Statistical power analysis framework to design robust vector control experiments in semi-field systems.

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Introduction

- Vector control (VC) remains one of the most efficient strategies against malaria.
- Primary VCs: Long-lasting insecticide net (LLIN) and Indoor residual spraying (IRS)
- Supplementary measures e.g., larviciding are potential complement to primary VCs
Semi-field experiments (SFE)

• Most of people doing SFE neglect power analysis due to limited number of people with particular expertise.

• Semi-field is self-contained system with all necessary conditions for vector lifecycle where SFE are conducted.

• SFE are good first way of understanding the impacts of potential new vector controls before field trials.

• However, proper design of SFE is critically important to ensure the outcomes are measurable and robust.

Lwetoijera et al. (2019)
Power analysis

• It is crucial to have information on whether the experimental study will be informative before its commencement. This is the aim of power analysis.

• The use of power analysis in vector control studies can potentially help to avoid:
  o Waste of resources
  o Ethical concerns
  o Promising control methods being prematurely dismissed

Johnson et al., (2015), Jennions & Moller (2003), and Ioannidis (2005)
This statistical power analysis framework

• Standard methods for power analysis are suitable only for simple statistical analysis i.e., comparing means using t-tests or ANOVA

• This simulation-based power statistical power analysis framework is flexible, easy to extend and can accommodate sources of random variations compared to standard power frameworks
Objectives

• **Objective:** Developing a statistical power analysis framework to design robust vector control experiments in semi-field systems

• **Research questions:**
  
  i. How many treatment chambers are needed?
  
  ii. How often should mosquitoes be sampled?
  
  iii. How many mosquitoes should be sampled?

• **Case study:**
  
  • LLIN alone, combination of LLIN and autodissemination of pyriproxyfen (PFPa).
Autodissemination of pyriproxyfen (PPFa)

- PPFa reduced and suppressed stable populations of mosquitoes under semi-controlled settings

Lwetoijera et al. (2019)
Methods

• Estimated statistical power across a range of semi-field experimental design objectives and scenarios
• Experiments were testing LLIN alone and the LLIN-PPFa interaction

Fig 1: Example of number of chambers per treatment
Methods...

• Simulated 1000 data sets assuming that the alternative hypothesis is true i.e., intervention effect is non-zero.

• For each simulated data set, a generalized linear mixed-effects model (GLMM) was fitted and a statistical test of the null hypothesis (H0) was performed.

• Calculated the proportion of simulated data sets in which the H0 was rejected. This proportion is the power estimate.
GLMM: single intervention

• A GLMM with a negative binomial distribution
• Response variable: mosquito counts from treatment chambers
• Explanatory variables;
  o LLIN
  o Time (in week)
  o LLIN*Time
  o Inter-chamber variance – random effect
• LLIN reduced population by 80% at the end of an experiment
GLMM: combined interventions

• A GLMM with a negative binomial distribution
• Response variable: mosquito counts from treatment chambers
• Explanatory variables:
  o LLIN
  o PPF
  o Time (in week)
  o LLIN*Time
  o PPF*Time
  o LLIN*PPF
  o LLIN*PPF*Time
• Inter-chamber variance – random effect
Treatment effects

Table 1: Proportions of mosquitoes we are assuming will remain in each compound at the end of the experiment

<table>
<thead>
<tr>
<th></th>
<th>PPF</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>LLIN</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3%</td>
</tr>
</tbody>
</table>
Results 1: Single intervention

- Power increased with increasing chambers per treatment, sampling frequency and number of mosquitoes to be sampled.
Results 2: Combined interventions

- Power increased with increasing chambers per treatment, sampling frequency and number of mosquitoes to be sampled.
Conclusion and future works

• For this case study, four chambers and weekly sampling, with at least ten mosquitoes to be sampled were recommend.

• A generic statistical power analysis framework developed may be adapted to design robust vector control experiments in semi-field settings.
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