies can substantially reduce severe malaria cases, especially in low treatment-seeking contexts, and provides evidence to guide more effective and equitable implementation.

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