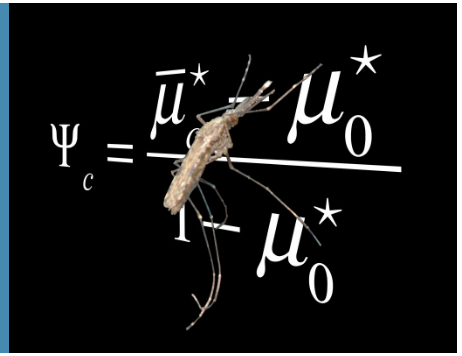
Swiss TPH
Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse
Associated Institute of the University of Basel

Infectious Disease Modelling Unit
Department of Epidemiology & Public Health



Pooled analysis of LLIN durability monitoring studies:

What is the effectiveness (in controlling malaria) of a mass distributed cohort of LLINs over time and where can the greatest gains be made?

- Improving physical durability? (more tear resistant nets / care and repair BCC)
- Improving insecticide retention? (nets with better decay profiles / care BCC)
- Improving use of existing nets? (BCC)
- Improving LLIN survival? (BCC on end of life)

Olivier Briët

VCWG LLIN Priorities Workstream, 7 February 2018

Swiss TPH
VECTORWORKS
Scaling Up Vector Control for Malaria Prevention
USAID FROM THE AMERICAN PEOPLE
CDC
U.S. President's Malaria Initiative

PMI country studies

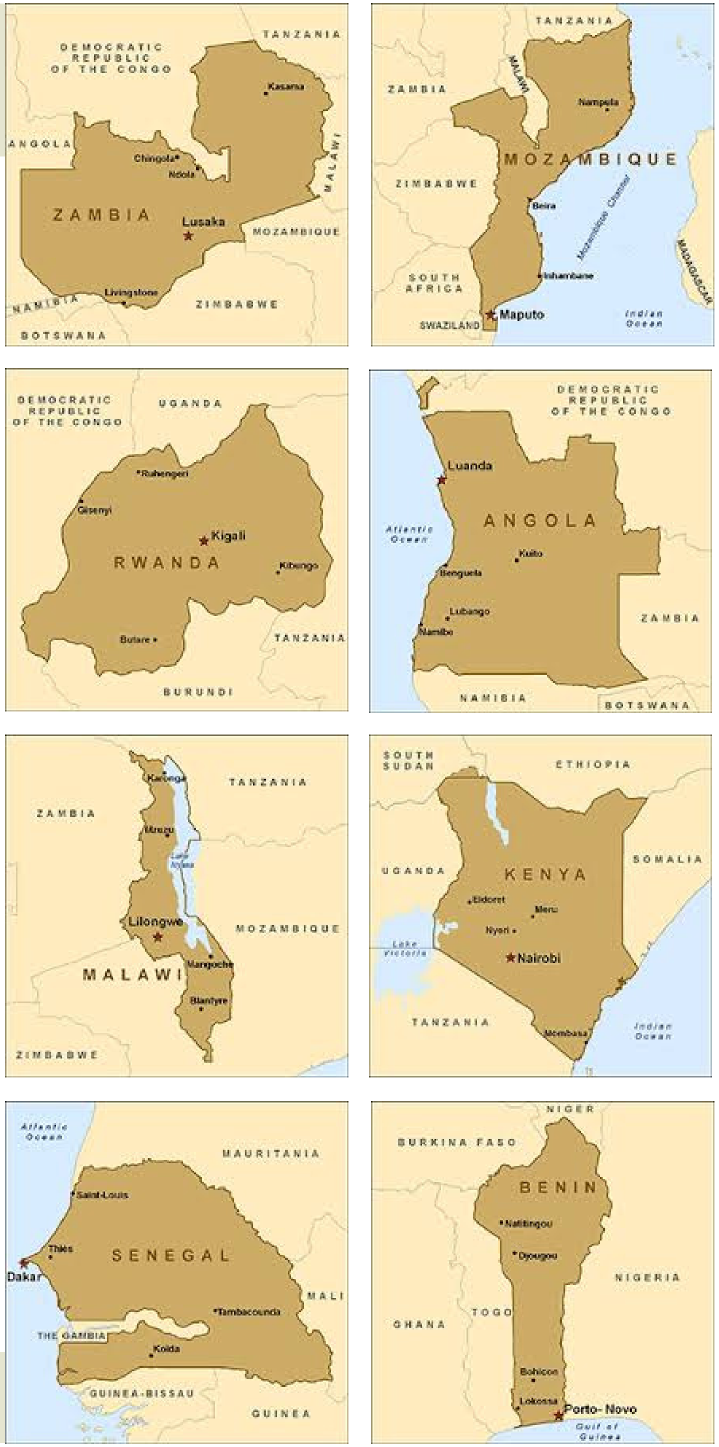
In 2009–2015, PMI has funded a number of LLIN durability studies

Pooled analysis of all data from 8 country studies

21,000 LLINs monitored in 37 sites

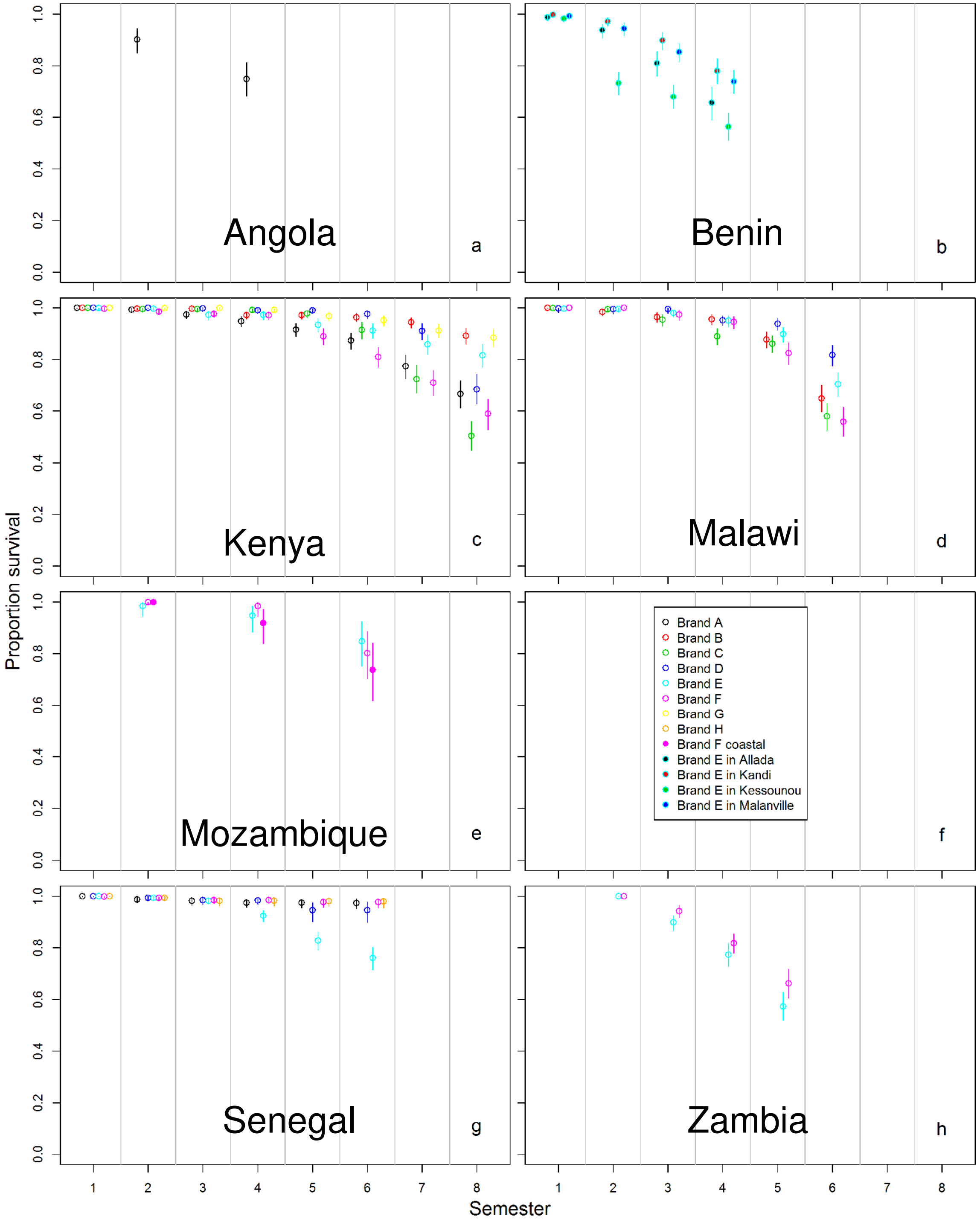
Raw data from Rwanda were not available for some key variables.

Net types:
1 DawaPlus 2.0
2 DuraNet
3 Interceptor
4 Netprotect
5 Olyset
6 PermaNet 2.0
7 PermaNet 3.0
8 LifeNet.

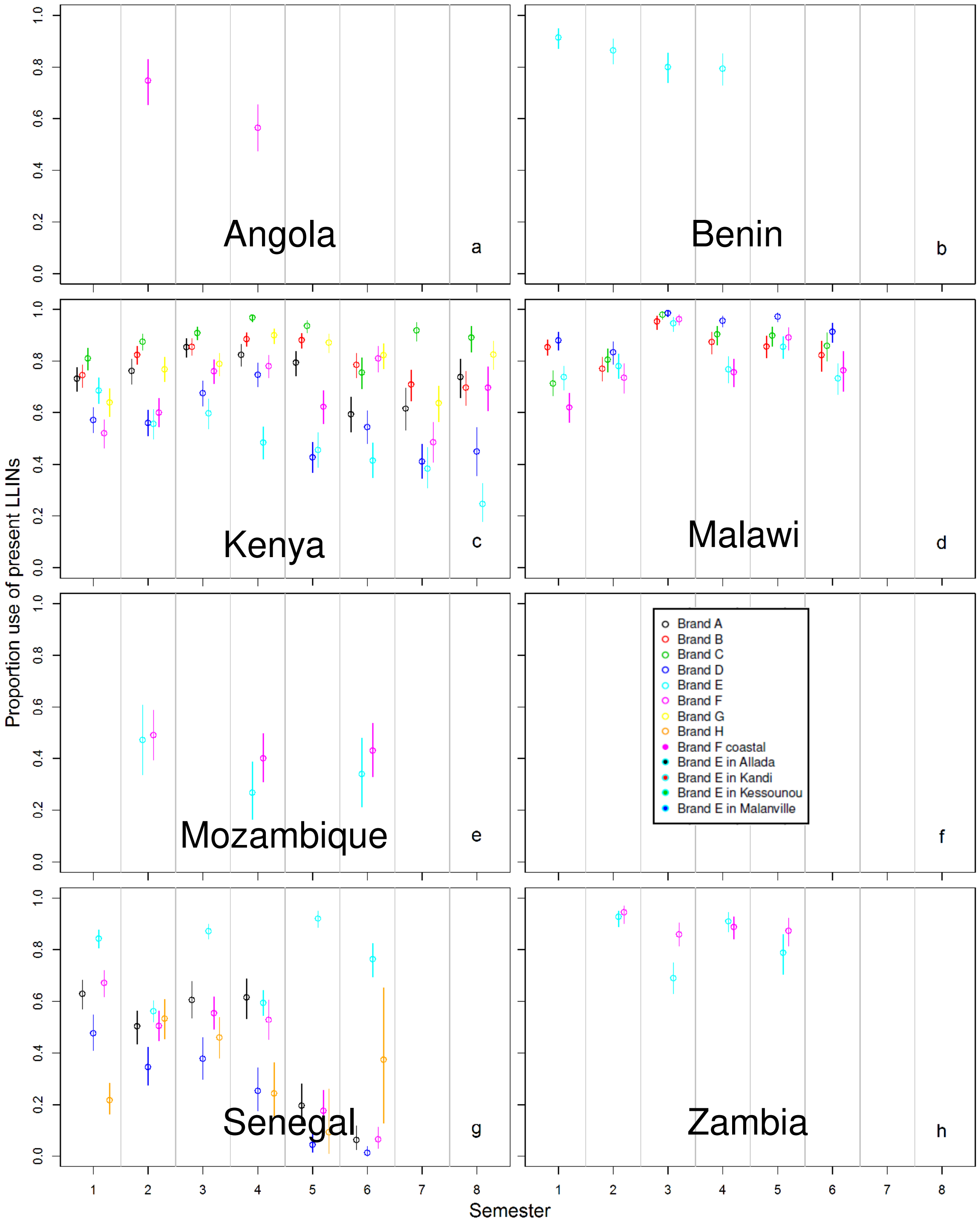


Survival (1-Attrition)

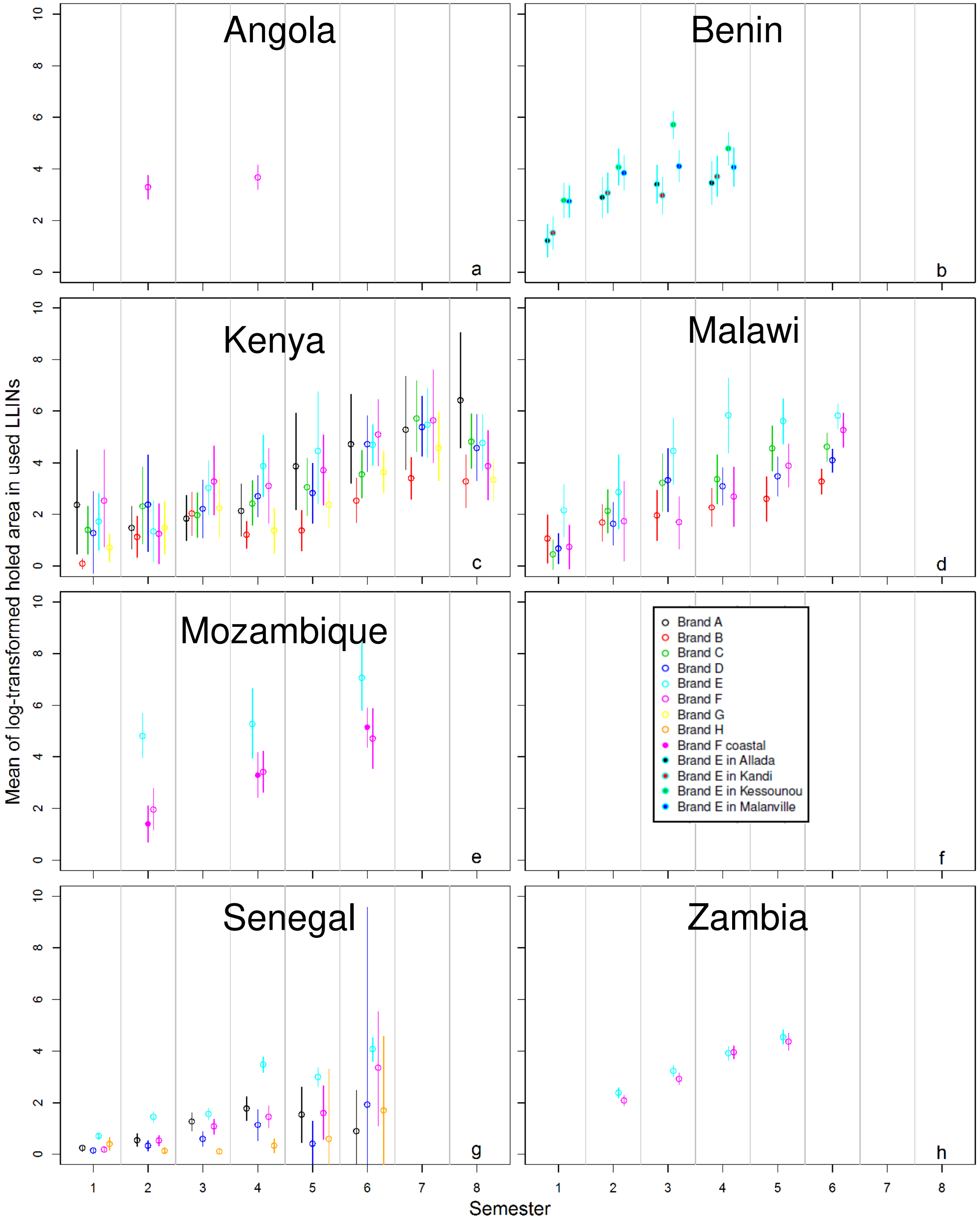
attrition due to being destroyed, not those lost due to being given away



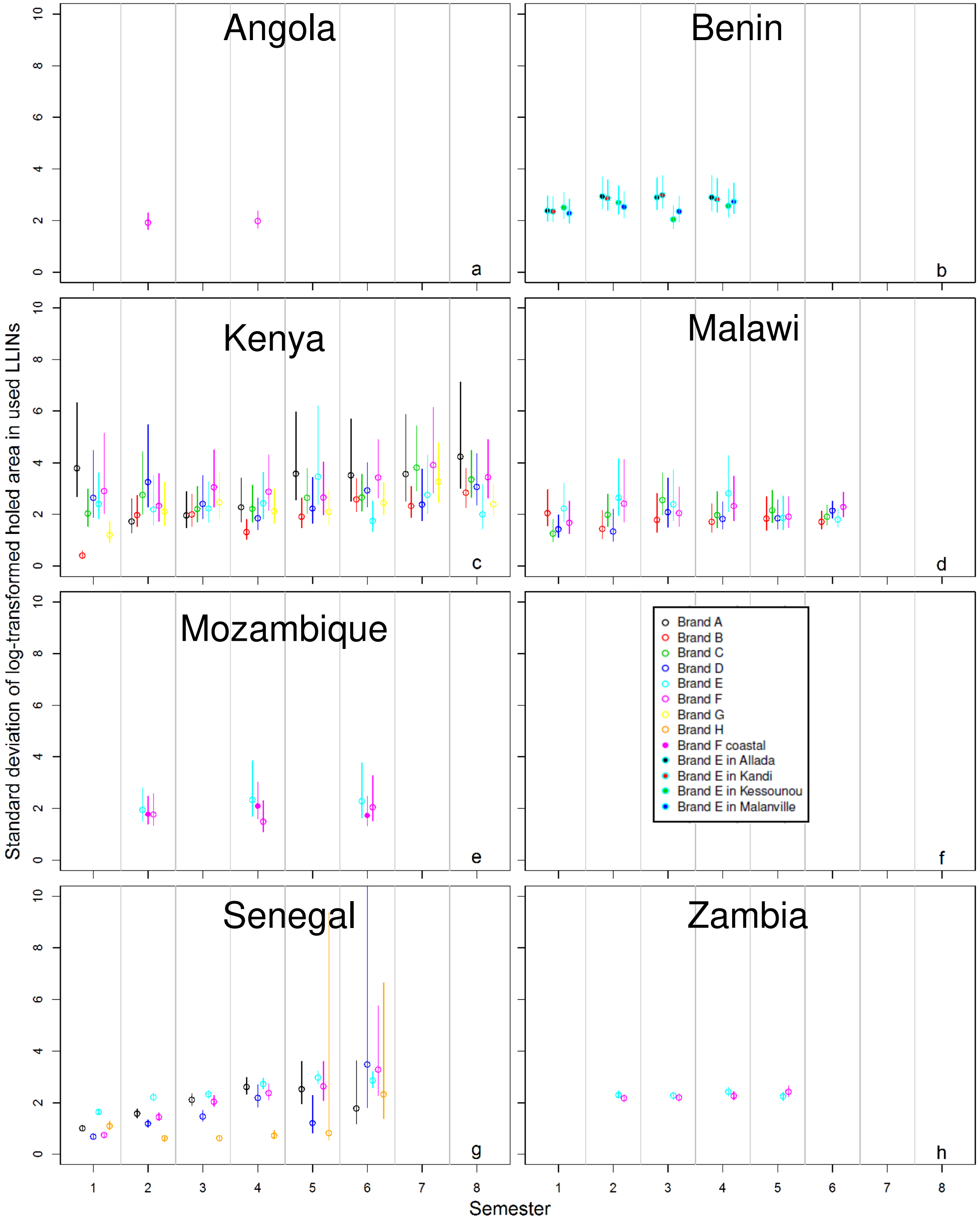
Use (of study nets)



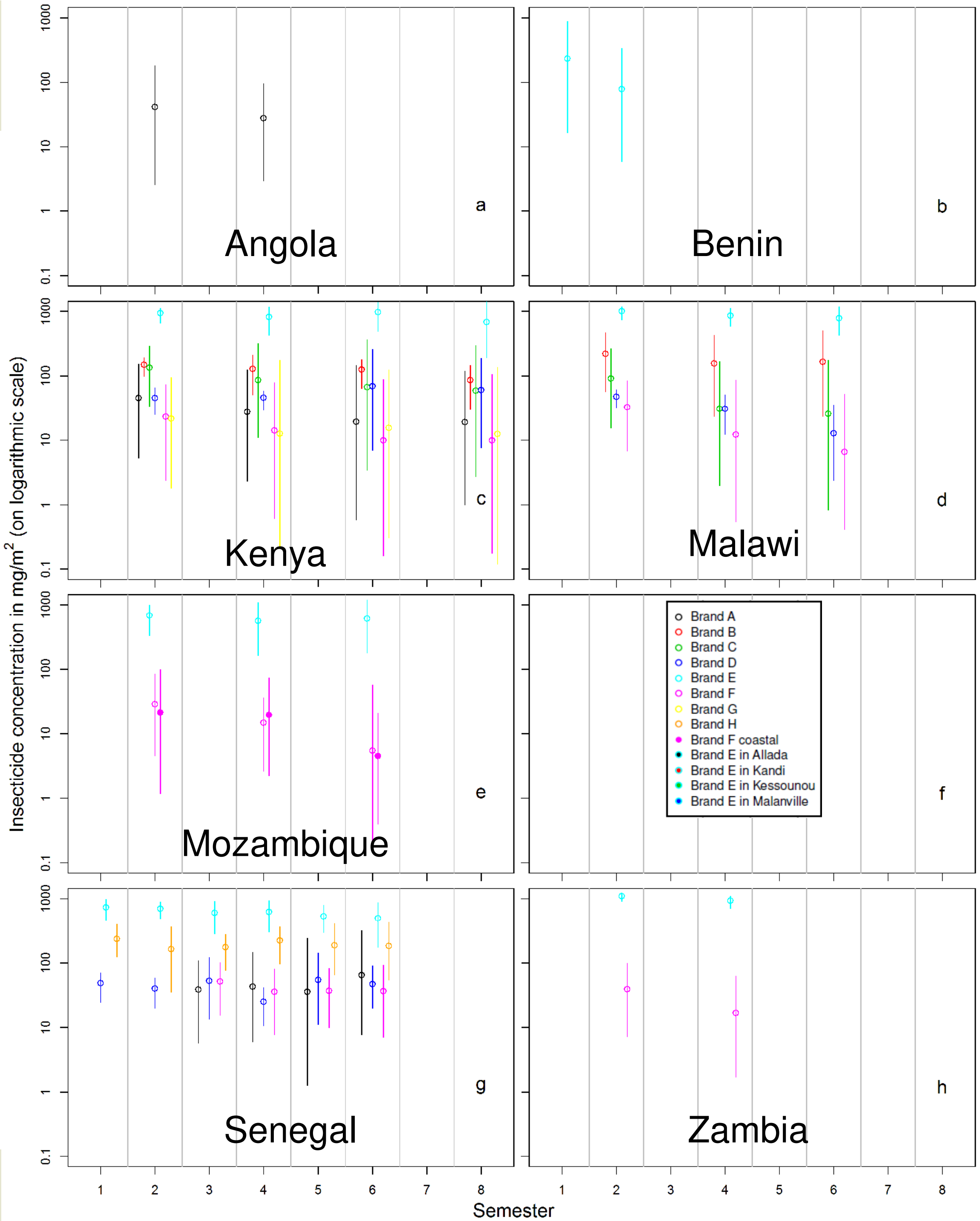
Mean of log holed area (in cm²) in used LLINs



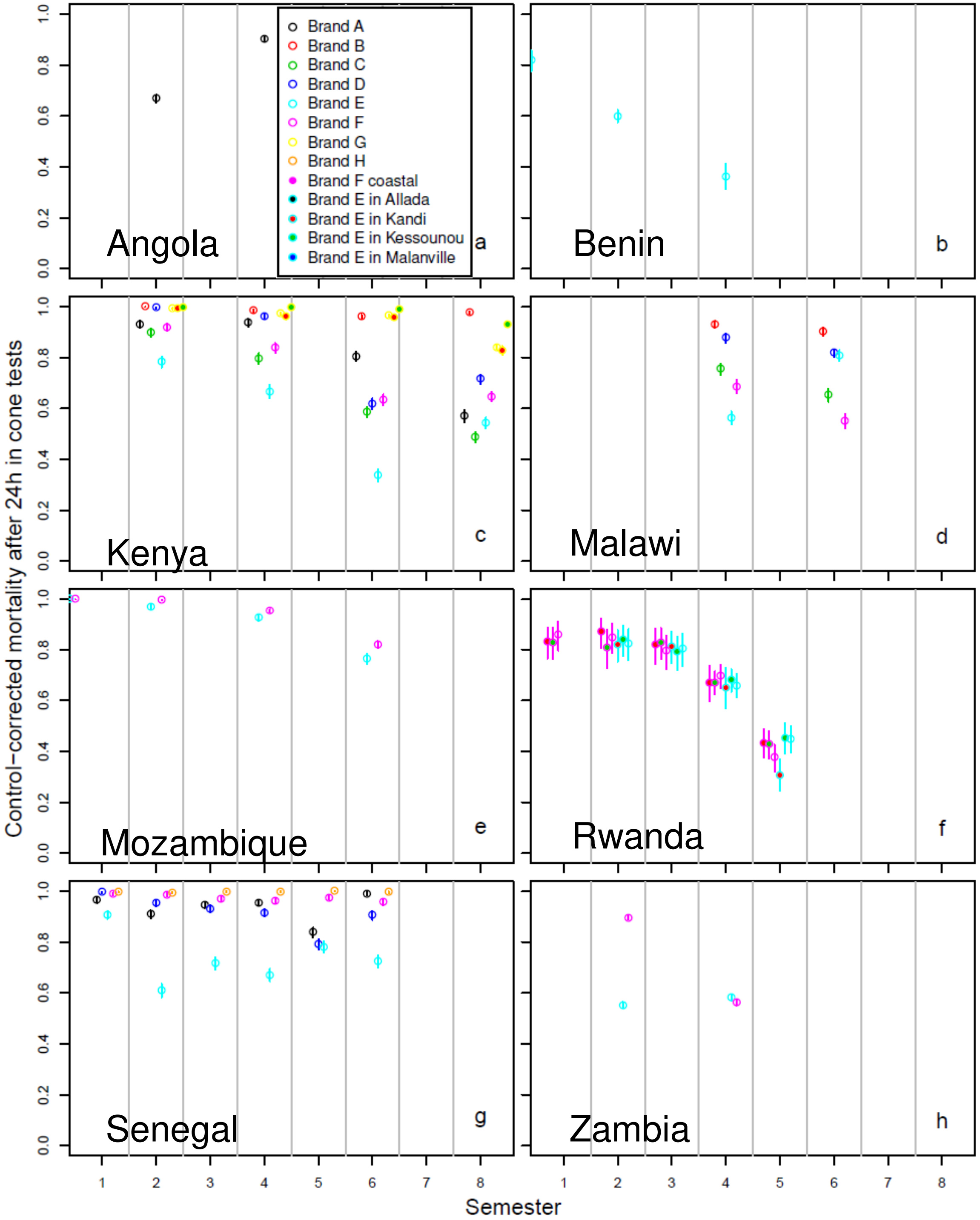
Standard deviation of log holed area (in cm²) in used LLINs



Insecticide content (mg/m²) in used LLINs



Corrected 24-h mortality in cone tests



Vector model (no feedback Human2Mosquito)

A mathematical model for the dynamics of malaria in mosquitoes feeding on a heterogeneous host population

Nakul Chitnis[a]*, Thomas Smith[a] and Richard Steketee[b]

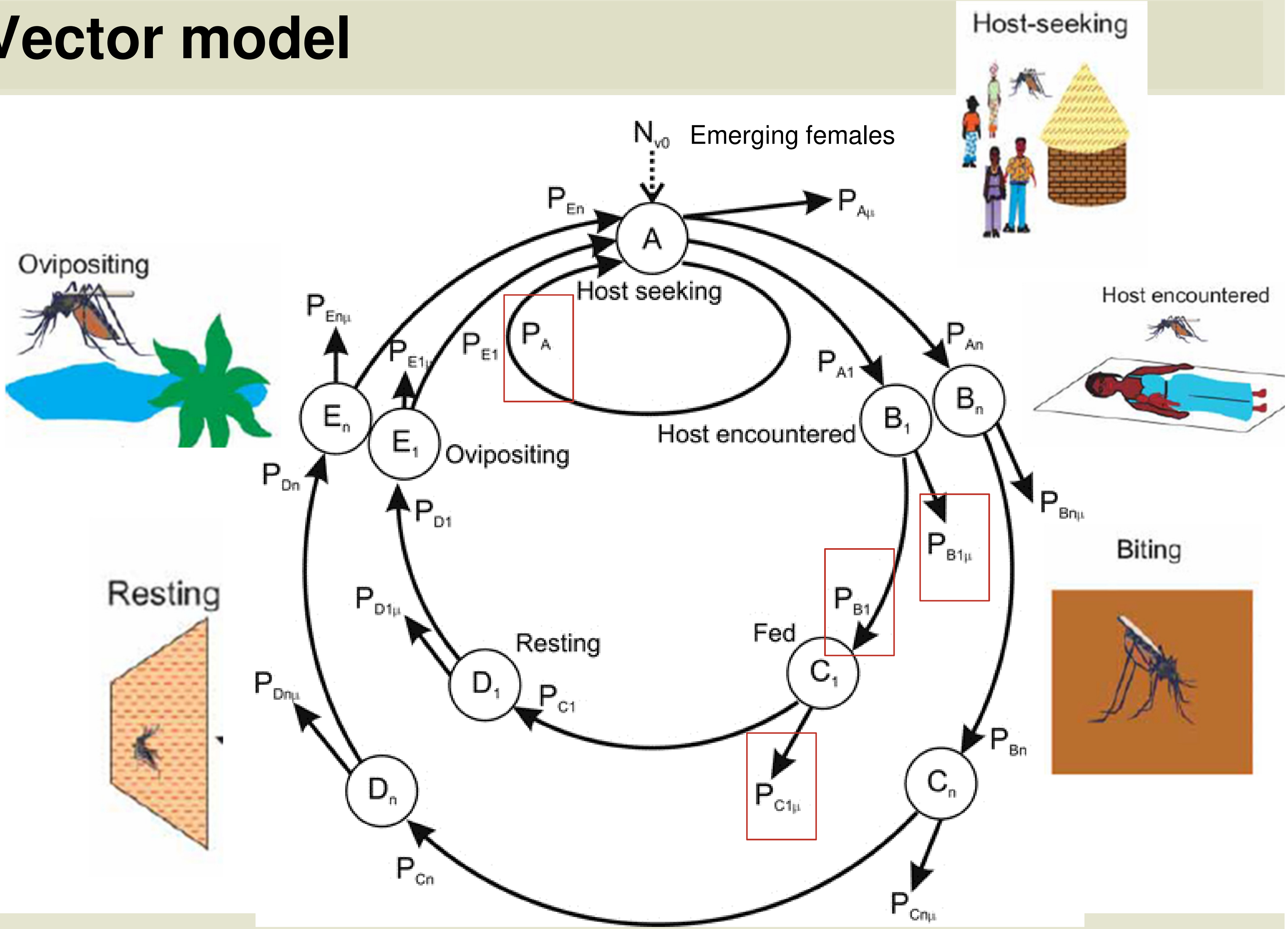
[a] *Department of Public Health and Epidemiology, Swiss Tropical Institute, Basel, Switzerland;* [b] *MACEPA, PATH-Europe, Ferney-Voltaire, France*

(*Received 01 June 2007; final version received 03 October 2007*)

We describe and develop a difference equation model for the dynamics of malaria in a mosquito population feeding on, infecting and getting infected from a heterogeneous population of hosts. Using the force of infection from different classes of humans to mosquitoes as parameters, we evaluate a number of entomological parameters, indicating malaria transmission levels, which can be compared to field data. By assigning different types of vector control interventions to different classes of humans and by evaluating the corresponding levels of malaria transmission, we can compare the effectiveness of these interventions. We show a numerical example of the effects of increasing coverage of insecticide-treated bed nets in a human population where the predominant malaria vector is *Anopheles gambiae*.

Keywords: mathematical model; epidemiology; malaria; mosquito; difference equations

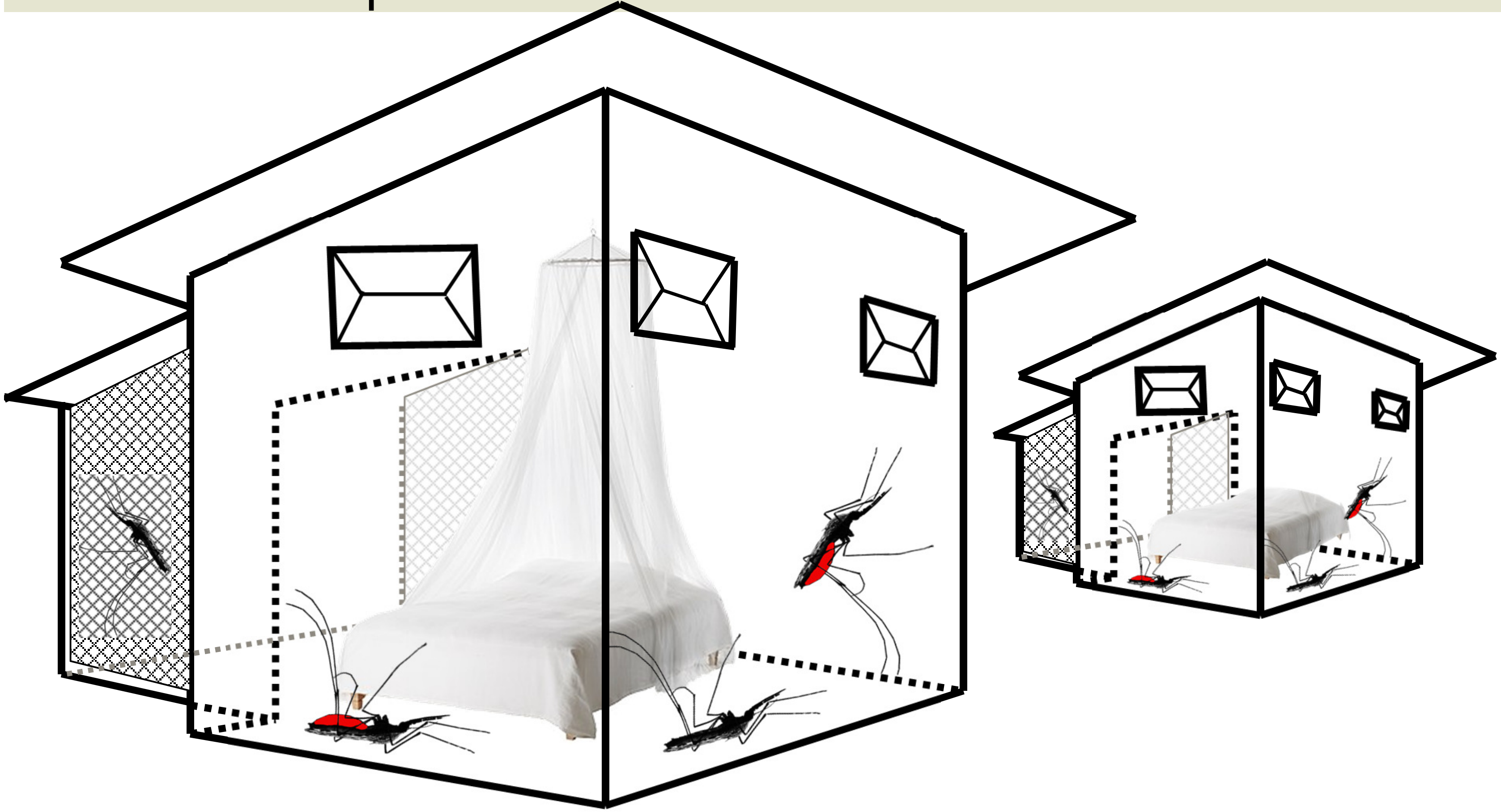
Vector model



Chitnis et al. Am J Trop Med Hyg. 2010 83(2): 230–240. Based on Saul et al, (1989); Discrete time extension of Ross-Macdonald

Experimental huts measure indoor nocturnal human-mosquito interaction

Swiss TPH



- Deterrence from entering (difference in entry between huts),
- Repellence from attacking (proportion unfed and alive),
- Mortality (proportion dead)
- Personal protection (proportion unfed)

Randriamaherijaona *et al. Malar J (2015) 14:332*
DOI 10.1186/s12936-015-0836-7

MALARIA JOURNAL

RESEARCH

Open Access

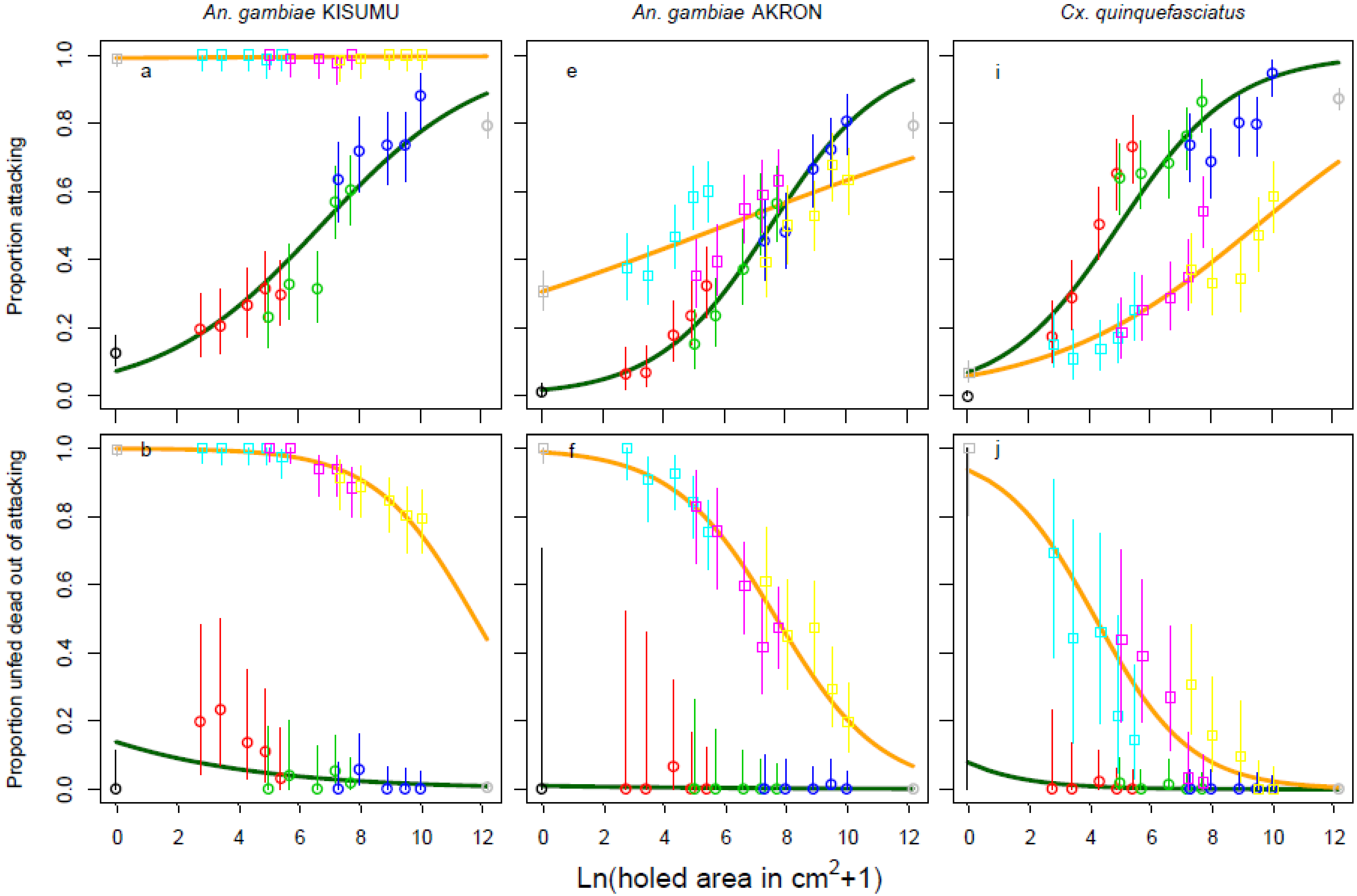
Do holes in long-lasting insecticidal nets compromise their efficacy against pyrethroid resistant *Anopheles gambiae* and *Culex quinquefasciatus*? Results from a release–recapture study in experimental huts

Sanjiarizaha Randriamaherijaona[1], Olivier J T Briët[2,3*], Sébastien Boyer[1], Aziz Bouraima[4], Raphael N'Guessan[4,5], Christophe Rogier[1,6,7] and Vincent Corbel[8,9*]

Abstract

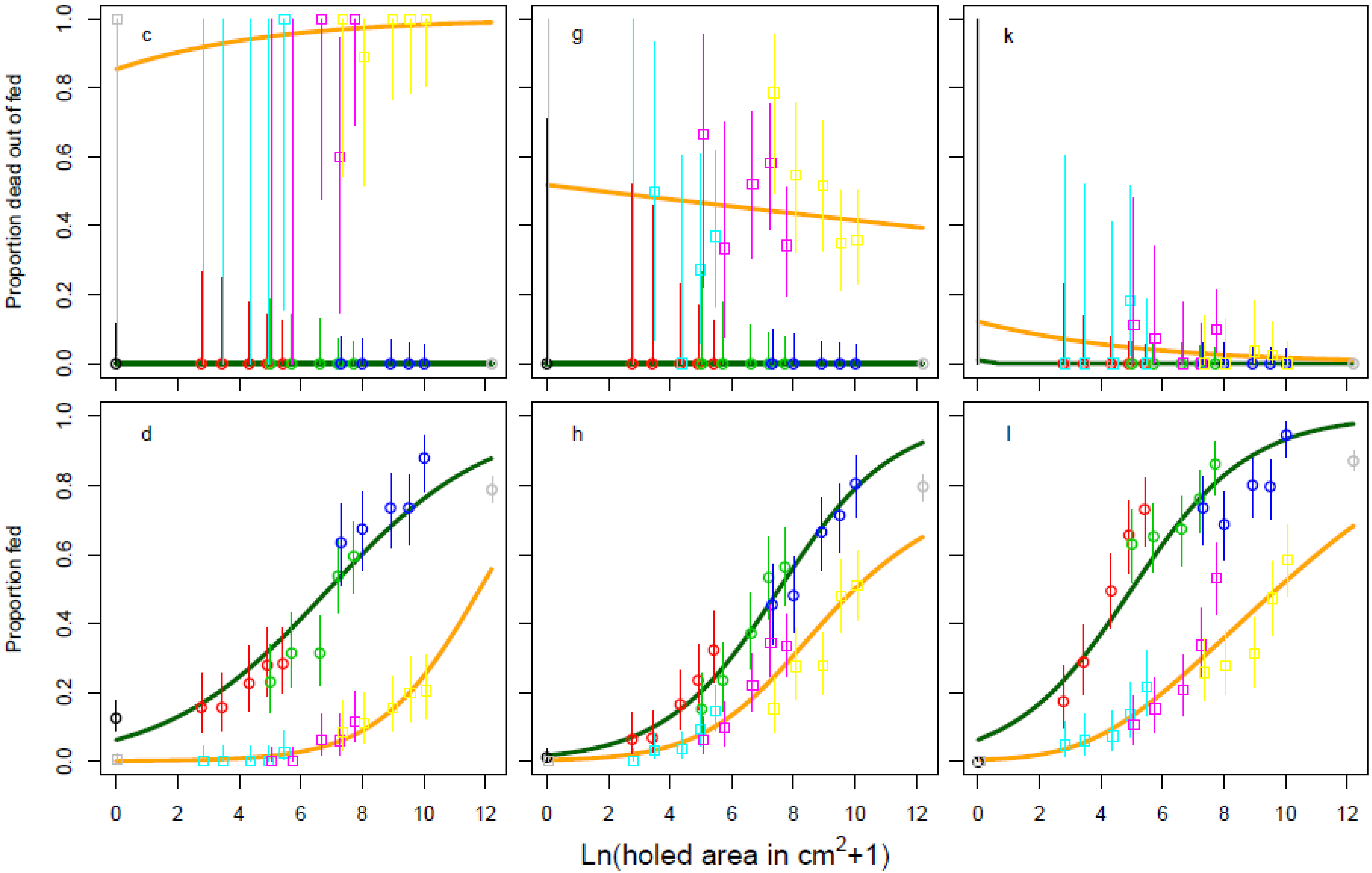
Background: Resistance of malaria vectors to pyrethroids threatens the effectiveness of long-lasting insecticidal nets (LLINs) as a tool for malaria control. Recent experimental hut and observational studies in Benin show that pyrethroid resistance reduces the insecticidal effect and personal protection of LLINs especially when they become torn. The World Health Organization has proposed a threshold for when nets are "too torn" at 1,000 cm^2 for rectangular holes and 790 cm^2 for round holes. This study examines whether there is a threshold above which LLINs no longer reduce malaria transmission.

Methods: Intact and artificially-holed LLINs under three months old and untreated nets were tested by releasing mosquitoes from a susceptible *Anopheles gambiae* colony, a pyrethroid-resistant *An. gambiae* population and a resistant *Culex quinquefasciatus* population in closed experimental huts in Southern Benin, West Africa. The efficacy of LLINs

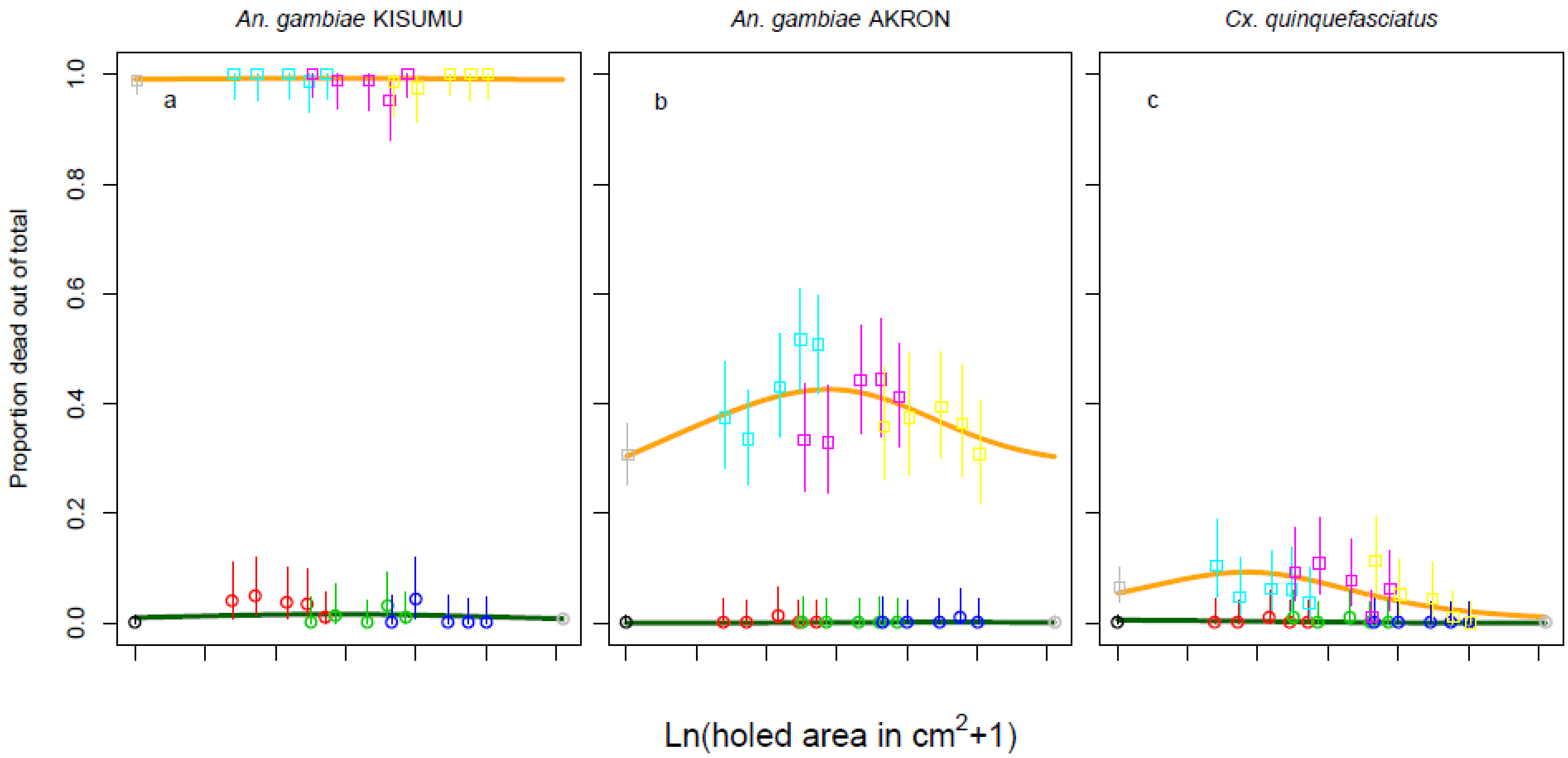


An. gambiae KISUMU
An. gambiae AKRON
Cx. quinquefasciatus
Proportion attacking
Proportion unfed dead out of attacking
a
b
e
f
i
j
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
Ln(holed area in cm2+1)

Swiss TPH



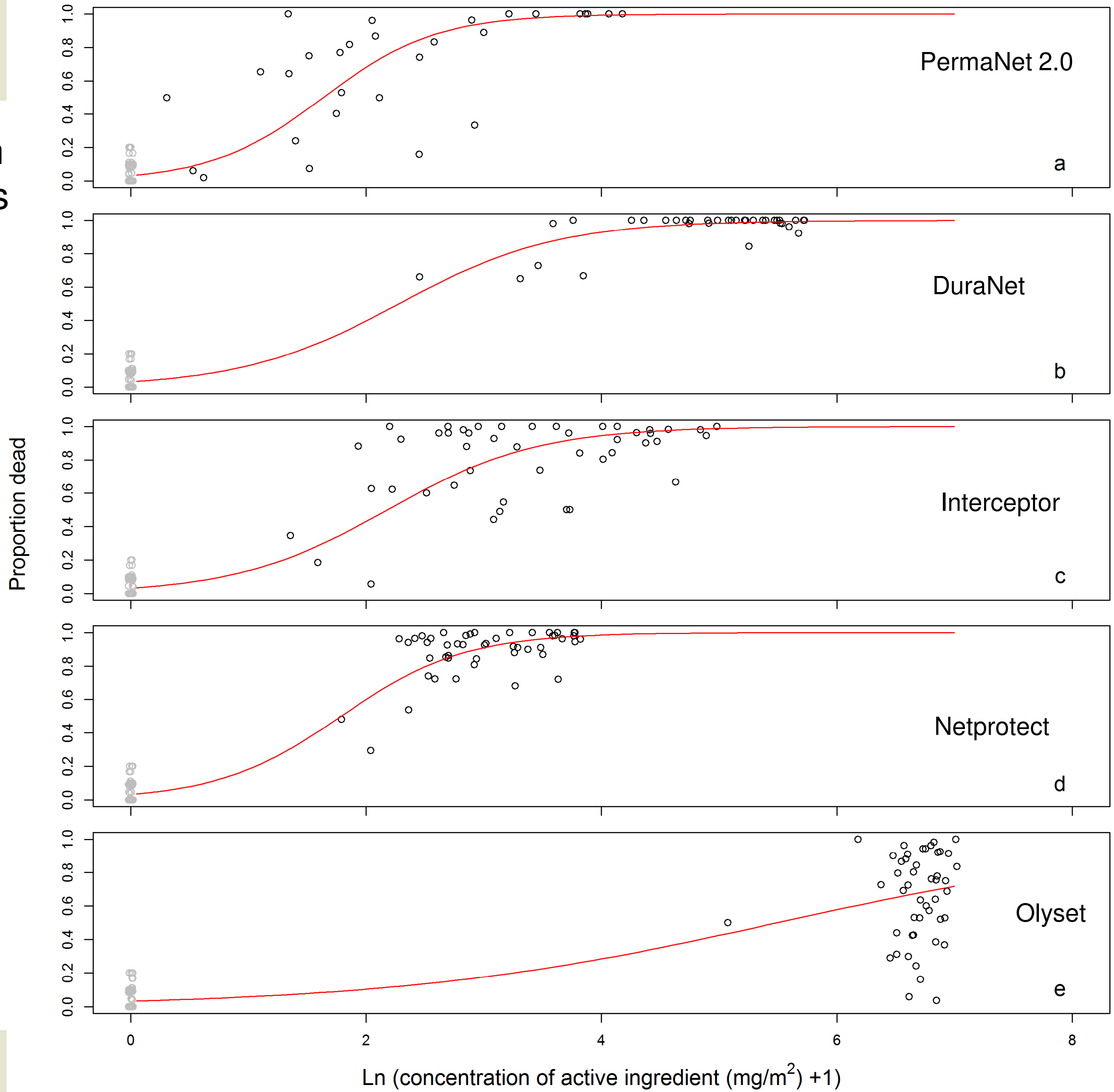
c
g
k
d
h
l
Proportion dead out of fed
Proportion fed
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
Ln(holed area in cm²+1)



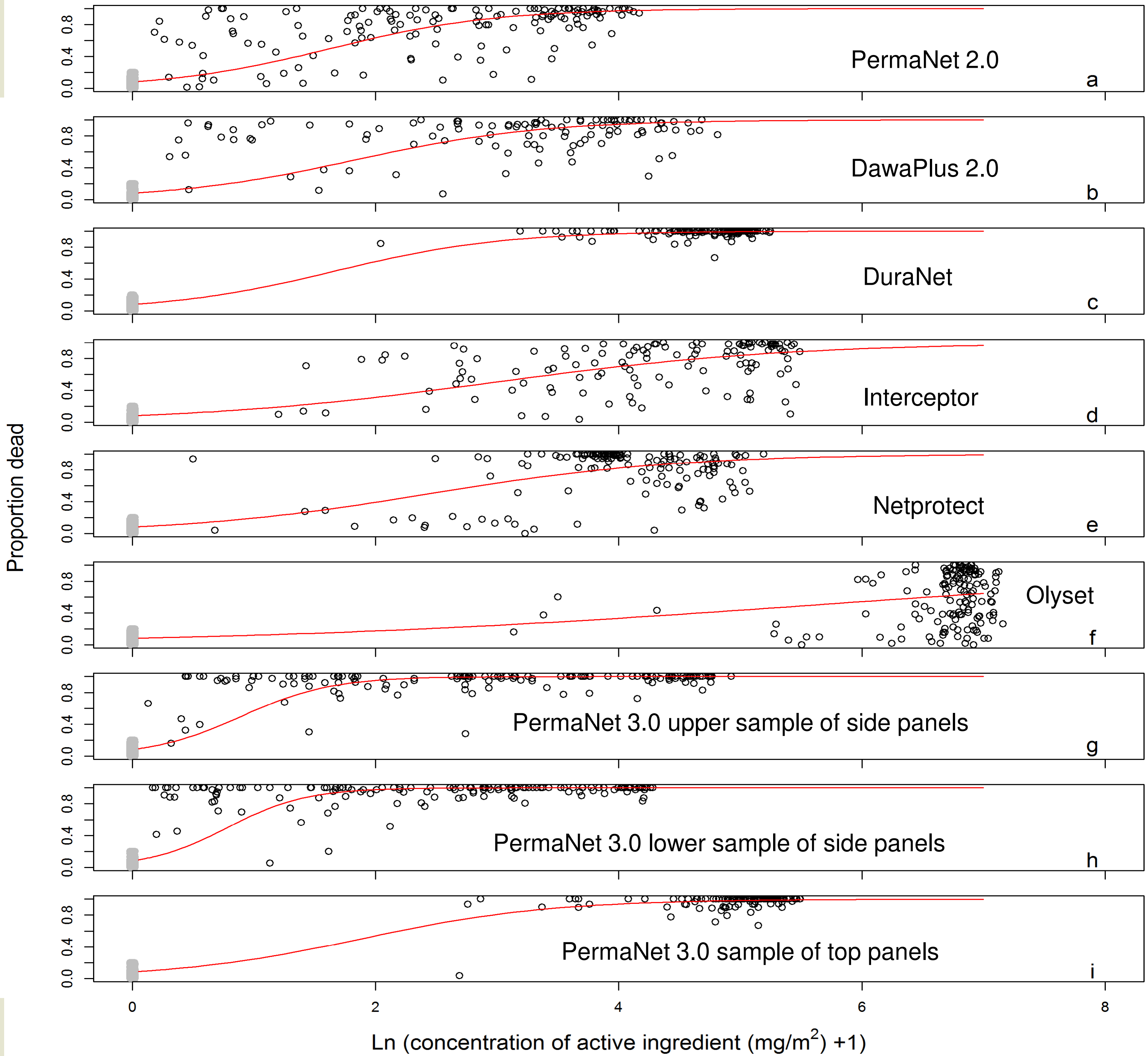
An. gambiae KISUMU
An. gambiae AKRON
Cx. quinquefasciatus
a
b
c
Proportion dead out of total
0.0
0.2
0.4
0.6
0.8
1.0
Ln(holed area in cm^2+1)

Malawi

Relationship between mortality in cone tests and insecticide content (mg/m^2), with logistic regression, is used to scale insecticide effect to that of Permanet 2.0.



Kenya



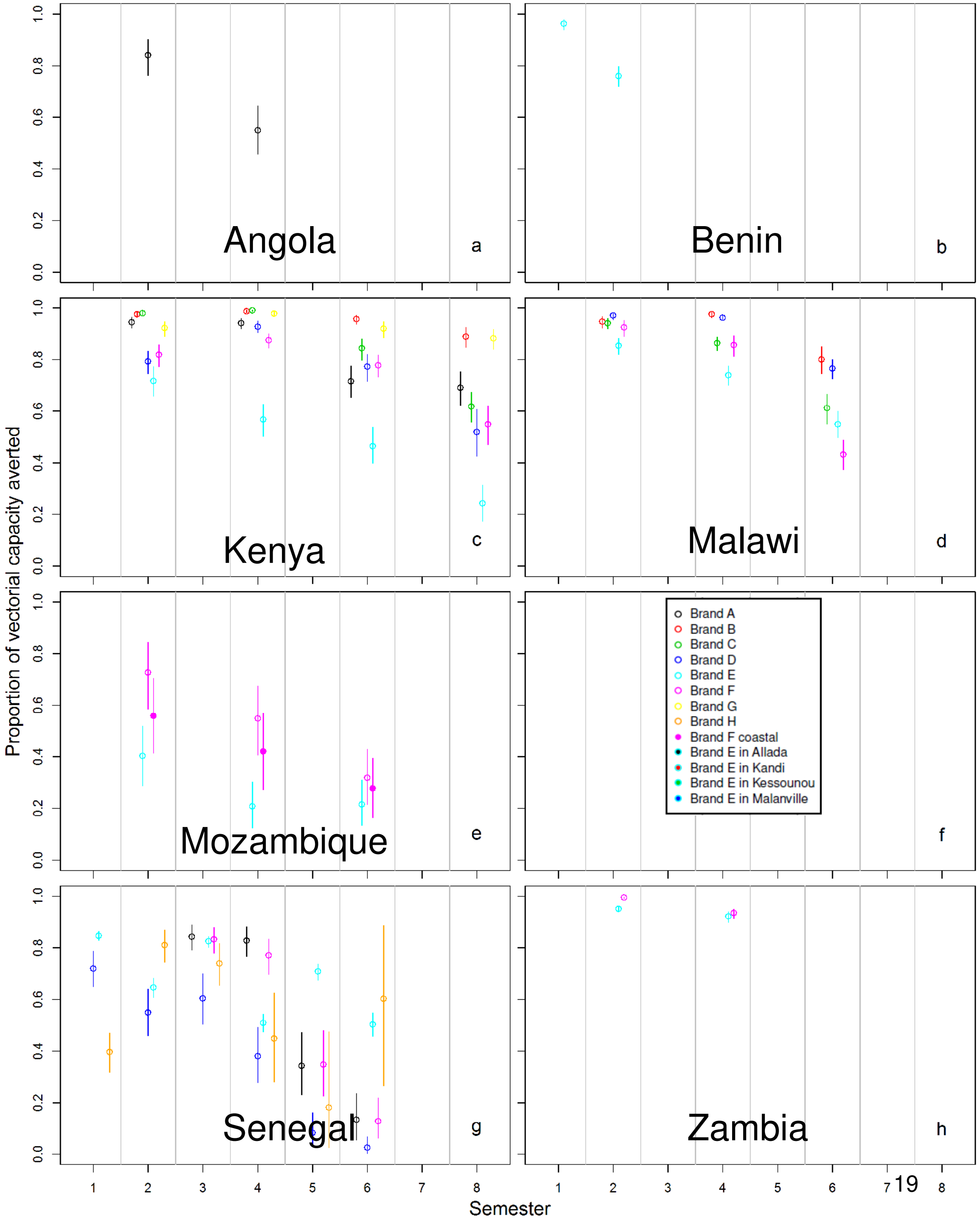
Proportion dead
0.0
0.4
0.8
PermaNet 2.0
a
DawaPlus 2.0
b
DuraNet
c
Interceptor
d
Netprotect
e
Olyset
f
PermaNet 3.0 upper sample of side panels
g
PermaNet 3.0 lower sample of side panels
h
PermaNet 3.0 sample of top panels
i
0
2
4
6
8
Ln (concentration of active ingredient (mg/m^2) +1)

LLIN type	Insecticide concentration (mg/m^2)	Scaling factor
PermaNet 2.0	55	1
DawaPlus	80	0.995
Duranet (alphacypermethrin)	261	1.043
Interceptor	200	0.682
LifeNet	63	0.991
Netprotect	68.1	0.831
Olyset	1000	0.355
PermaNet 3.0 lower side panels	85	2.317
PermaNet 3.0 upper side panels	85	2.092
PermaNet 3.0 top panel	121	1.020

Proportion of vectorial capacity averted by LLINs

Assumptions

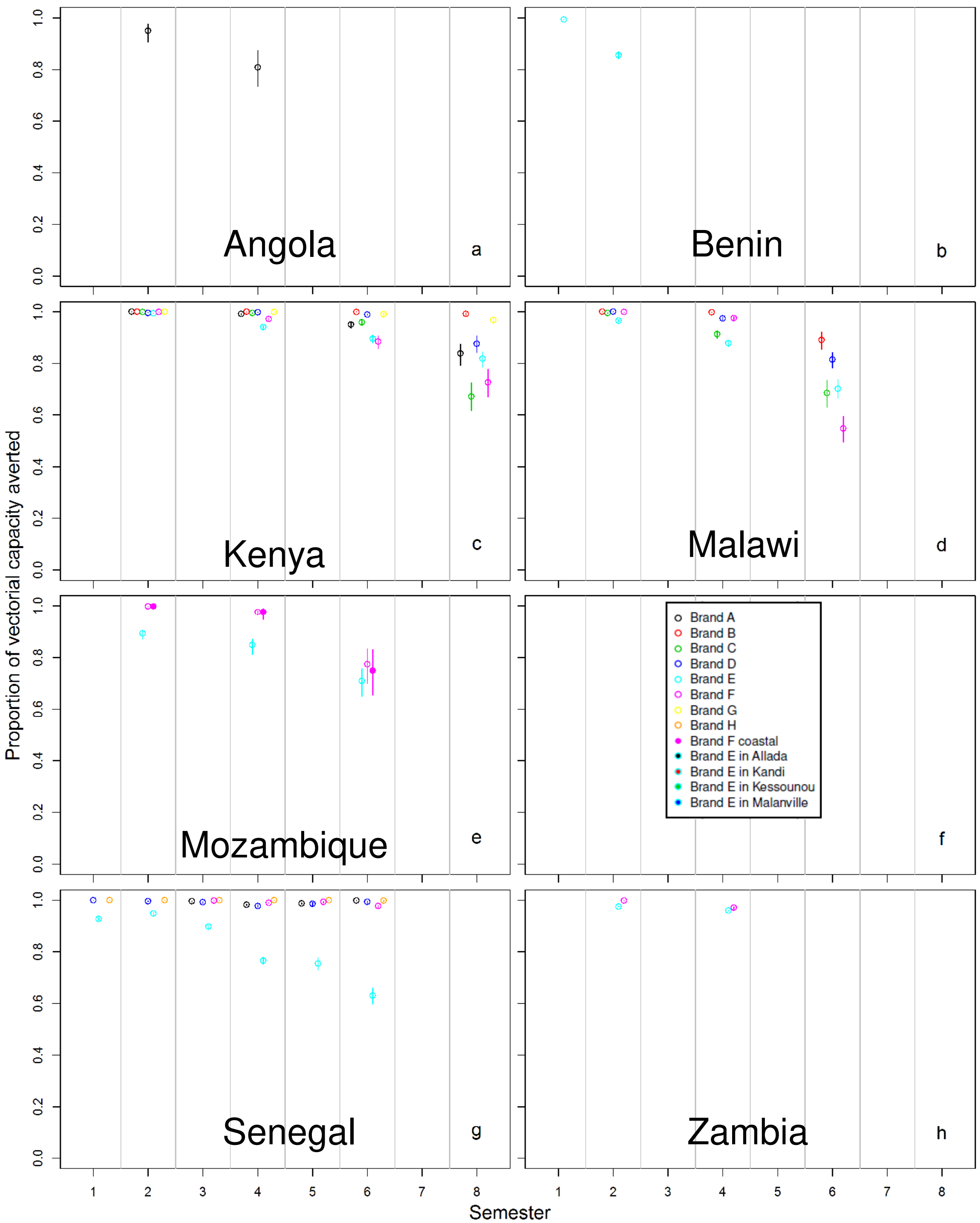
1) in the mass distribution, enough study LLINs are distributed to provide exactly 100% population access;
2) population access and use scale linearly with study-LLIN survival and use, respectively;
3) no other (non-study) nets are used in the population (unreasonable, but lack of information on non-study nets)



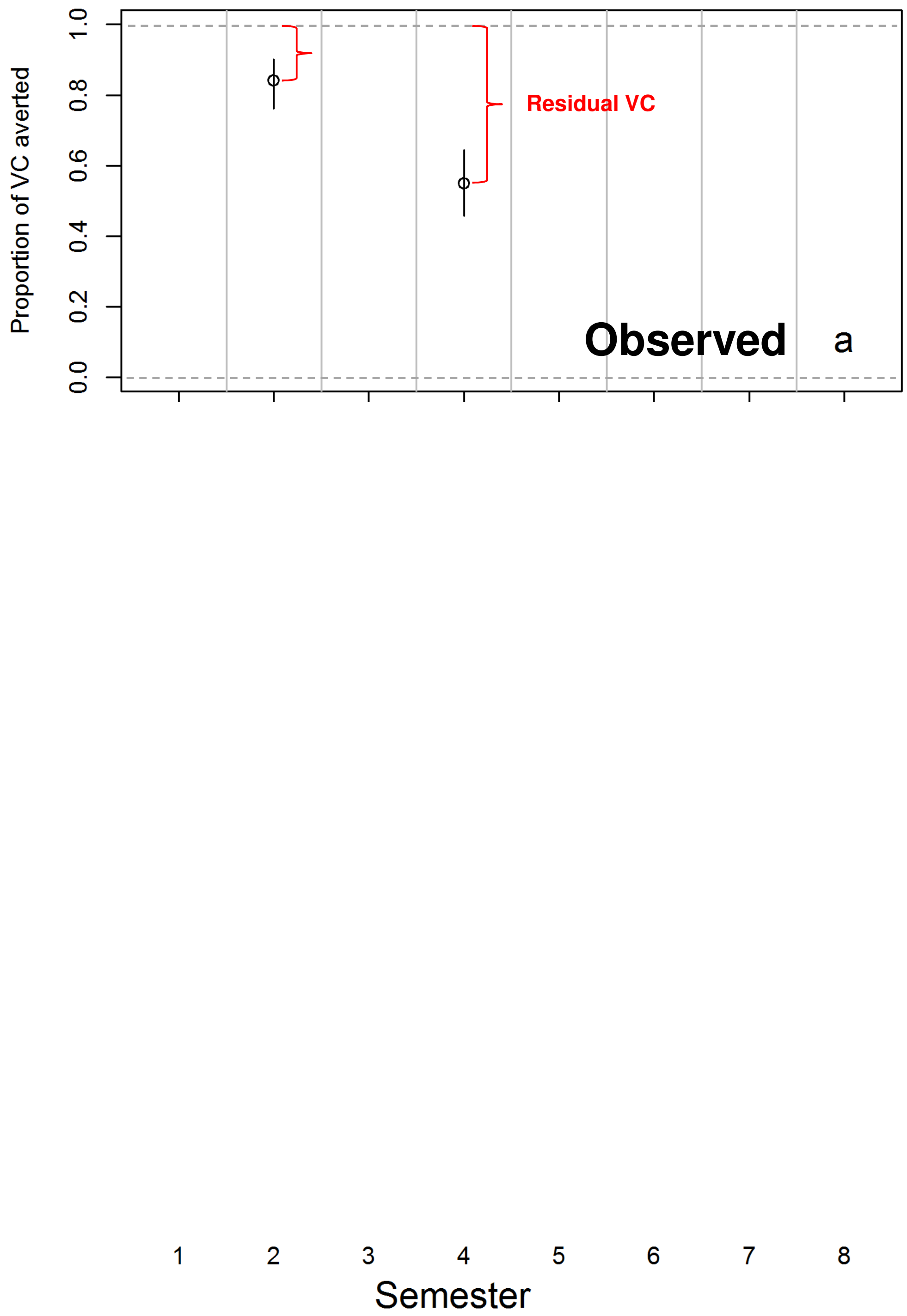
Proportion of vectorial capacity averted by LLINs in a scenario where all LLINs are being used

Other scenarios examined (ceteris paribus):

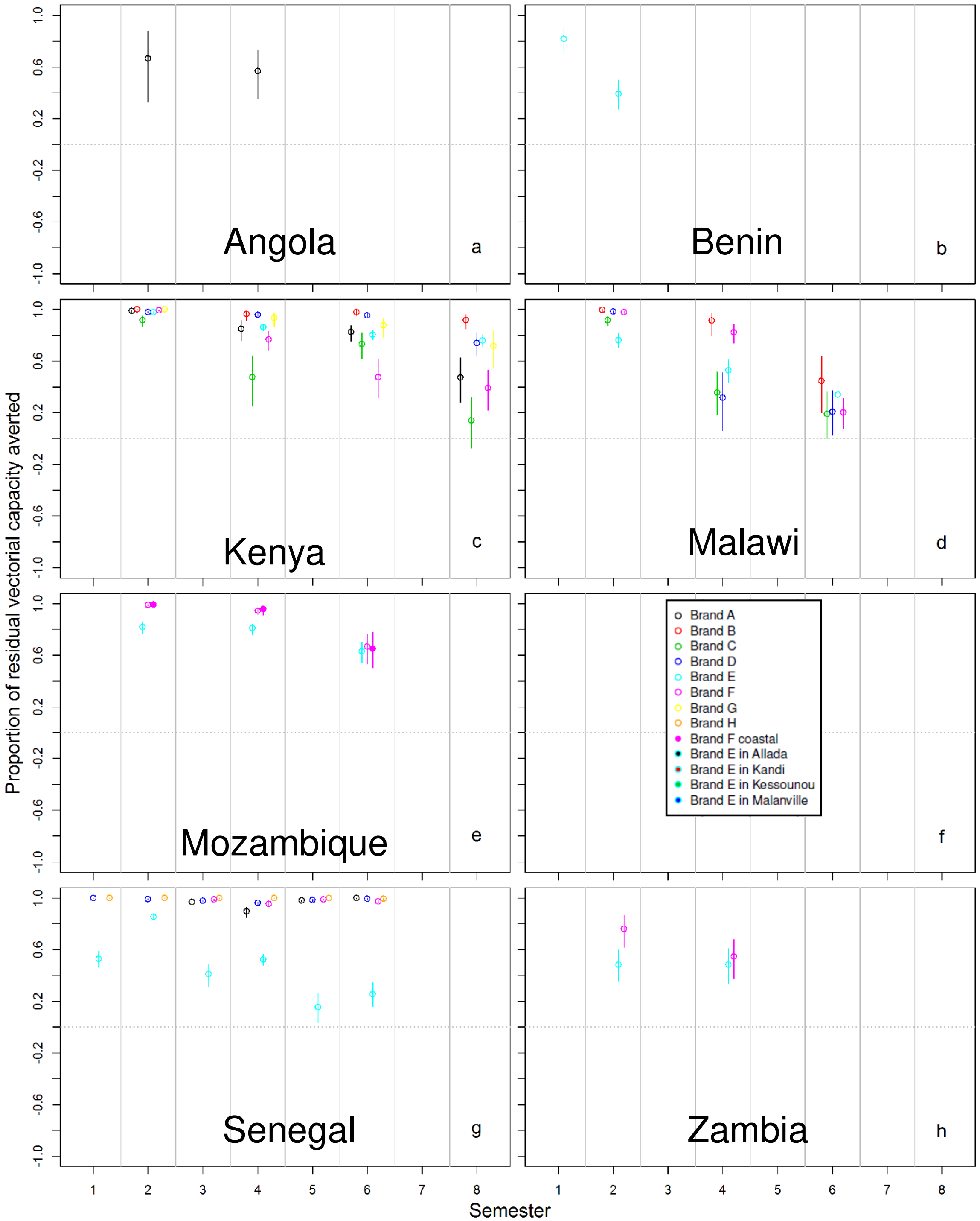
- ‘physically indestructible’, intact LLINs
- ‘chemically every lasting’ LLINs at target insecticide content
- ‘no attrition’ = 100% survival / access



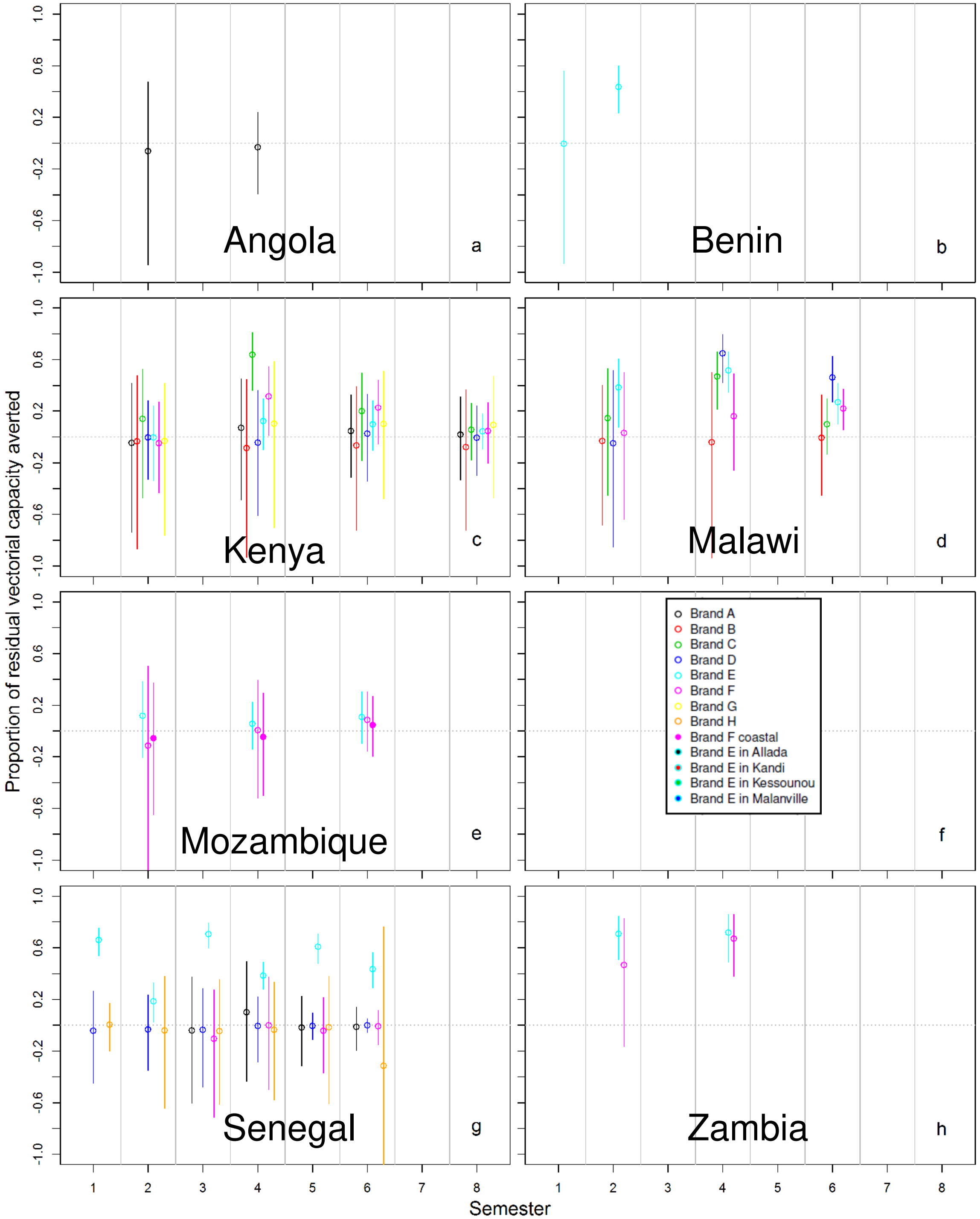
Calculation of *residual* VC averted in 100% use scenario compared to observed counterfactual



Proportion of *residual* vectorial capacity averted by LLINs in a scenario where all LLINs are used instead of measured use



Proportion of *residual* vectorial capacity averted by LLINs in a scenario where all LLINs are intact instead of holed



Summary of proportion of *residual* vectorial capacity prevented by improving LLIN durability properties, by country

Country	LLIN type	Semesters	Intact scenario	Target concentration scenario	Maximum use scenario	Maximum survival scenario
Angola	1	2,4	-0.02 (-0.51-0.27)	0.22 (-0.17-0.45)	0.63 (0.42-0.76)	0.54 (0.28-0.69)
Benin	5	1,2	0.24 (-0.24-0.52)	0.36 (0.01-0.56)	0.61 (0.52-0.67)	0.20 (-0.29-0.46)
Kenya	1,2,3,4,5,6,7	2,4,6,8	0.07 (-0.02-0.15)	0.08 (-0.01-0.17)	0.80 (0.78-0.82)	0.21 (0.13-0.27)
Malawi	2,3,4,5,6	2,4,6	0.22 (0.10-0.31)	0.28 (0.18-0.37)	0.60 (0.57-0.63)	0.30 (0.19-0.38)
Mozambique	5,6	2,4,6	0.02 (-0.13-0.15)	0.17 (0.04-0.27)	0.83 (0.80-0.85)	0.03 (-0.11-0.14)
Senegal	1,4,5,6,8	1,2,3,4,5,6	0.10 (-0.04-0.17)	0.08 (-0.02-0.15)	0.86 (0.85-0.87)	0.03 (-0.10-0.10)
Zambia	5,6	2,4	0.65 (0.46-0.77)	0.34 (0.14-0.47)	0.57 (0.50-0.63)	-0.01 (-0.30-0.19)

Figures between round brackets are 95% credible intervals. Cells highlighted in green have credible intervals entirely above zero. Numbers between square brackets indicate LLIN type number.

Discussion / Conclusions (1)

We compared impact of mass distributed LLINs on VC in durability studies with hypothetical scenarios, in each of which one durability property was ‘idealized’ while keeping the other properties as observed.

These hypothetical scenarios are unrealistic, as these properties are correlated:

- LLINs that do not decay physically may improve use and reduce attrition;
- LLINs that do not decay chemically might have similar effects, although use and attrition are probably less correlated with chemical content;
- stimulating use might lead to more rapid hole formation and loss of insecticide;
- stimulating people to hold on to LLINs would lead to lower use of such LLINs.

Discussion / Conclusions (2)

Nevertheless, it gives insight on which properties LLIN programmes might focus in order to improve impact on transmission, and direction of research.

Non-use is the most important property reducing LLIN impact on vectorial capacity over the first 4 years, generally outweighing effects of attrition, hole formation and decaying insecticide content.

But, this result is biased because:

1. of the assumption (due to lack of info on non-study nets) that people did not use other nets when not using study nets
2. study effects may have reduced attrition in these prospective durability studies.

MIS-like cross-sectional surveys with complete net-rosters that include holed area and insecticide content would remove these biases, but would measure attrition indirectly.

Due to strength of effect, use might still be most important in unbiased studies.

In universal coverage settings, improving net use (e.g. through BCC) appears to be the 'lowest hanging fruit' for programs to improve LLIN impact.

Thanks for listening

and thanks to:

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Project Management: Hannah Koenker (VectorWorks), Konstantina Boutsika (Swiss TPH), Laura Norris and Jen Armistead (PMI)

Questions / suggestions?

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