RESIDUAL MALARIA HOTSPOTS IN PERU:

Findings for Policy Makers – Draft Document

Summary

The greatest proportion of malaria in the Americas is located in the Peruvian and Brazilian Amazon Basin. However, there have been few studies into the characteristics of the malaria vectors in these sites. In order to improve malaria control interventions, and move towards malaria elimination in Peru and Brazil, it is essential to have a complete understanding of malaria transmission in these areas.

The Peruvian Ministry of Health has recently released a document on malaria interventions that include: identification and stratification of risk areas, strengthening diagnosis and treatment, participation in the fight against malaria, comprehensive interventions, epidemiological surveillance systems, a communication campaign, and operational research. This plan is currently in the preparation stage, and it is therefore an especially important time to share this research with the Ministry of Health.

This study aimed to evaluate current control measures, social characteristics of the affected communities, and the biology of the malaria-transmitting vectors. This policy brief focuses on the research carried out in Peru. The project was located in four villages with an Annual Parasitological Index greater than 10, in two different riverine areas in the Mazán district of the Loreto Department. This study included the use of satellite and drone imagery, interviews, and mosquito collections and analysis. The findings showed that there are different malaria transmission patterns between the Napo and Mazán Rivers, and that different bacteria populate the larvae of different anopheline species. Recommendations include implementing intervention strategies that take into account the differences between the two rivers and measuring the impact of those strategies.

Key findings:

- *Anopheles darlingi* was the most abundant species, and the mosquitoes fed mostly outdoors in the Mazán and Napo river basins.
- Analysis of *An. darlingi* blood showed that the mosquitoes fed on humans more than they fed on chickens, cows and dogs.
- There was greater abundance of *An. darlingi*, a higher *An. darlingi* Human Biting Rate (HBR) and greater proportions of human blood meals in mosquitoes in the two Mazán River villages than in the two Napo River villages.
- More anopheline larvae (approx. 75% of 856) were present in water bodies within one kilometre of villages on the Napo River than in water bodies within one kilometre of villages on the Mazán River.
- High-resolution images collected using drones can detect *An. darlingi* breeding sites with 86.73% - 96.98% accuracy in the Amazonian Peru. This method could be crucial for managing vector breeding sites as an intervention against malaria.

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RESEARCH APPROACH

The research was conducted in two different riverine areas in the Mazán district of the Maynas province. Along the Napo river are Salvador (401 inhabitants) and Urcomiraño (329 inhabitants); along the Mazán River are Libertad (320 inhabitants) and Visto Bueno (65 inhabitants).

The objectives of this study were:

1. To compare prevalence/incidence of parasitemia among households with and without bednet use (ITNs/LLINs) and with/without IRS.
2. To assess the socioeconomic, behavioural, and environmental determinants of residual malaria through a combination of household surveys and satellite imagery.
3. Determination of vector biology metrics; quantification of environmental variables of aquatic mosquito habitats and genetic characterization of immature and adult *Anopheles darlingi* along Mazán River.

To do this, the following methodology was undertaken:

Comprehensive data on the local population was gathered through household surveys

House-to-house interviews were conducted using a structured questionnaire to collect information on the demographics of participants and their ownership and use of mosquito nets. Malaria morbidity data was collected both retrospectively and prospectively, and malaria prevalence for the communities along the Mazán and Napo Rivers was estimated using data from 2015-2016. All households and reported malaria cases were recorded and georeferenced, and maps were created using this data.

Satellite imagery and drone footage were used to map Anopheles *aquatic habitats*

Conventional and multispectral images were collected to identify and characterize the aquatic habitats of immature mosquitoes (larvae and pupae).

Comprehensive entomological data from study sites was collected

Adult mosquitoes were collected using the human landing catch technique and the barrier screen methodology. Mosquitoes were identified morphologically and analysed in the laboratory to determine whether they were infected with the malaria parasite (and which species of parasite), and what the mosquitoes last fed on (humans or animals, and what type of animal).

Analysis of the Anopheles *aquatic habitats*

Spatial distribution, physico-chemical and biological characterization of water bodies located up to approximately 1km from each village were performed. *Anopheles* larvae were collected from permanent and temporary water bodies. Water samples were taken and analysed. Molecular identification and georeferencing of larvae is in progress.

Full details of experiments carried out are available on:

www.vbd-environment.org

KEY ENTOMOLOGICAL RESULTS

1 An. darlingi *was the most common species*

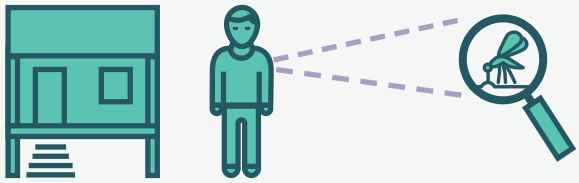
***Anopheles darlingi* was the most abundant species collected in each of the sites**

The infectivity rate (IR) of about 6,300 *An. darlingi* was approximately 1.6% (for *Plasmodium falciparum* and *Plasmodium vivax*).

- Other anopheline species identified were *An. oswaldoi*, *An. nuneztovari* and *An. triannulatus* s.l.

2 *Similarities and differences in vector behaviour between the Napo and Mazán Rivers*

Mosquito populations in both river basins were more likely to rest outdoors (exophilic), feed outdoors (exophagic) and feed on humans (anthropophagic).



- Villages located on the Mazán River presented greater abundance of *An. darlingi* and higher *An. darlingi* Human Biting Rate (HBR), Entomological Inoculation Rate (EIR) and Human Blood Index (HBI) than those on the Napo River, with a common abundance peak in June.
- The information obtained so far supports other findings at the epidemiological level, which show different transmission patterns between the Napo and Mazán Rivers.

3 *Similarities and differences in larvae between the Napo and Mazán Rivers*

Anopheline larvae (approximately 75% of 856) were present in water bodies within one kilometre of villages on the Napo River. This was more than in water bodies within one kilometre of villages on the Mazán River.

- There was bacterial diversity in larvae of *An. darlingi*, *An. triannulatus* s.l., and *An. rangeli*; in particular, greater differences in microbiota were found between anopheline species than between water bodies.

POLICY IMPLICATIONS

1

Intervention Strategies

Intervention strategies should be adapted to take into account the epidemiological and entomological differences between the two rivers.

2

Measurement

Once the strategies have been implemented, researchers and public health authorities should work together to measure their impact. Measurement could be conducted using the methods that the Malaria Zero team designed based on the entomological findings of this project. The methods measure the impact of interventions in three scenarios: 1) the effects of long-lasting insecticidal nets (LLINs); 2) the effects of environmental management in eliminating larval aquatic habitats; and 3) the effects of both intervention strategies.

About this project

This policy brief summarizes outcomes of the research project on *Residual malaria hotspots in Peru and Brazil: setting the stage for testing improved interventions*. The principal investigator of this project was Dr Dionicia Gamboa Vilela, Faculty of Science and Philosophy and Instituto de Medicina Tropical Alexander von Humboldt, Universidad Peruana Cayetano Heredia, Lima, Peru, as well as Marta Moreno Leirana, PhD, University of California San Diego La Jolla, CA, USA , current affiliation: The London School of Hygiene & Tropical Medicine. Other technical collaborators included: Universidad Peruana Cayetano Heredia (Lima, Peru), University of California San Diego (CA, USA), Institute of Biomedical Sciences, University of São Paulo (São Paulo, Brazil), Harvard T.H. Chan School of Public Health (MA, USA), Wadsworth Center, New York Department of Health (NY, USA), Biotechnology Institute and Institute of Bioscience, São Paulo State University Botucatu (São Paulo, Brazil), and the Instituto de Medicina Tropical Alexander von Humboldt, Universidad Peruana Cayetano Heredia (Lima, Peru).

This work was financially and technically supported by TDR, the Special Programme for Research and Training in Tropical Diseases. Technical support was also provided by the World Health Organization Global Malaria Programme. UK Aid also provided financial support.

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