Abstract

Vector bionomics and transmission intensities of malaria vectors on Bioko Island over 14 years of integrated vector control

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Entomological surveillance has been an integral part of the Bioko Island Malaria Control Project (BIMCP) since the implementation of the project in 2004. Systematic vector surveillance over the years continued to inform and guide the vector control interventions in attaining remarkable outcomes. This study analyses the trend in the vector bionomics and transmission intensities of the local vectors since the inception of the BIMCP. The feeding and resting behaviors, as well as the compositions of the local vectors, were monitored using window traps, CDC light traps, and human landing catches. Trends in vector densities, sporozoite rates, and the entomological inoculation rates (EIR) were determined. Phenotypic resistance profile of the malaria vectors as well as target-site resistance and metabolic resistance patterns were also monitored. An gambiae s.s., (S and M forms) constituted 45% of the local vectors at baseline with An funestus 45% and An melas 10%. However after two years of IRS An. funestus s.l. was eliminated. In 2009, An gambiae s.s. S. was also eliminated and as of 2017, An gambiae s.s. M (An. coluzzii) (70%) and An. melas (30%) remained the main vectors on the Island. Biting rates have reduced from an average of 35 bites per person per night in 2009 to an average of 8 bites per person per night in 2017. Vectors biting behavior shifted to more of outdoor biting between 2004 and 2014. The EIR has dropped from 1,214 infective bites person per annum at baseline to 13 infective bites person per annum in 2017. The frequency of kdr-w has increased to over 85% in the vector population in addition to the presence of P450s pyrethroid metabolizers. However, AChE mutations have not been detected. The planning, implementation, monitoring and evaluation of vector control interventions rely on the knowledge of the local vectors for effective programs. Changes in vector behaviors and transmission intensities are essential in directing vector control interventions and measuring the impacts of such interventions.
Malaria vectors bionomics and transmission intensities on Bioko Island over 14 years of integrated malaria control.

ASTMH 2018, Session 116
New Orleans, 31 October 2017

Godwin Fuseini

Medical Care Development International
The Bioko Island, Equatorial Guinea

- Bioko is the main Island of Equatorial Guinea of about 32km of the coast of Cameroon.
- A population of about 335,000 people
- Malaria situation pre-intervention, in 2004
  - *P. falciparum* prevalence in children 2-14 years in 2004 was 45%
  - Prevalence of moderate/severe anaemia (Hb< 8 g/dl) in children aged 1 to 5 years in 2004 was 15% *(Cook et al., 2018. Malar J)*
  - EIR of over 800 infective bites per person per annum *(Cano et al., 2004. J. Med. Entomol)*
Review of EIRs across 23 sub-Saharan Africa

Entomological inoculation Rates

- Equatorial Guinea
- Cote d'Ivoire
- Burundi
- Congo
- Sierra Leone
- Burkina Faso
- Nigeria
- Madagascar
- Benin
- Liberia
- Mali
- Sudan

Malaria Journal

The multiplicity of malaria transmission: a review of entomological inoculation rate measurements and methods across sub-Saharan Africa

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Published: 22 January 2009
Malaria journal 2009, 8:9 doi:10.1186/1475-2875-8-9
Accepted: 12 January 2009
The Bioko Island Malaria Control Project

The Bioko Island Malaria project
• Implemented since 2004 by Medical Care Development international (MCDI) in Partnership with MoHSW

Project funding (Public Private Partnership)
• Marathon Oil, Noble Energy, Atlantic Methanol, GEPetrol, SONAGAS, and the Government of Equatorial Guinea

Integrated malaria control approach
• Vector control, Case management and SBCC
• Capacity training and M&E
• Malaria Vaccine trial Initiative
Bioko Island vector control Interventions

- Continuous distribution of LLINs at ANC and primary schools
- Larval Source Management
  - 2014-present: Targeted larviciding with *Bti* in priority areas.
Bioko Island Entomological monitoring

- Baseline HLC/WET (Cano et al., 2004/BIMCP)
  - Species composition
  - Feeding behavior/HBI
  - Vector densities
  - Sporozoite rates
  - EIR
  - Insecticide resistance monitoring
Composition of vector species

Species at baseline (2003)
- An. gambiae s.s.: 45%
- An. coluzzii: 29%
- An. melas: 10%
- An. funestus: 16%

Species in phase III (2018), n=2,959
- An. coluzzii: 78%
- An. melas: 22%

Species in phase I (2006)
- An. coluzzii: 89%
- An. melas: 11%

Species in phase II (2009)
- An. coluzzii: 52%
- An. melas: 48%

Window traps

2 rounds IRS

25 rounds IRS

Human landing Catches

Species phase III (2018), n=2,959
- An. coluzzii: 22%
- An. melas: 78%
Biting rates (HLC)

- Decreased biting rates (30HBR to 5)
- More outdoor biting between 2009 and 2014
- Additional intervention between 2014 and 2016
Blood meal analysis and biting period

- Blood meal analysis-2017
  - HBI-0.84. Dog-0.05. Chicken 0.03 and Mixed-0.08
  - Vectors are largely anthropophagic
  - Biting rate still peaks at 11pm
Impact of outdoor biting on malaria transmission

• Earlier study suggested vectors were endophilic (Molina et al., 1993 J Med Entomol)
• Between 2009 to 2014 changed in biting behavior
• Survey in 2013 indicated 95% of the population is indoor at 11pm, peak biting period of vectors
• The majority of resources should remain with control measures that target indoor
Insecticide resistance monitoring

Bioassays using the WHO’s standard susceptibility tests

- Indication of vector-resistance from 2014 – present
  - Deltamethrin and DDT
  - Vectors susceptible to carbamates and organophosphates

![Bar chart showing mortality rates for different insecticides over time.](chart.png)

- % Mortality at 24hrs
- % susceptibility

<table>
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<td>82%</td>
<td>80%</td>
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BIMCP II

BIMCP III

MCDI
Target-site and metabolic resistance

- Frequency of *kdr-w* (L1041F) allele has increased significantly over the last 9 years.
- Ace1 (G119S) mutation has not been detected.
- Presence of metabolic resistance to pyrethroid.
Operational Plan for insecticide resistance management on Bioko Island

Recommendations for vector control

- Pyrethroid should no more be used for IRS
- Use of PBO LLINS.
- Use of carbamates and organophosphates. Currently using ACTELLIC 300CS
- Larviciding with non-pyrethroid insecticide
- Considering the use of neonicotinoid/pyrethroid formulations
- Routine insecticide resistance monitoring should be maintained
Sporozoite rates (HLC)

![Bar chart showing sporozoite rates from 2009 to 2018 (Jan-Jul) for An. coluzzii and An. melas in BIMCP II and BIMCP III.]
EIR_Bioko Island

The graph shows the number of EIR Historic sites and EIR Expanded sites from 2003 to 2017. The x-axis represents the years, and the y-axis represents the number of sites. The red bars represent EIR Historic sites, and the black bars represent EIR Expanded sites.

- 2003: The number of EIR Historic sites is significantly higher than the EIR Expanded sites.
- 2009: The number of EIR Historic sites is slightly lower than the EIR Expanded sites.
- 2010: The number of EIR Historic sites is lower than the EIR Expanded sites.
- 2011-2017: The number of EIR Historic sites is consistently lower than the EIR Expanded sites.
Moderate to severe anaemia in children aged 1–5 years
• Reduced from 14.9 to 1.6%.

Bioko Island malaria parasite prevalence (2-14yrs)
Infection importation: a key challenge

- Parasite prevalence on mainland (Bata) in 2015 46.7% vs 15.4% on the Island in 2015
- Four boat sailings per week and approximately ten flights per day between Malabo on Bioko and Bata on mainland Equatorial Guinea,
- Around 21,000 people arriving on Bioko every month from the mainland.
- Infection in arriving boat passengers was substantially higher than in those departing (70 vs 38%, $p = 0.017$).
- Phase IV aims at standard control and the introduction of malaria vaccine currently on trial.
Conclusion

• Vector species composition has changed
  • *An funestus* and *An gambiae s.s* disappeared

• Biting behavior has changed but does not impact on malaria transmissions

• Vectors are still anthropophagic and bite largely at mid night
  • LLINs and IRS still effective

• Vectors developed resistance to 2 classes of insecticides
  • Operational plan to manage insecticide resistance in place

• Infection importation remains a challenge
Acknowledgements

Bioko Island Malaria Control Project Implementers

Collaborators

Bioko Island Control Malaria Project Donors