MSWG
Kigali, Rwanda
18 April 2024

Jo Lines

Mosquitoes as pollution: an unintended consequence of Agro-economic development

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How Agriculture affects human infectious disease

- Occupational infections
- Zoonoses
- Landscape / Environment
- Intervention interactions

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Outline

- Man-made Rural Environments
- A Range of Examples
  - Mechanisms
- Malaria
  - the role of landscape in previous elimination stories
  - end-game:
    - what will stabilize the absence of malaria in Africa?

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100% man-made rural environment in Tuscany

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100% man-made rural environment in Cambodia

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100% man-made rural environment in Nigeria

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Urban breeding sites in Dar es Salaam: **Cultivation ridges in a roadside drain.**

1. This roadside drain filled with silt, became waterlogged and overgrown with tall reeds. Some mosquito larvae were present – but only non-vector species.
2. Then local residents cut down and burned the reeds, dug cultivation ridges, and planted sweet potato and maize. The disturbed soil and sunlit shallow water in the ridges then became perfect for *An. gambiae* breeding.

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Stories 1

- Breeding Sites / Man-made Habitat
  - Drip irrigation Leishmania in Tunisia (sandflies and rodents)
  - Triatomines and peridomestic palms
  - Buruli?
  - Rubber and Aedes

- Man-vector contact
  - HAT in Uganda

- Amplifying host
  - Pigs and JE.

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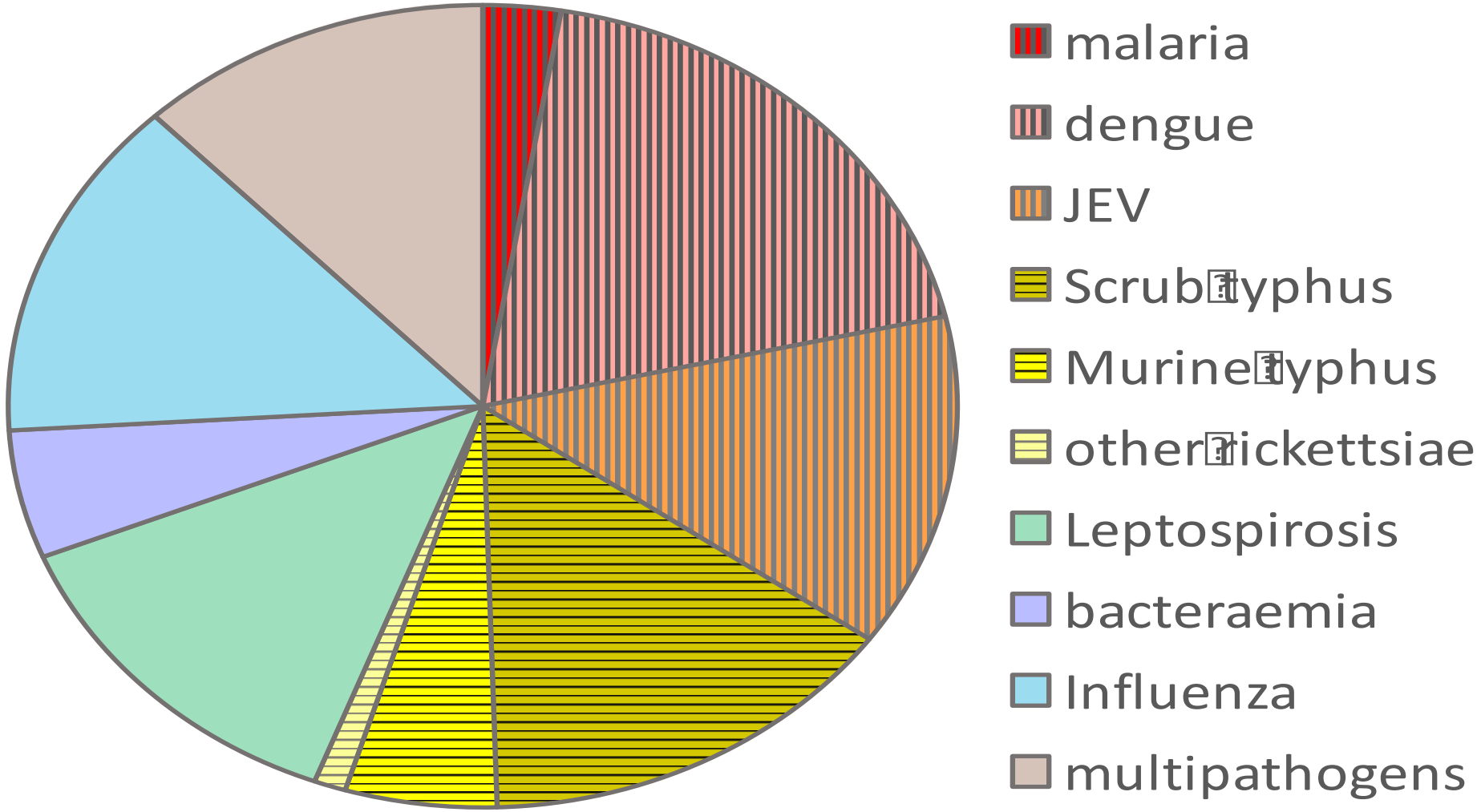
Out-patient Fevers in two locations in Laos

N = 799 patients with a diagnosis

NB Vector-borne diseases are shaded
vertical shading = mosquito-borne; horizontal shading = ectoparasite-borne



Mayxay et al. Lancet Global Health 2013 1:e46-54.

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Stories 2

- Malaria in Chiapas – the effect of sterile male control
- Forest Malaria in SE Asia
- Rice and Malaria in Africa

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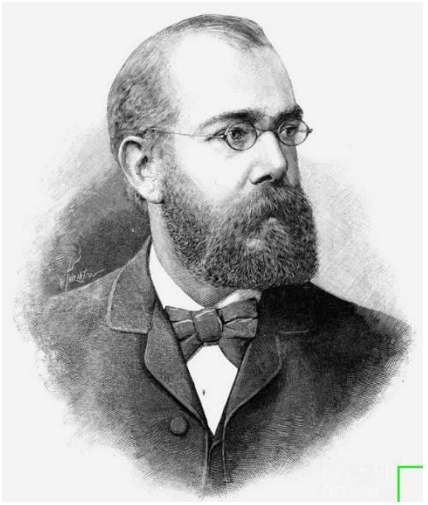
Medical vs Social vs Environmental



Robert Koch:

- "Malaria is a Medical Problem"
  - Treat the patient, not the mosquito

Angelo Celli, Manson et al.

- "Malaria is a Social Disease"
  - Malaria flees before the Plough
  - Bonification = housing, landscape, wages

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SP James:

"...the diminution of local malaria in England was due neither to natural causes nor to the intentional application of any particular preventive method reputed to be specific, but to progressive improvements of a social economic, educational, medical, and public health character."

1929

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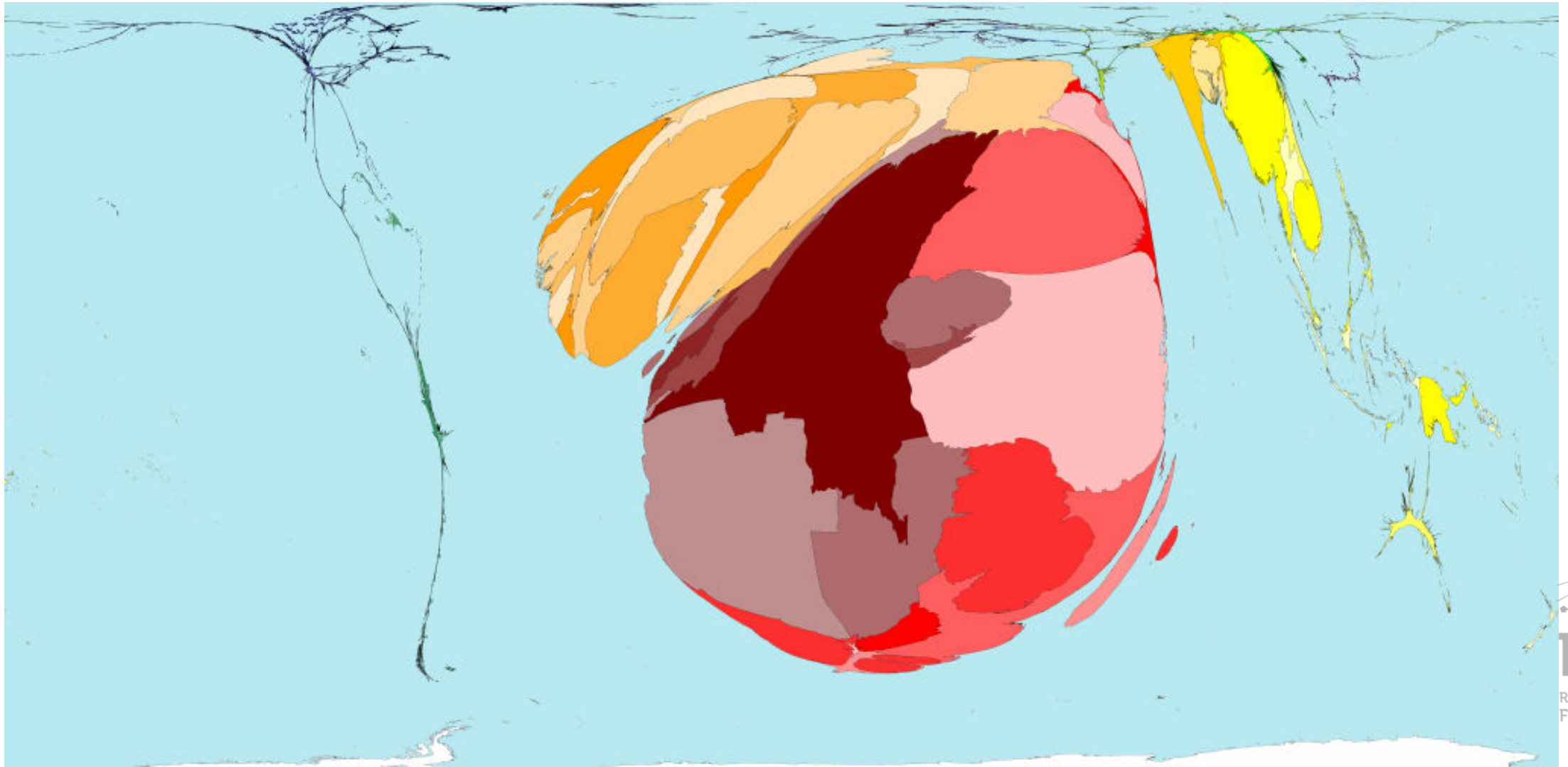
The *Anopheles gambiae* problem:

Global distribution of malaria deaths in 2004



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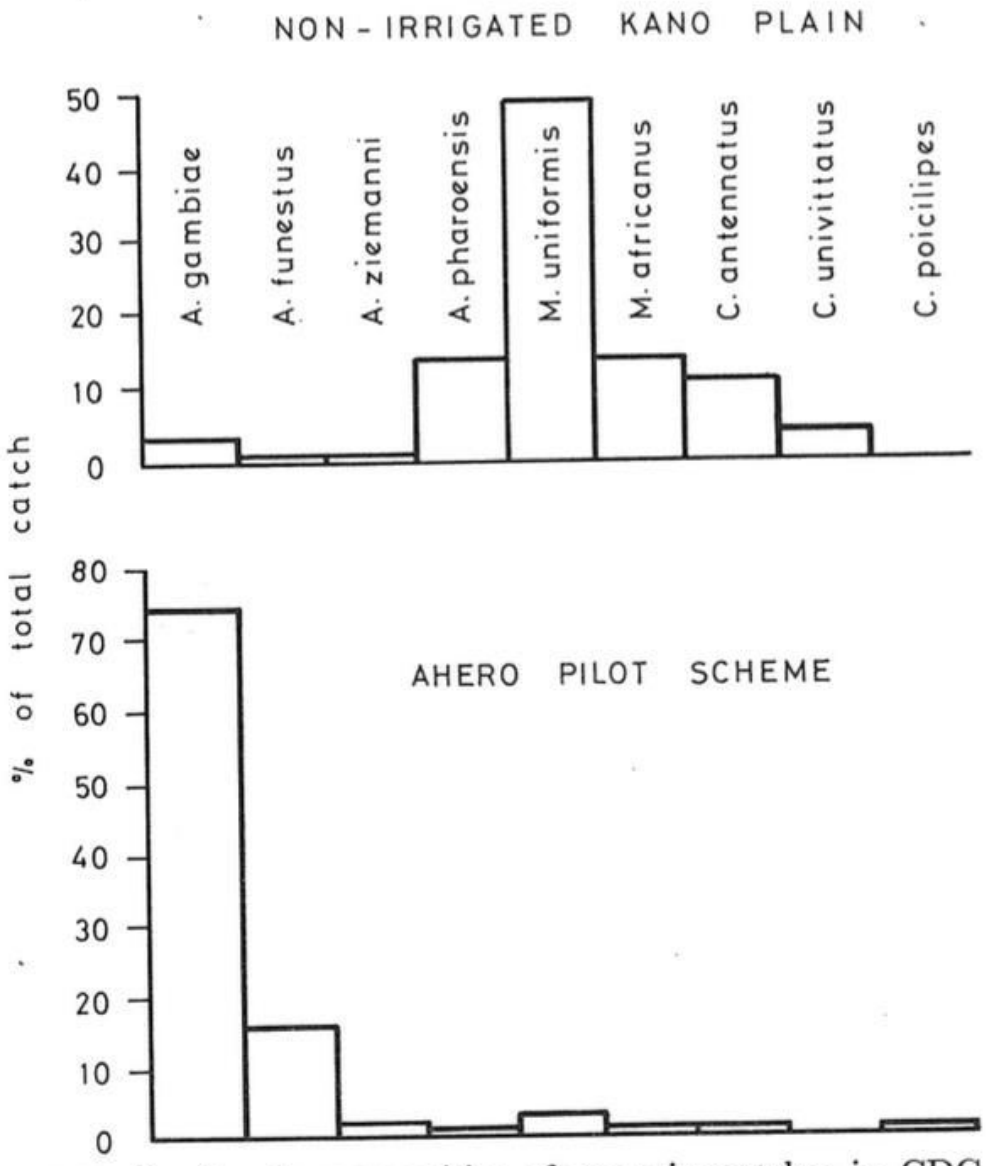

FIG. 3. Species composition of mosquito catches in CDC light traps indoors on the Kano Plain and the Ahero rice fields.

Introducing irrigated rice into W. Kenya: Chandler *et al*. (1975).

Q: What happens to the mosquito fauna when a natural swamp is replaced by irrigated rice?

A: Non-vector culicines are replaced by malaria vector anophelines in roughly equal numbers.

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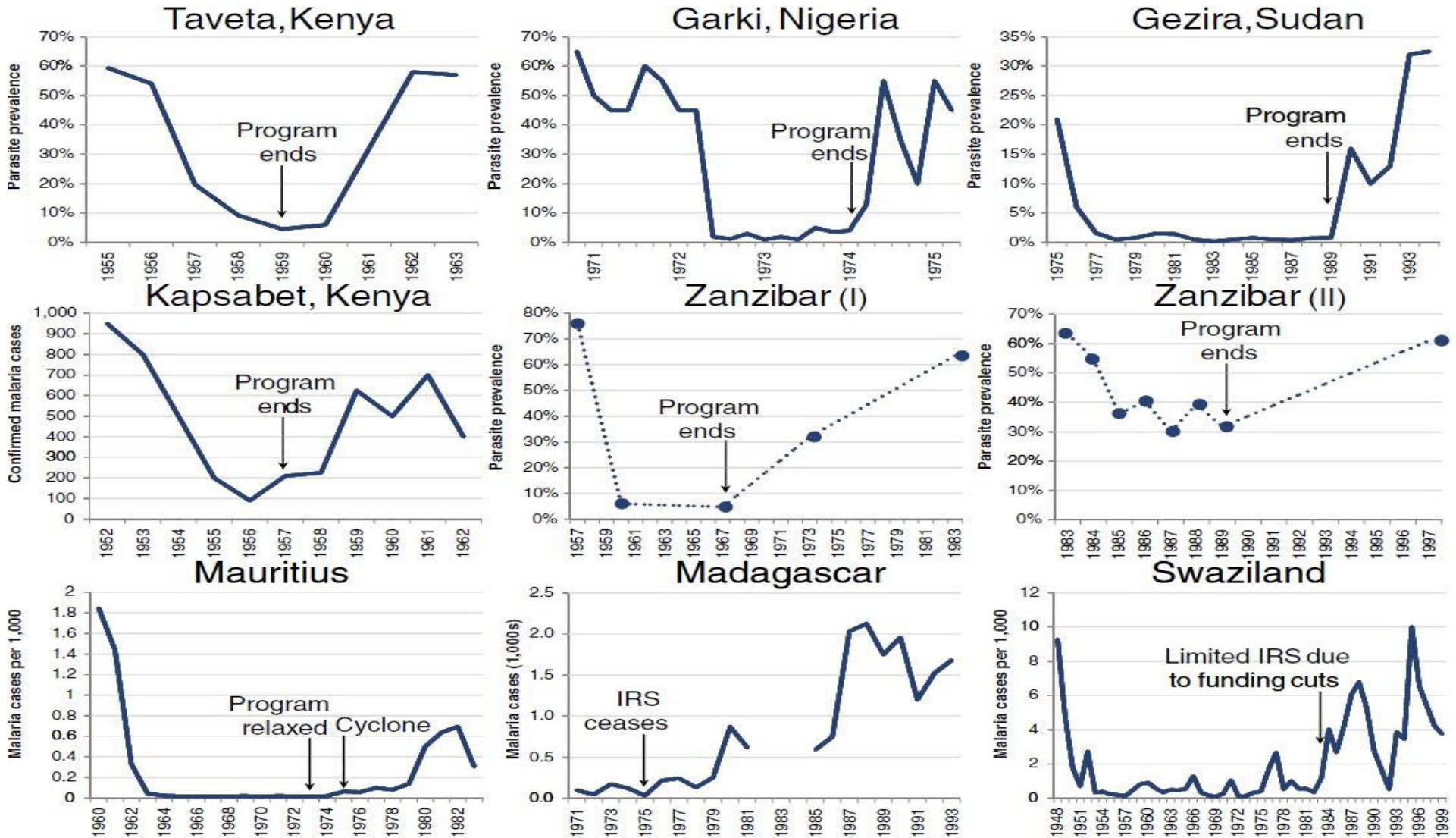
Coverage and resurgence: we cannot relax the pressure



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The *Anopheles gambiae* problem:

The absence of malaria in Africa:

What will make it stable?

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The Role of Agriculture in previous Success Stories of Malaria Elimination

- USA -- DDT in the ricefields
- Peru – intermittent irrigation imposed by government
- Portugal -- rice cultivation banned
- Eastern Europe / Central Asia --- larvivorous fish
- China – rice/fish co-cultivation (incl Tilapia), intermittent irrigation

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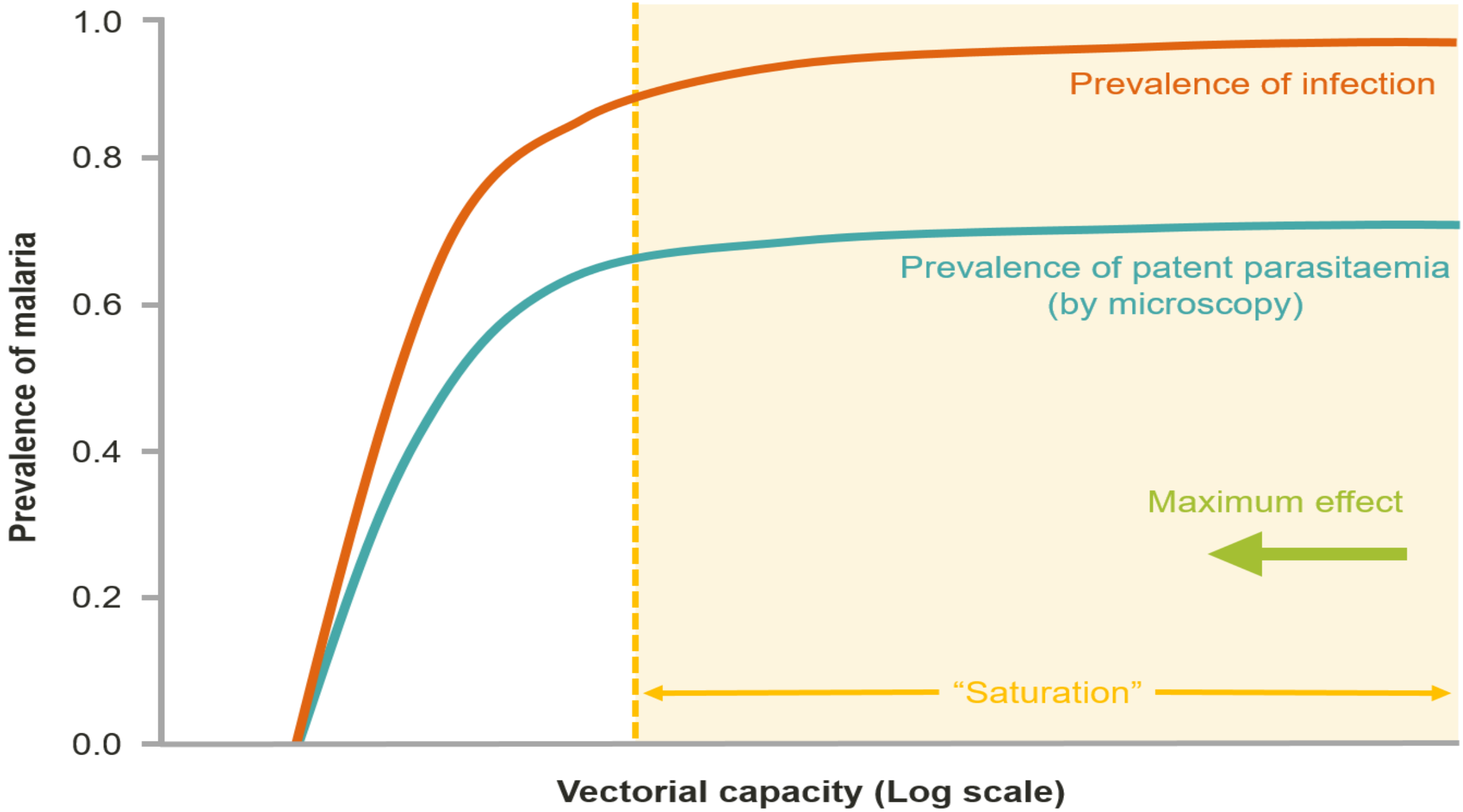
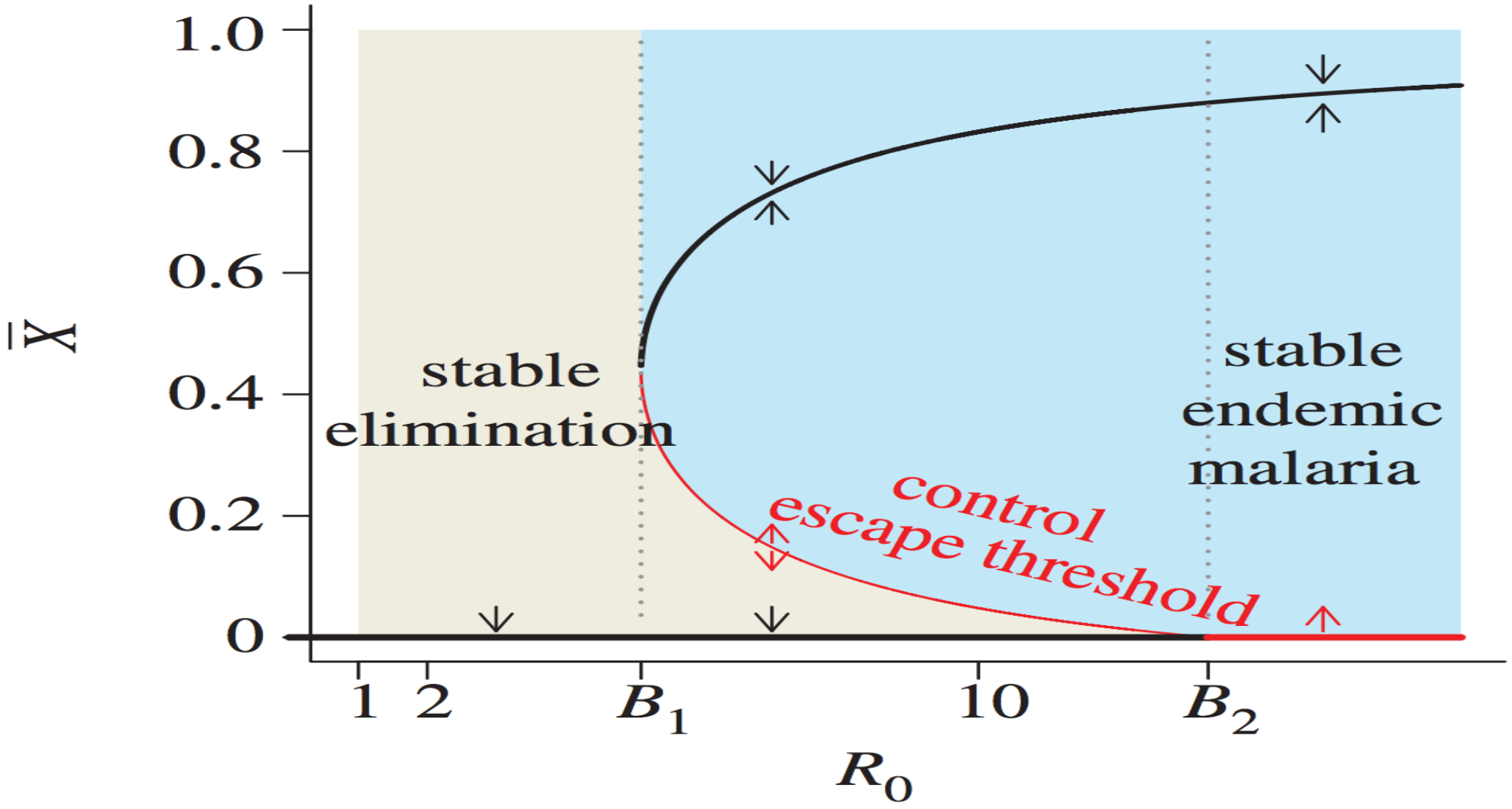
“Stickiness” 1

- As transmission declines, immunity declines,
- So new infections are more likely to be symptomatic
- and thus detected and removed by the health service…….
- So Zero Malaria IS a stable equilibrium ….. if….

Dave Smith: the concept of stickiness DOI: 10.1098/rstb.2012.0145


1.0
0.8
0.6
0.4
0.2
0.0
Prevalence of malaria
Prevalence of infection
Prevalence of patent parasitaemia
(by microscopy)
Maximum effect
"Saturation"
Vectorial capacity (Log scale)

Stickiness 2



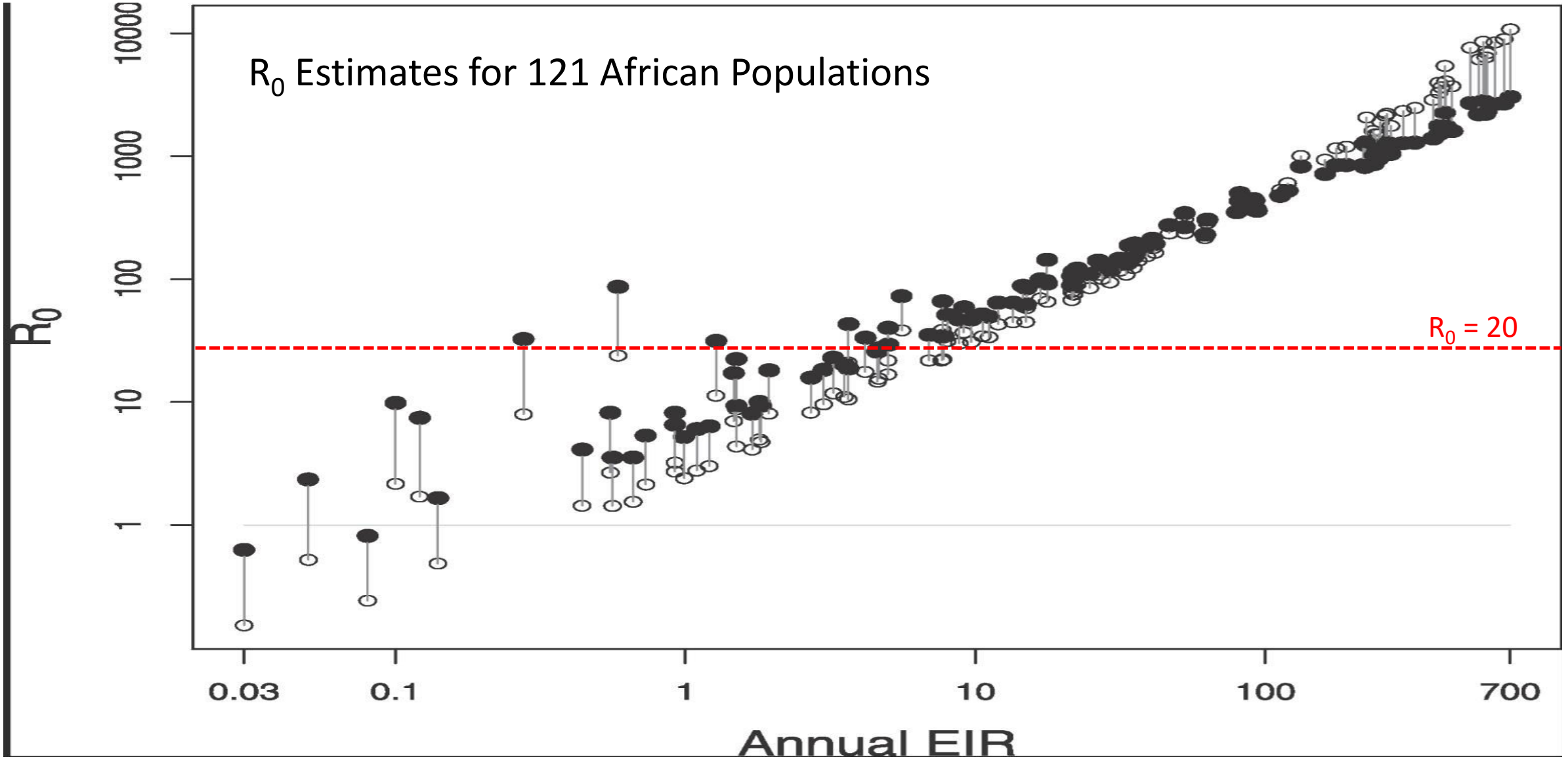
Dave Smith: the concept of stickiness DOI: 10.1098/rstb.2012.0145

Stickiness. 3

- So the absence of malaria IS a stable situation ….
- BUT ONLY IF R0 < 15 (approximately)
- But in many African settings, before modern malaria control, estimates of R0 varied up 800
- **If R0 >> 20 (as originally in many African settings) then there is no "stable elimination" area**

Dave Smith: the concept of stickiness DOI: 10.1098/rstb.2012.0145

Stickiness 4



Smith et al. revisiting R0 doi:10.1371/journal.pbio.0050042.t002

Conclusions

- In China, N America, Southern and Eastern Europe, and Sri Lanka, R0 was < 20
- So Smith's Stickiness probably did help
- Likely that Economic and Environmental Development also helped….
- But Africa is different:
- What was enough in other regions will NOT be enough in Africa

THANKS

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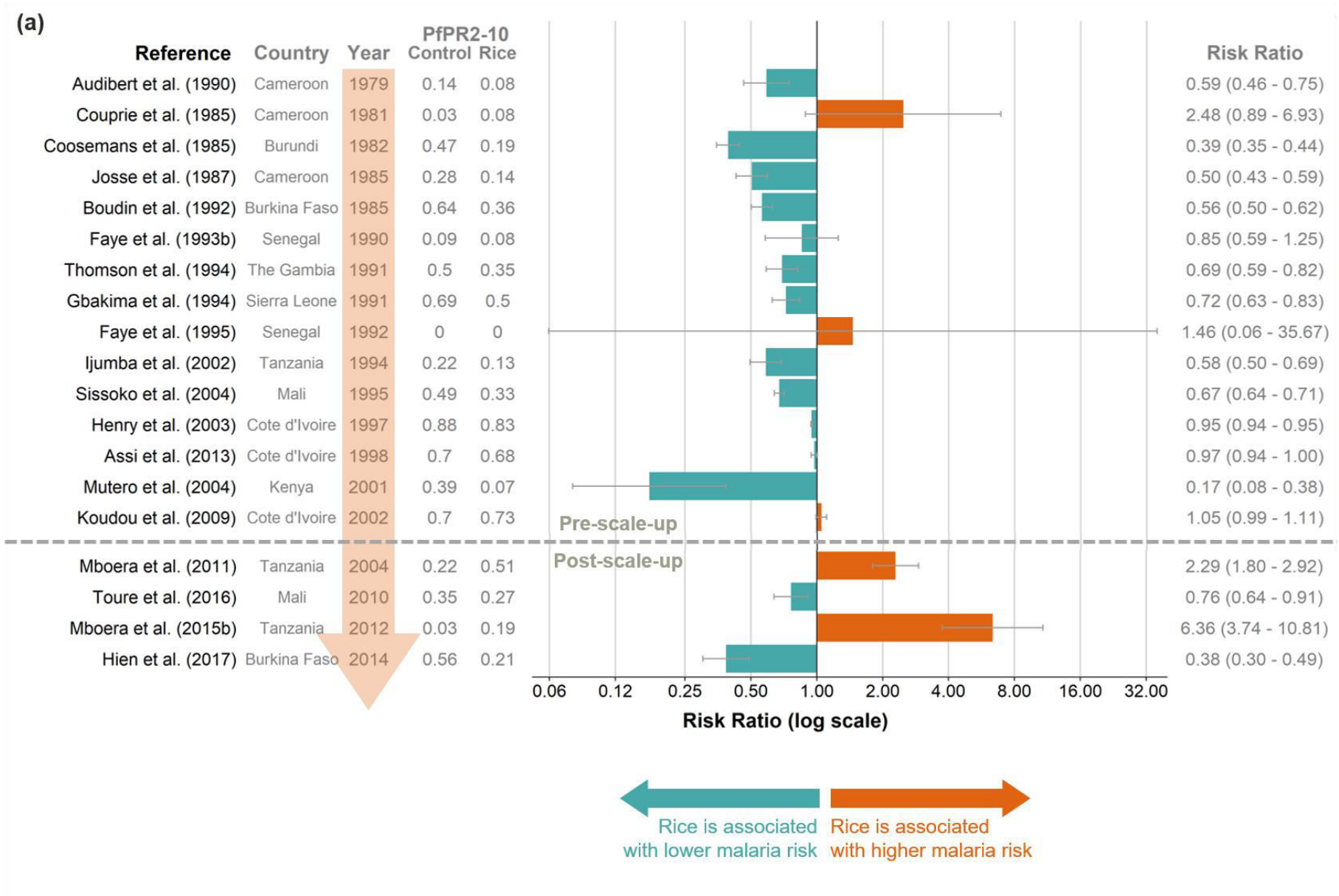
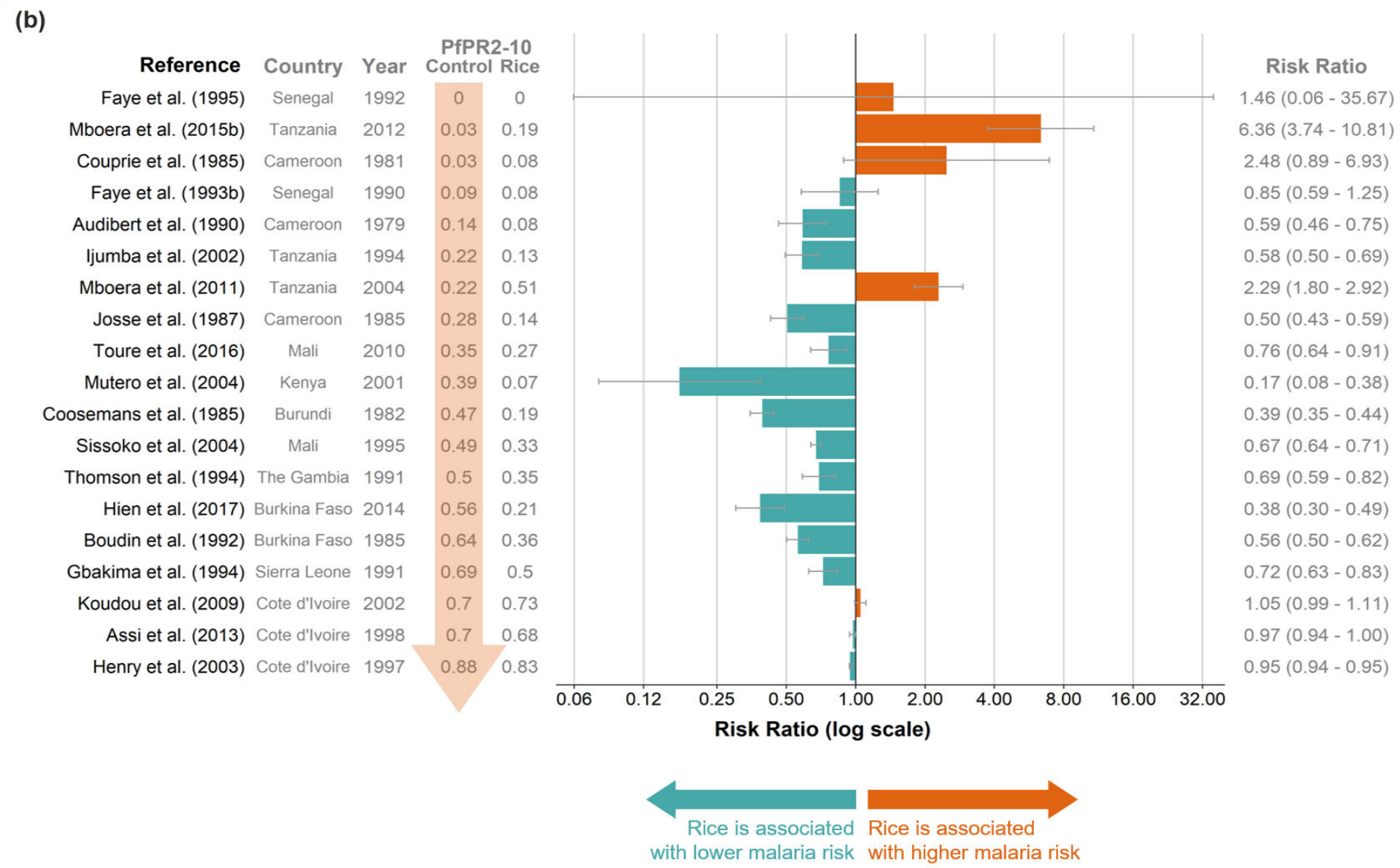
A ricefield in Zanzibar producing abundant malaria vectors: in the village near here, >2000 *Anopheles gambiae s.s* have been caught biting a single person in one night

We have known for several decades that intermittent irrigation, as here in Mwea, Kenya, can reduce mosquito productivity and may also ncrease rice productivity– but it is not widely adopted. Why not?



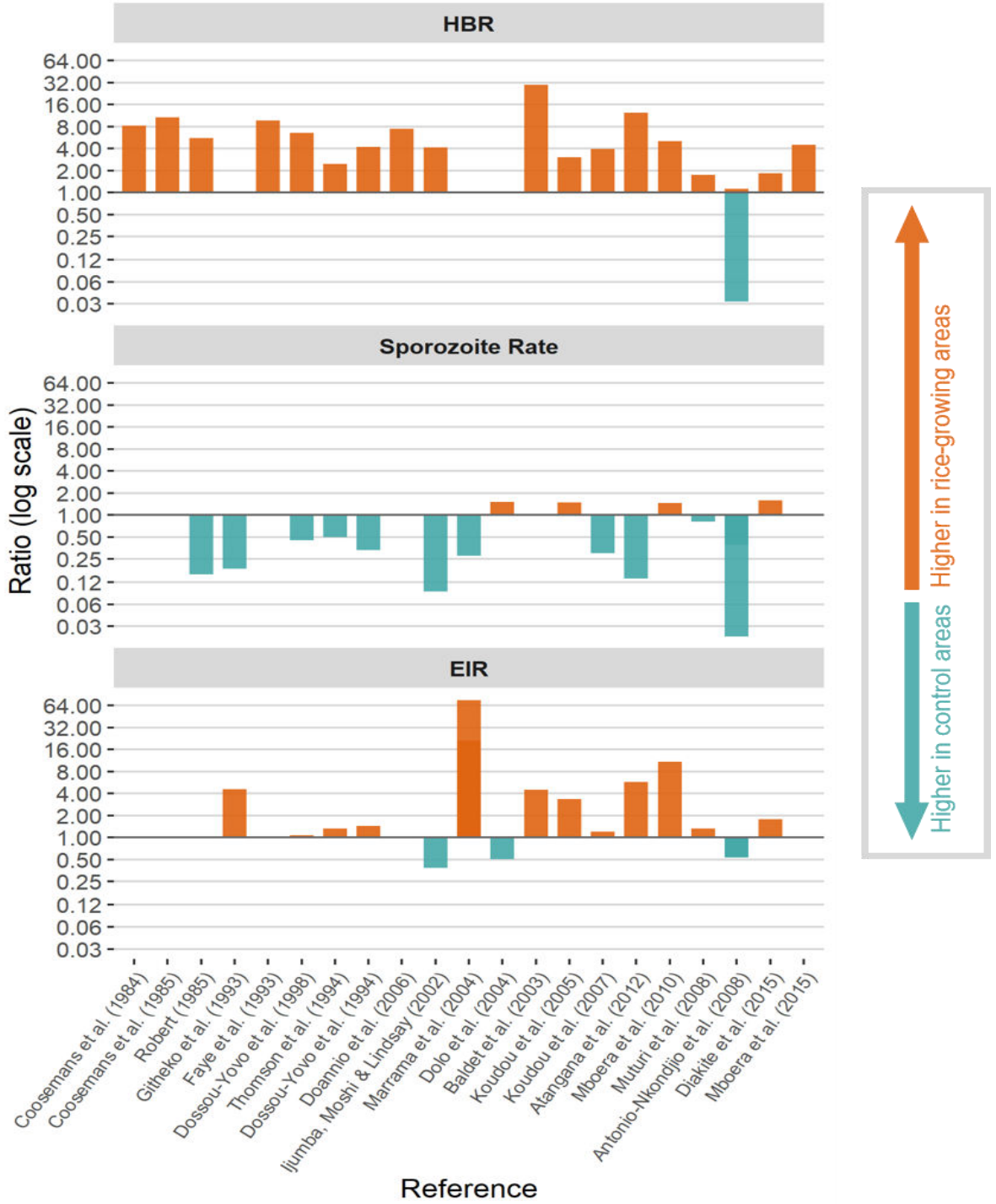
The association between rice and malaria prevalence.

Risk ratios (and their confidence intervals, presented as error bars) were calculated to compare malaria infection prevalence in rice and non-rice communities and plotted according to **(A)** year of study.



The association between rice and malaria prevalence.

Risk ratios (and their confidence intervals, presented as error bars) were calculated to compare malaria infection prevalence in rice and non-rice communities and plotted according to **(B)** underlying malaria intensity. Underlying malaria intensity is the prevalence of baseline (control) areas of each study.

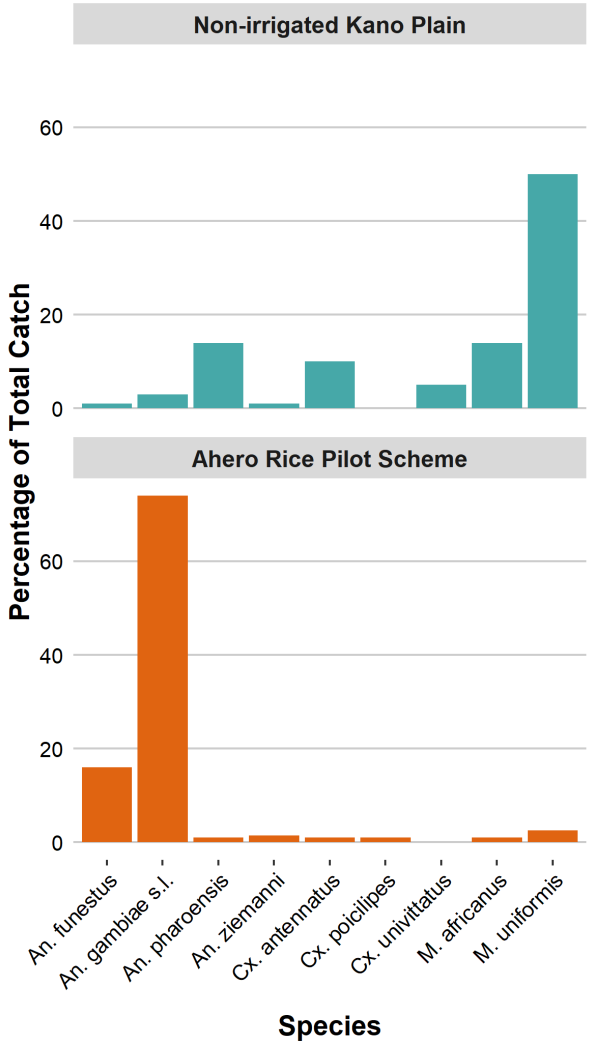


The association between rice and *An. gambiae* s.l..

Relative ratios of *An. gambiae* s.l. human biting rate (HBR), sporozoite rate and entomological inoculation rate (EIR) between rice and non-rice communities were calculated.

Studies included are arranged by the year of study.

Turquoise bars indicate that, compared to control areas, the entomological measure was higher in rice-growing areas, whilst orange bars indicate lower measures in rice.



Mosquito species found in wetlands vs. irrigated rice.

A comparison of indoor mosquito catches between natural, non-irrigated wetlands (turquoise) and irrigated rice fields (orange) in Kenya.

Mosquito numbers generated from the two different systems were similar, but species composition has completely changed.

This is adapted from a study conducted in 1971–72 by Chandler, Highton and Hill.