Current state of residual malaria transmission in the Amazon region: knowledge gaps and potential control strategies

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Malaria in the Amazon

- In 2012: 469,000 malaria cases in the Americas, 91% in Amazonian countries, >70% *Plasmodium vivax* (WHO 2013). Transmission risk: low to moderate, hotspots.
- Diversity of anopheline vectors, *An. darlingi* most important.
ITNs and IRS coverage in the Amazon

- Variable use, less than 80% coverage in all countries.
- Few efficacy studies: ITNs provided 50% malaria reduction in Colombia and Venezuela.
- Differences in vector and human behavior: ITNs and IRS may not be effective in all transmission settings.
Residual transmission in the Amazon?

- ITNs and IRS may not provide transmission control:
  - Malaria transmission hotspots: mining/logging camps and new agricultural settlements in remote forest areas composed mainly of malaria-naïve immigrants that live in open dwellings and move frequently.
  
  - Amazonian anopheline vectors: exophagic/endophagic, unimodal, exophilic. Environmental changes alter their behavior and ecology.
  
  - Medical care and vector control is limited in these human settlements: residual transmission foci.

- Low transmission areas where context-specific malaria control strategies are lacking.
Residual transmission in the Amazon

• Residual transmission likely but it is not yet perceived as a problem:
  - NMCPs following standard malaria control practices that do not directly address this issue.
  - NMCPs conducting very limited active/passive surveillance in highly-mobile populations in remote forest areas difficult to access.

• Evidence for the role of residual transmission in maintaining malaria in the Amazon needs to be gathered and quantified so that it is clear that it should be a target for malaria eradication.

What information is available to address residual transmission?
Malaria vector distribution and bionomics

- Distribution of DVS, *An. darlingi* most dominant.
- Behavioral plasticity: natural/man-made larval sites, anthro/zoo philic, exo/endophagic, dusk/night/dawn biting, exo/endophilic.

**Table 6 Adult feeding and resting behaviour**

<table>
<thead>
<tr>
<th>Species</th>
<th>Source</th>
<th>Feeding habit</th>
<th>Biting habit</th>
<th>Biting time</th>
<th>Pre-feeding resting habit</th>
<th>Post-feeding resting habit</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Anthrophilic</td>
<td>Zoonphilic</td>
<td>Exophagic</td>
<td>Dusk</td>
<td>Night</td>
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<td><em>An. darlingi</em></td>
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<td><em>An. nuneztovari</em></td>
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<td><em>An. quadrimaculatus</em></td>
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<td>●</td>
<td>●</td>
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</table>

TAG: Rubia-Palis & Manguin (unpub. obs., 2009, 2010). ● = typical, ○ = examples exist. Numbers indicate the number of studies that found adults under each listed circumstance. *Anopheles albitorus* refers to the *An. albitorus* complex, which includes *An. albitorus*, *An. albitorus* sp. B, sp. E and *An. dagnarii*. *Anopheles marajoara* is listed separately.
Integrated vector management efficacy

- *Anopheles darlingi* predominant species in new agricultural settlements in Western Brazil.
- Positive correlation between *An. darlingi* HBRs and MIR.
- Control measures (ITN/IRS) reduced *An. darlingi* HBRs and EIRs.

![Figure 3](image_url) Correlation between malaria incidence rates (MIRs) and human biting rates (HBRs) for *Anopheles darlingi* (A) and *Anopheles albitrasis* (B), with 95% confidence intervals (dashed lines), respectively.  

Martins-Campos et al. 2012
Different collection strategies for different epidemiological situations (landscape, vector, human culture/behavior).

HLC/Shannon trap most accurate, effective anopheline collection method.

<table>
<thead>
<tr>
<th>Anopheline species</th>
<th>Human landing catch n (%)</th>
<th>Shannon nylon n (%)</th>
<th>CDC CO₂ + octenol n (%)</th>
<th>CDC UV n (%)</th>
<th>CDC CO₂ n (%)</th>
<th>CDC light + octenol n (%)</th>
<th>Total (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. stroedoi</em></td>
<td>220 (54.1)</td>
<td>125 (30.7)</td>
<td>58 (14.3)</td>
<td>2 (0.5)</td>
<td>2 (0.5)</td>
<td>0 (0)</td>
<td>407</td>
</tr>
<tr>
<td><em>An. marajoara</em></td>
<td>116 (57.1)</td>
<td>54 (26.6)</td>
<td>23 (11.3)</td>
<td>4 (2)</td>
<td>5 (2.5)</td>
<td>0 (0)</td>
<td>203</td>
</tr>
<tr>
<td><em>An. darlingi</em></td>
<td>111 (44)</td>
<td>136 (54)</td>
<td>1 (0.4)</td>
<td>4 (1.6)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>252</td>
</tr>
<tr>
<td><em>An. triannulatus</em></td>
<td>100 (35.6)</td>
<td>179 (63.7)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (0.7)</td>
<td>0 (0)</td>
<td>281</td>
</tr>
<tr>
<td><em>An. muneziavori</em></td>
<td>92 (52.6)</td>
<td>71 (40.6)</td>
<td>3 (1.7)</td>
<td>7 (4)</td>
<td>0 (0)</td>
<td>2 (1.1)</td>
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<tr>
<td><em>An. rangoi</em></td>
<td>57 (45.2)</td>
<td>68 (54)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.8)</td>
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<td><em>An. oswaldoi</em></td>
<td>9 (23.7)</td>
<td>29 (76.3)</td>
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<td>0 (0)</td>
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<tr>
<td><em>An. argyritarsis</em></td>
<td>7 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>7</td>
</tr>
<tr>
<td><em>An. benarrocki</em></td>
<td>4 (80)</td>
<td>1 (20)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>5</td>
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<tr>
<td><em>An. rondoni</em></td>
<td>2 (22.2)</td>
<td>7 (77.8)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>9</td>
</tr>
<tr>
<td><em>An. ovansae</em></td>
<td>0 (0)</td>
<td>4 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4</td>
</tr>
</tbody>
</table>

Total: 718 (47.6) | 674 (44.7) | 85 (5.6) | 17 (1.1) | 10 (0.7) | 2 (0.1) | 1 (0.1) | 1,507

CO₂: carbon dioxide; UV: ultraviolet light.

Bento Pereira Lima et al. 2014
Highly mobile populations (clinical/asymptomatic) in areas difficult to access in terms of malaria treatment and vector control:
- Agricultural settlements
- Gold mining and logging camps
- Military outposts


3. Establishment of *An. darlingi* laboratory colonies.


5. Identification and treatment of asymptomatic cases.

6. ITNs efficacy studies: vector control and human practices.
Development of new tools for residual transmission control


3. Models to quantify residual transmission.

4. Alternative insecticides (chemical and biological) to reduce development of insecticide resistance.

5. Rapid, reliable diagnostics and effective treatment for asymptomatic cases.

Partnerships to target residual transmission

• Strategic partners:
  - NMCPs
  - WHO RBM
  - USAID/AMI
  - PAHO/RAVREDA
  - BMGF
  - Research and academic institutions working in the region: 2 ICEMRs, CDC-CAP, NAMRU-6.

Goal: Develop evidence-based, strategic plans to control residual transmission in the Amazon taking into account eco-epidemiological context (vector, pathogen, human variation).
Role of residual transmission work stream

• Establish a regional initiative, (e.g. South American Residual Malaria Transmission Working Group- SARMaT WG) headed by regional experts (strategic partners) to increase exchange and dissemination of relevant information from current malaria surveillance and control activities.

• SARMaT WG will use existing initiatives such as WHO RBM/PAHO, AMI/RAVREDA, BMGF to access the larger network of research/academic institutions conducting epidemiological, entomological and social studies relevant to residual transmission.

• SARMaT WG will reach potential industry partners from multiple sectors and encourage them to participate so that their efforts can be focused through close communication with regional NCMPs and scientific institutions.
Following successful establishment of research priorities and goals, a regional plan approved by each participating partner will be developed. SARMaT will use the existing initiatives to disseminate information through traditional and online media, and ultimately develop an online database where partners can contribute epidemiological, social information regarding populations at risk; information on anopheline vector behavior, abundance, geographic distribution, insecticide resistance; efficacy of treatment (malaria drugs) and vector control practices, both standard and novel.

SARMaT will support continuous technology transfer and capacity building in NCMPs.
Acknowledgements

- AMI/RAVREDA
- CDC
- PAHO/WHO
- Regional NMCPs
- Swiss TPH & RBM VCWG
- USAID