VCWG 2023

Rice & Malaria in Africa:
Suppressing the breeding of malaria vectors in rice fields

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Two parts:

1. Nowadays, rice areas in SSA bring more malaria – in the future, in elimination settings, their effect will be more conspicuous

2. Modified rice cultivation practices can control malaria vectors

Part 1:
Nowadays, rice areas bring more malaria, and, in the future, they will become a problem in elimination settings

Ministry of Health
is planning for
the elimination of malaria

Ministry of Agriculture
is planning for
a major expansion in irrigated rice

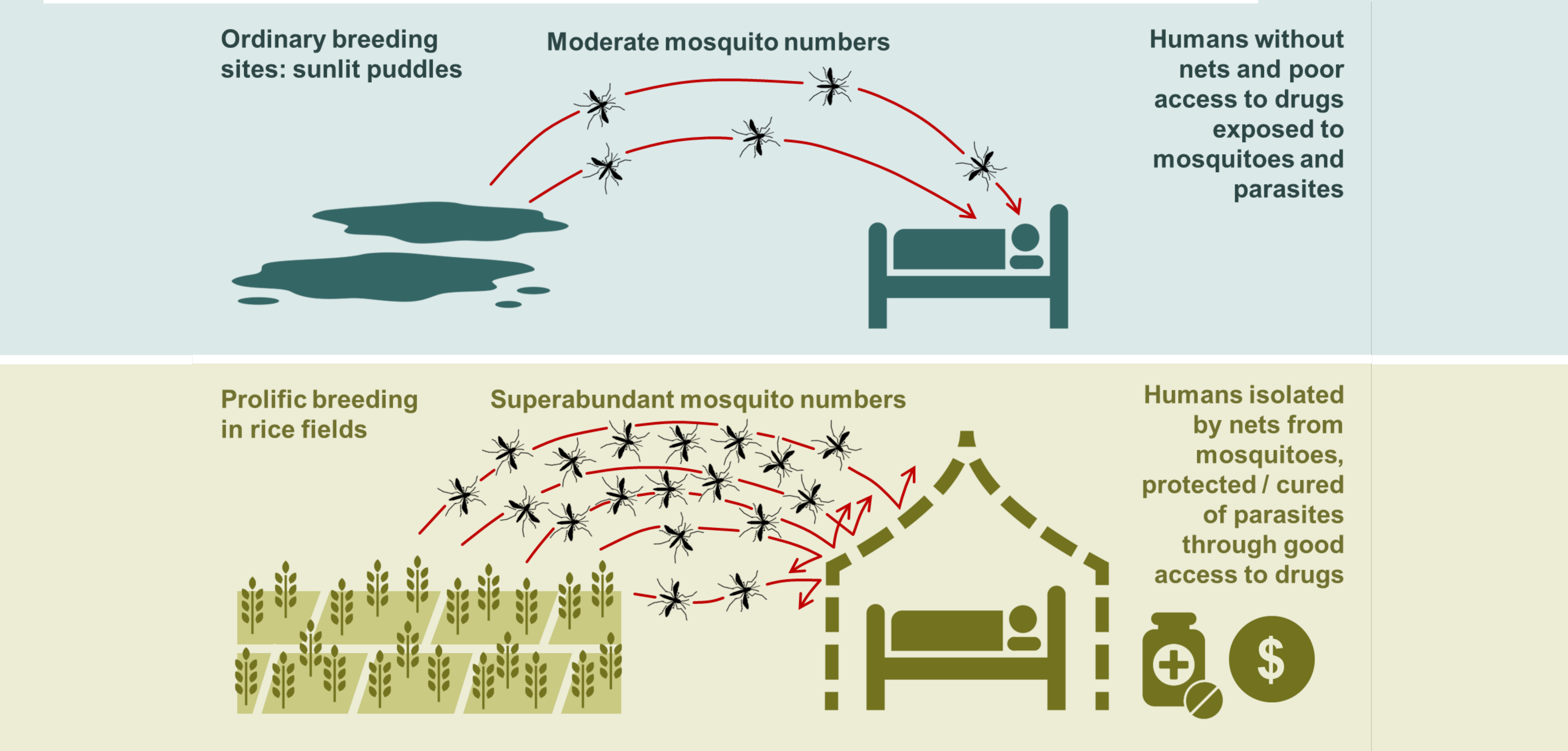
The effect of rice cultivation on malaria

vs.

A series of studies (1990s -2000s) in East & West Africa investigated the difference in *malaria prevalence* between *rice and non-rice communities*

Paddies paradox: Rice fields generate a large amount of malaria vectors, but the amount of malaria in rice communities remains unaltered or is decreased.

The effect of rice cultivation on malaria

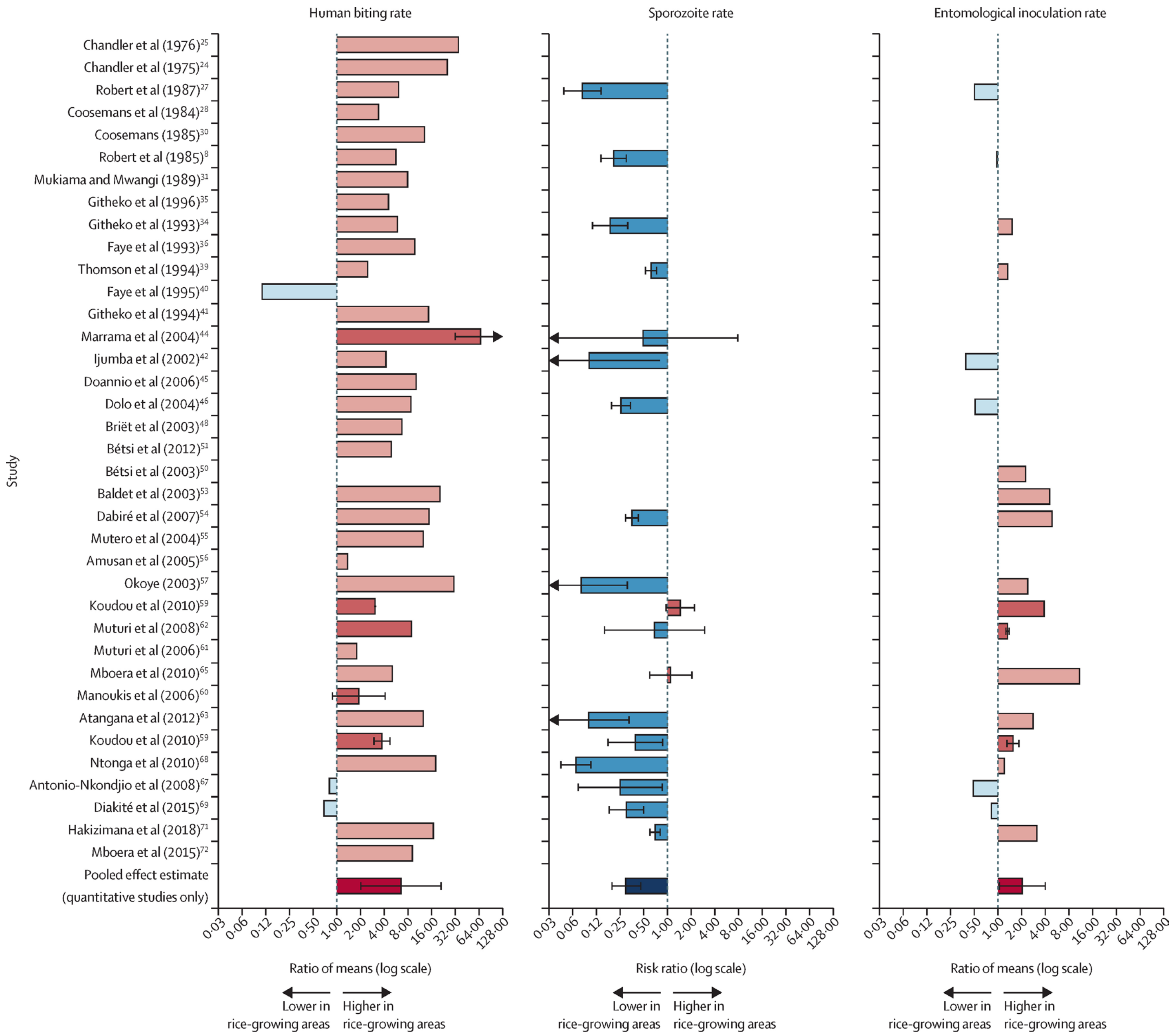


Why re - examine the paddies paradox?

1. The wrong counterfactual: mosquitoes were never harmless – the paradox depends on inequity

2. Intervention coverage has changed

3. Malaria in Africa has changed = pathway to elimination



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

Relative ratios of *An. gambiae* s.l.

- human biting rate (HBR),
- sporozoite rate (SIR) and,
- entomological inoculation rate (EIR)

between rice and non -rice growing areas were calculated.

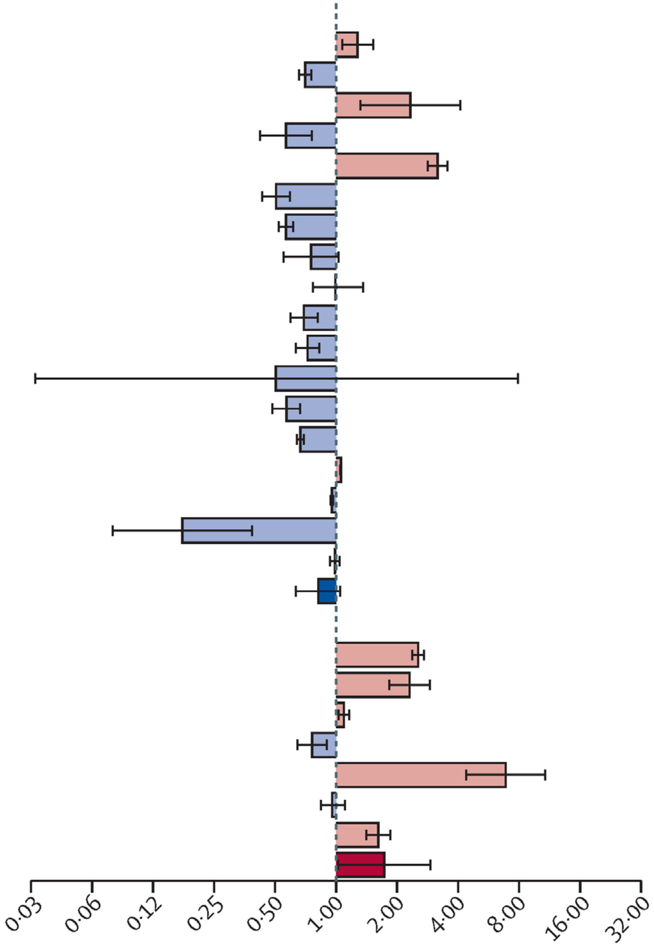
Blue bars indicate that, compared to non-rice growing areas, the entomological measure was higher in rice-growing areas, whilst red bars indicate lower measures in rice.

A

	Country	Year	Control areas: Total participants	Control areas: *Pf*PR$_{2-10}$	Rice-growing areas: Total participants	Rice-growing areas: *Pf*PR$_{2-10}$	Risk ratio (95% CI)
Pre-2003 studies							
Audibert et al (1990)[26]	Cameroon	1979	1470	19·4558	491	24·8473	1·28 (1·06–1·54)
Robert et al (1987)[27]	Burkina Faso	1980	817	62·4235	1505	43·8538	0·70 (0·65–0·76)
Couprié et al (1985)[29]	Cameroon	1981	554	3·2491	370	7·5676	2·33 (1·31–4·15)
Audibert et al (1990)[26]	Cameroon	1981	775	12·5161	864	7·0602	0·56 (0·42–0·77)
Coosemans (1985)[29]	Burundi	1982	1335	17·2045	2357	54·7553	3·18 (2·81–3·60)
Josse et al (1987)[32]	Cameroon	1985	966	26·9151	1409	13·5557	0·50 (0·43–0·60)
Boudin et al (1992)[33]	Burkina Faso	1985	1033	62·8359	1087	35·4221	0·56 (0·51–0·62)
Audibert et al (1990)[26]	Cameroon	1985	469	14·7122	542	11·0701	0·75 (0·54–1·04)
Faye et al (1993)[37]	Senegal	1990	685	9·6825	1035	9·7871	1·01 (0·75–1·36)
Thomson et al (1994)[39]	The Gambia	1991	1167	50·3844	298	35·0622	0·69 (0·59–0·82)
Gbakima (1994)[38]	Sierra Leone	1991	105	68·9089	1001	49·5132	0·72 (0·63–0·83)
Faye et al (1995)[40]	Senegal	1992	329	0·3180	656	0·1595	0·50 (0·03–7·99)
Ijumba et al (2002)[43]	Tanzania	1994	1483	21·4820	1468	12·2114	0·57 (0·48–0·67)
Sissoko et al (2004)[47]	Mali	1995	3308	51·0108	5826	33·9839	0·67 (0·63–0·70)
Henry et al (2003)[49]	Côte d'Ivoire	1997	11 951	83·2694	24 266	88·0288	1·06 (1·05–1·07)
Assi et al (2013)[52]	Côte d'Ivoire	1998	8189	50·7864	21 141	48·5513	0·96 (0·93–0·98)
Mutero et al (2004)[55]	Kenya	2001	116	38·9543	90	7·0057	0·17 (0·08–0·38)
Koudou et al (2009)[58]	Côte d'Ivoire	2002	245	90·9072	171	90·1236	0·99 (0·93–1·05)
Pooled effect estimate							0·82 (0·63–1·06)
Post-2003 studies							
Rumisha et al (2019)[64]	Tanzania	2004	3283	18·7713	4605	47·8074	2·55 (2·36–2·75)
Mboera et al (2011)[66]	Tanzania	2005	289	22·6452	289	51·8647	2·31 (1·81–2·94)
Koudou et al (2009)[58]	Côte d'Ivoire	2005	795	63·7318	714	69·6313	1·09 (1·02–1·17)
Touré et al (2016)[70]	Mali	2010	417	34·7716	728	26·5096	0·76 (0·64–0·91)
Mboera et al (2015)[73]	Tanzania	2012	1016	1·9322	1022	13·6478	6·91 (4·36–10·95)
Hien et al (2017)[74]	Burkina Faso	2014	329	55·6231	285	53·3333	0·96 (0·83–1·11)
Babamale et al (2020)[75]	Nigeria	2018	137	58·9749	93	95·9538	1·62 (1·40–1·87)
Pooled effect estimate							1·73 (1·01–2·96)

Pre-2003 studies

Post-2003 studies



B

VERY HIGH

MEDIUM - HIGH

LOW

	Country	Year	Control areas		Rice-growing areas		Risk ratio (95% CI)
			Total participants	*Pf*PR$_{2–10}$	Total participants	*Pf*PR$_{2–10}$	
Very high (>75%) baseline prevalence							
Koudou et al (2009)[58]	Côte d'Ivoire	2002	245	90·9072	171	90·1236	0·99 (0·93–1·05)
Henry et al (2003)[49]	Côte d'Ivoire	1997	11 951	83·2694	24 266	88·0288	1·06 (1·05–1·07)
Medium to high (26–75%) baseline prevalence							
Gbakima (1994)[38]	Sierra Leone	1991	105	68·9089	1001	49·5132	0·72 (0·63–0·83)
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Low (≤25%) baseline prevalence							
Mboera et al (2011)[66]	Tanzania	2005	289	22·6452	289	51·8647	2·31 (1·81–2·94)
Ijumba et al (2002)[43]	Tanzania	1994	1483	21·4820	1468	12·2114	0·57 (0·48–0·67)
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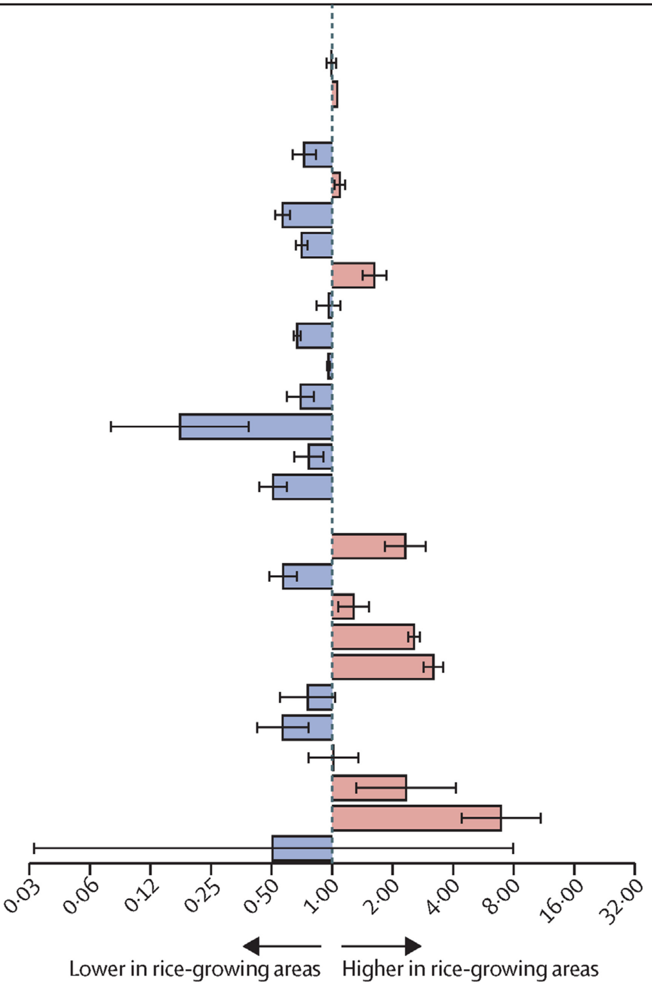

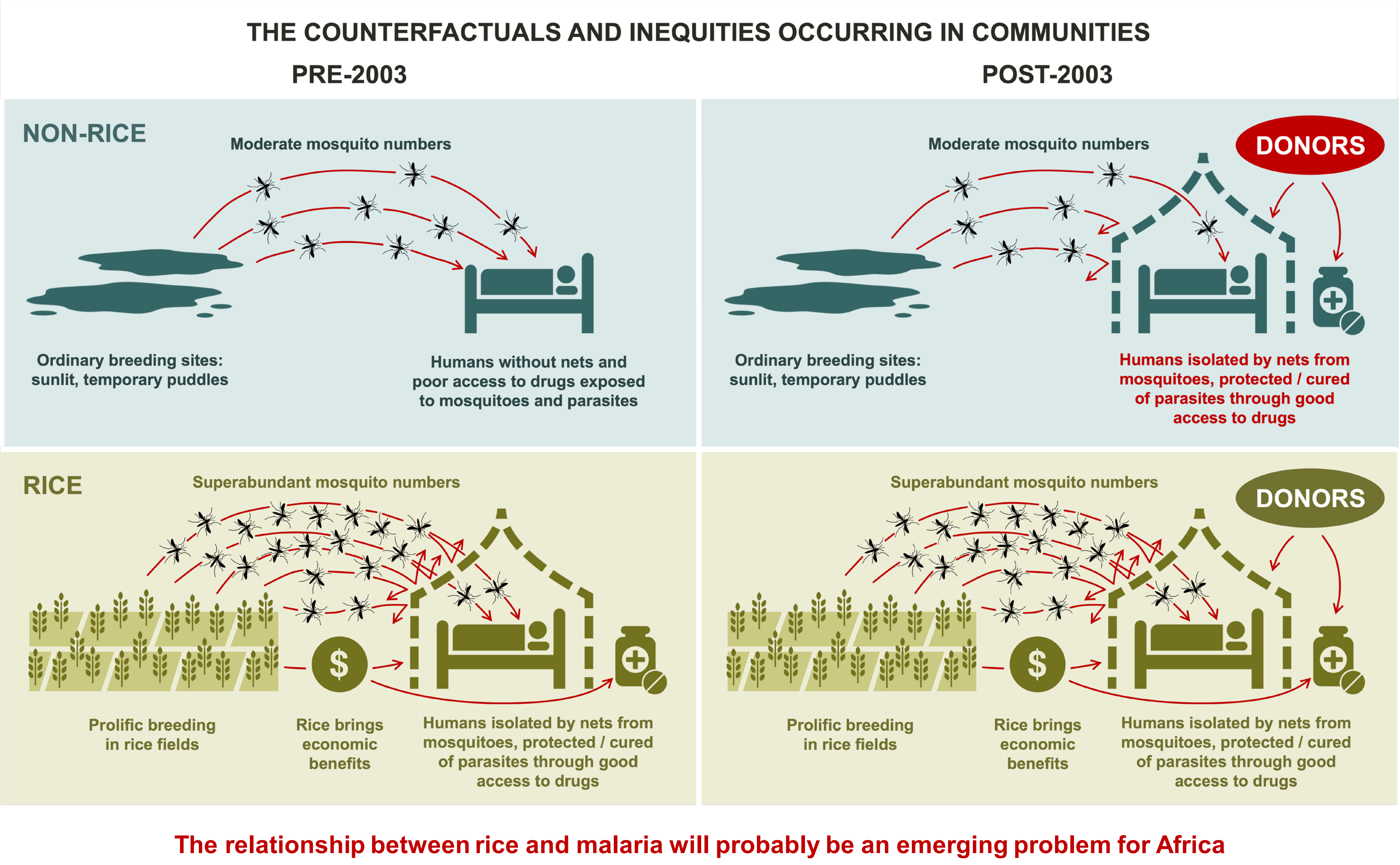
THE COUNTERFACTUALS AND INEQUITIES OCCURRING IN COMMUNITIES
PRE-2003
POST-2003
NON-RICE
Moderate mosquito numbers
Ordinary breeding sites: sunlit, temporary puddles
Humans without nets and poor access to drugs exposed to mosquitoes and parasites
Moderate mosquito numbers
DONORS
Ordinary breeding sites: sunlit, temporary puddles
Humans isolated by nets from mosquitoes, protected / cured of parasites through good access to drugs
RICE
Superabundant mosquito numbers
$
Prolific breeding in rice fields
Rice brings economic benefits
Humans isolated by nets from mosquitoes, protected / cured of parasites through good access to drugs
Superabundant mosquito numbers
DONORS
$
Prolific breeding in rice fields
Rice brings economic benefits
Humans isolated by nets from mosquitoes, protected / cured of parasites through good access to drugs
The relationship between rice and malaria will probably be an emerging problem for Africa

How can we grow rice without growing mosquitoes?

Whose problem?

Agricultural sector or public health sector?

How can they work together on this problem?

Part 2:
Modified rice cultivation practices, incl. alternate wetting and drying irrigation, can control malaria vectors in some settings

Background

JUNE 1990 JOUR. AMER. MOSQUITO CONTROL ASSOC. VOL. 6

THE MEDICAL IMPORTANCE OF RICELAND MOSQUITOES AND THEIR CONTROL USING ALTERNATIVES TO CHEMICAL INSECTICIDES

LAWRENCE A. LACEY AND CYNTHIA M. LACEY

Vector Biology and Control Project, AID/MSCI, 1611 N. Kent Street, Suite 503, Arlington, VA 22209

Journal of the American Mosquito Control Association, 18(4):329-24), 2002
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THE POTENTIAL OF INTERMITTENT IRRIGATION FOR INCREASING RICE YIELDS, LOWERING WATER CONSUMPTION, REDUCING METHANE EMISSIONS, AND CONTROLLING MALARIA IN AFRICAN RICE FIELDS

JENNIFER KEISER, JÜRG UTZINGER AND BURTON H. SINGER

Office of Population Research, Princeton University, Princeton, NJ 08544

- Lots of riceland LSM studies, but still major gaps
- What about the effect of rice cultivation practices on mosquitoes e.g. land preparation, crop establishment, fertiliser application?
- Rice yield takes priority
- What about water use, greenhouse gas emissions, weed production, soil conditions, etc.?

Systematic review & meta - analysis

Field experimental studies: controlled time series and controlled interrupted time series

	Larviciding				Biological control		Environmental management / rice cultivation practices		
	Oils and surface agents	Synthetic organic chemicals	Biological larvicides	Insect growth regulator	Fish	Copepod, *Azolla*, neem	Irrigation	Other: land preparation, water height, plant height	Total
Publication period									
1941-1950		1					2		3
1951-1960		1							1
1961-1970									0
1971-1980	1	3			1				5
1981-1990		3	9*	1	4*		2*	2	21
1991-2000	1	1*	4*		2	3*	3*	2	16
2001-2010		1*	3*		1			2	7
2011-2021	1						1*	1*	3
Geographical region									
Africa	3	2*	3*		1*		1*	3*	13
South Asia		2	2*		1*	2*	4*	1	12
America		4*	9*	1	3	1	1*	2	21
East and SE Asia		2*	2*		3		1	1	9
Europe							1		1
Total	**3**	**10**	**16**	**1**	**8**	**3**	**8**	**7**	

66%

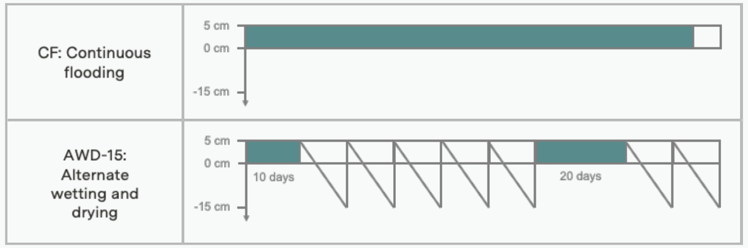
Systematic review & meta - analysis

	Does it work? (% effectiveness)	No. of studies (no. in SSA)
Monomolecular surface films	-57.2 (-69.4, -40.3) / -91.6 (-99.9, +486.3)	3 (3)
Biological larvicides	-60.0 (-71.8,-43.1)	10 (2)
Synthetic organic chemicals	-73.1 (-83.8, -55.4) / -72.3 (-89.5, -26.9)	6 (2)
Fish	-81.5 (-91.4,-60.2) / -87.1 (-93.9, -72.7)	6 (1)
Copepods	-40.5 (-82.8, +105.6)	1 (0)
Azolla	-10.3 (-86.4, +493.3)	1 (0)
Neem	-30.7 (-57.2, +12.3)	1 (0)
Intermittent irrigation	-34.5 (-43.5, -24.0) late-stage larvae	7 (2)
Rice variety	+150.0 (-66.1, +1745.1)	1 (0)
Rice variety & plant spacing	-66.3 (-90.0, +13.4)	1 (0)
Weed control (herbiciding)	+77.4 (+65.7, +89.9)	1 (0)
Agricultural insecticide	-76.4 (-88.8, -50.2)	1 (0)
Land preparation: tillage	-64.7 (-85.5, -14.1)	1 (1)
Land preparation: levelling	-12.8 (-65.2, +118.5)	1 (1)

Experimental trials in Cote d’Ivoire & Tanzania

7 trials, arranged in a randomised complete block design with 3 replicates
Assessed effect of rice growing techniques on mosquito density, water consumption, rice yield and GHG emissions

Water management



Treatment	Yield (t/ha)	Mosquito density (immatures/dip) Early instars	Late instars	Pupae	Irrigation water (m^3/ha)	No. of irrig - ations	Water productivity (kg/m3/ha)	CH_4 (kg/ha)	N_2O (kg/ha)	CO_2 (kg/ha)	GWP (t CO_2/ha)
Trial 6: Water management (CIV)											
CF	5.5 a	0.295 a	0.120 a	0.034 a	2057 a	9 a	0.24 c	343 a	0.16 e	0.001 a	8.61 a
AWD-15	5.5 a	0.241 a	0.156 a	0.046 a	868 c	3 b	0.53 ab	204 b	0.39 a	0.001 a	5.21 b
FD-II	5.3 a	0.405 a	0.190 ab	0.038 a	539 c	4 b	0.72 a	183 c	0.28 d	0.001 a	4.66 c
FD-II2	5.7 a	0.543 a	0.296 b	0.082 a	726 c	4 b	0.63 a	139 e	0.33 b	0.001 a	3.57 e
Supplemental	5.3 a	0.415 a	0.161 a	0.059 a	1384 b	4 b	0.34 bc	156 d	0.29 c	0.001 a	3.99 d
*LSD**	*1.8*	*p=0.435*	*p=0.0495*	*p=0.166*	*513*	*2*	*0.20*	*6.0*	*0.008*	*ns*	*6.0*
Trial 7: Water management (TZN)											
CF	2.0 a	2.944 b	0.141 b	0.043 b	446 a	63 a	0.46 b	-	-	-	-
AWD-15	1.6 a	1.088 a	0.039 a	0.019 ab	209 ab	25 c	0.90 ab	269 a	0.17 a	-	6.8 a
AWD-30	1.6 a	1.706 a	0.043 a	0.017 a	166 b	21 c	1.29 a	350 a	0.29 a	-	8.8 a
DF	1.6 a	1.402 a	0.050 a	0.024 ab	468 a	63 a	0.36 b	-	-	-	-
II3	1.8 a	1.557 a	0.052 a	0.013 a	341 ab	45 b	0.52 b	-	-	-	-

Rice yield

No yield penalties

Mosquitoes

- AWD-15 not effective in CIV
- AWD-15 reduced late-stage malaria vectors in TZN by 72.3%

Water use

AWD-15 reduced water use by 41-71% (across both trials and countries)

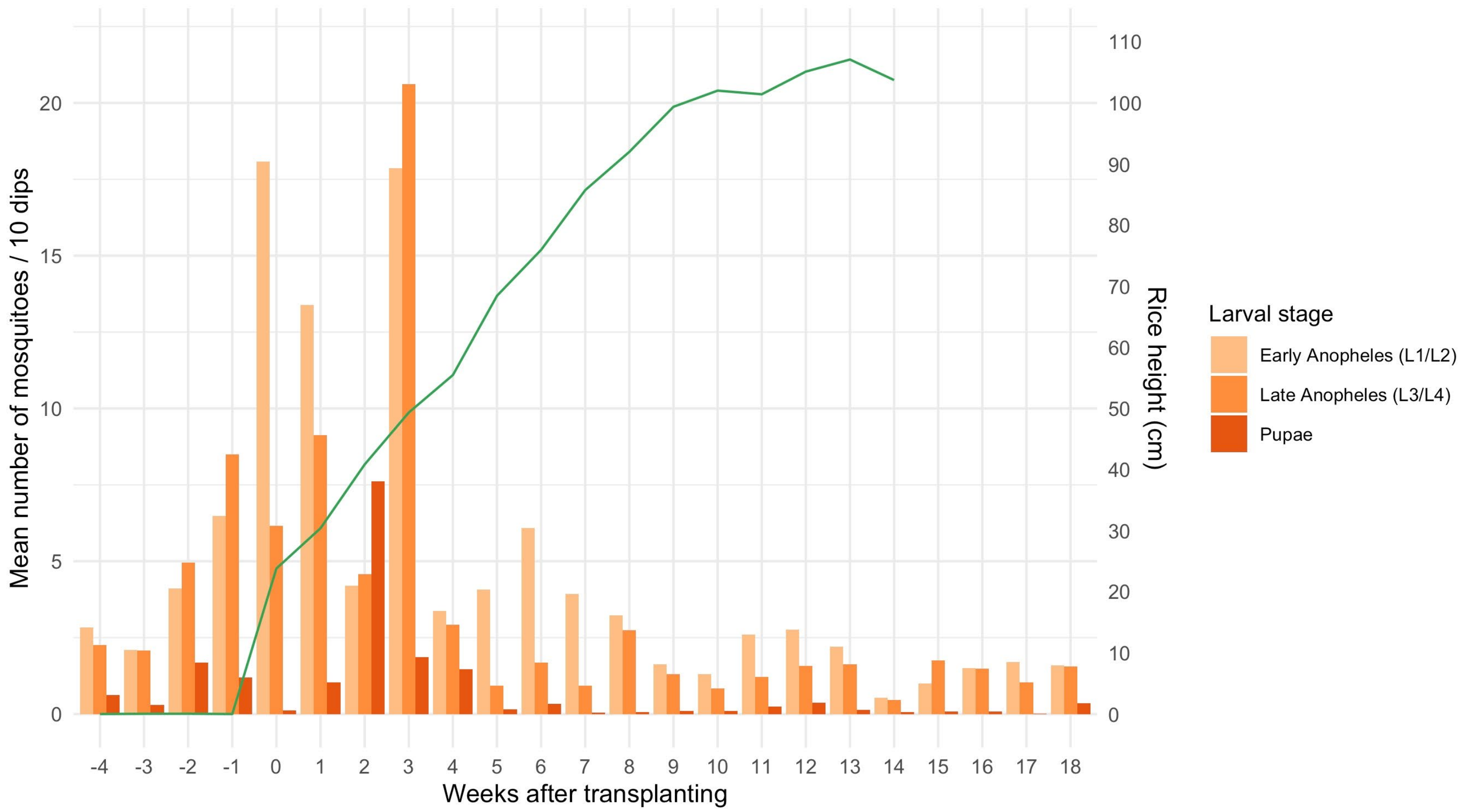
GHG emissions

- AWD-15 produced 41% less methane
- AWD-15 produced 2-fold more nitrous oxide but yield-scaled global warming potential still less

The effect of rice cultivation practices on malaria vector productivity

Land preparation	Minimal tillage	-
	Puddling of <7 days	-
Crop establishment	Direct seeding (vs. transplanting)	+
Water management	Intermittent irrigation (active or passive drainage)	- (late stage)
	Active drainage: intermittent irrigation of 3 -day wet and 3 -day dry cycles	- (in one field trial)
	Passive drainage: alternate wetting and drying irrigation at 15 cm	- (in one field trial)
Pest management	Pesticide application	-
Nutrient management	Fertiliser application	+
Weed management	Herbicide application	+

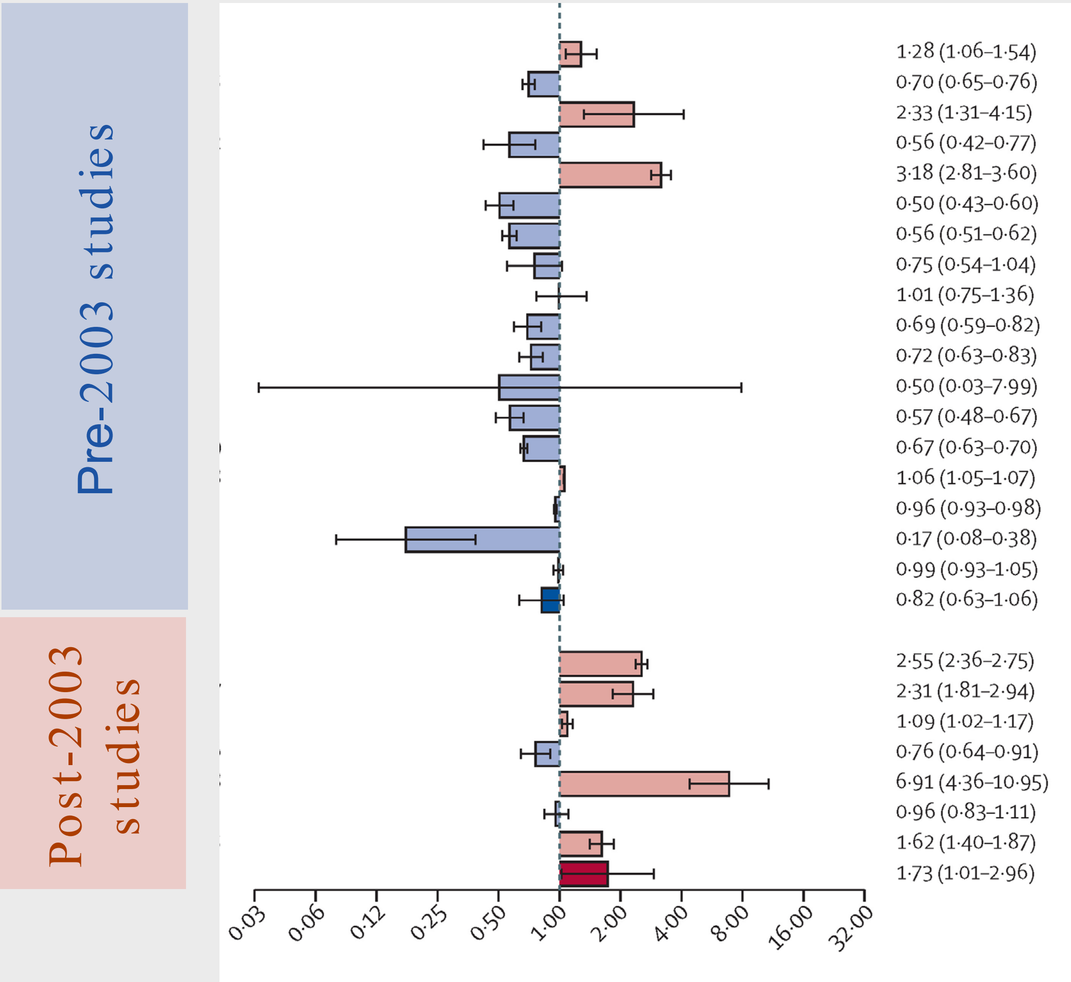
Our task:



Interventions that kill quickly but don't last long

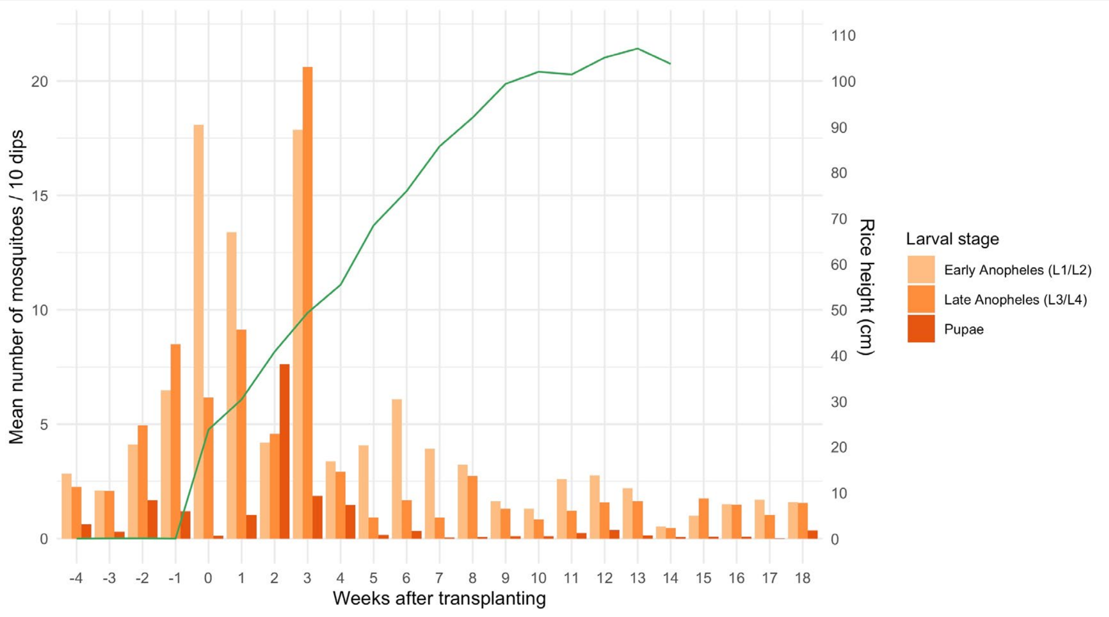
+

Interventions that suppress breeding more consistently



Nowadays, rice areas bring more malaria

In the future, **rice fields will become more strategically important for elimination**



Using current rice cultivation methods, malaria vectors produced will always be a **harmful unintended** side effect

Conversely…

Using modified rice cultivation methods that can suppress malaria vectors would be a **beneficial intended** side effect

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE · AfricaRice · IRRI · RAFT RESILIENCE AGAINST FUTURE THREATS

How can we grow rice without growing mosquitoes?

Rice experts should know
– sooner and better than anyone else –
what effect their recommended production methods have on mosquitoes