Broadening vector control targets for malaria elimination

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Historic PHC malaria cases (2003)

An. fluviatilis (S)  
- High

An. culicifacies (BCE)  
- Low

An. culicifacies (BCE)  
- High

Anthropophilic  
Zoophilic
PHC malaria cases (Pf)

2003

2004

2005

2006

2007

2008

2009

2010

2011

2012

2013
PHC malaria cases (Pf)

• Historic malaria peak in winter months (Nov-Jan).
• Current data suggest peak has disappeared.
• Why?
Vector density in different dwellings (Cattle Sheds – CS; Human Dwellings – HD)

- An. culicifacies – CS
- An. culicifacies – HD
- An. fluviatilis – CS
- An. fluviatilis – HD
Genetic analysis of species complex and Blood Meal Analysis

BMA Analysis

- Bovine: 61.7%
- Human: 26.8%
- Bovine+Human: 4.8%
- Others: 4%
- Unfed: 2.4%

Sibling species

- S: 55.80%
- T: 29.20%
- ??: 14.20%
Genetic analysis of species complex and Blood Meal Analysis

- Historic data indicate S type only (strongly anthropohilic and anthropophagic).

- We now find many more T type (and this is much more zoophagic).

- Provides an explanation for loss of classic malaria peak in Nov-Jan.

- Shift is in species complex (not a shift in behavior *per se*). This mirrors shift from *An. gambiae* to *An. arabiensis* in parts of Africa.

- Possible result of LLINs and IRS?
Current situation:

• In our study site, transmission is by *An. culicifacies* and *An. fluviatilis*. Both are predominantly zoophagic, with higher densities found in cattle sheds than domestic dwellings.

• More broadly, *An. culicifacies* is the key vector throughout India, with *An. stephensi* in urban areas also very zoophilic.

• Yet IRS and LLINs target vectors in human dwellings – is this sufficient for elimination (India joined APMEN with the aim of elimination by 2030)?
We have been conducting some basic modeling of malaria transmission to evaluate impact of IRS and how additional targeting of cattle sheds might alter prospects for elimination in areas dominated by zoophilic vectors.
Effect of cattle feeding (zoophagy) and mortality from human-based intervention (IRS or LLIN) on malaria transmission intensity (basic reproductive number, $R_0$)
Potential for elimination using cattle- vs human-based intervention depending on level of cattle feeding

5% human-feeding

50% human-feeding

95% human-feeding

1.3 equivalent to 40% average mortality per feed from intervention
4.1 equivalent to 80% average mortality per feed from intervention
- Residual transmission is sustained by zoophilic vectors.
- Use of IRS or LLINs in domestic dwellings is not sufficient to reduce transmission below the elimination threshold, even at maximal coverage.
- The extension of IRS to attack the zoophilic cycle can tip malaria over the edge.
- This could be achieved with even modest coverage (and use of non-repellant product).
- IRS of cattle sheds was part of the eradication campaign in the 1960’s but is not part of current control policy.
- IRS technology exists and could be deployed now (i.e. an operational tool that does not need years of R&D).
- Also creates opportunities for development of novel resistance management strategies.