
USAID
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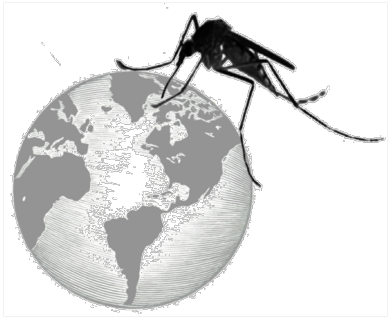
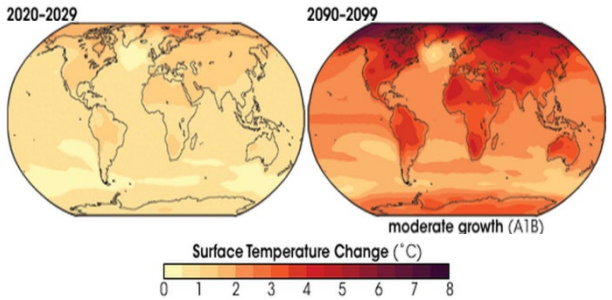
May Adaptation Community Meeting
Shifting Burdens of Malaria in a Hotter Africa:
A Framework for Planning and Intervention
May 16, 2019
ATLAS
Adaptation Thought Leadership and Assessments
Photo: : USAID





Shifting burdens of malaria in Africa under climate change: a framework for planning and intervention

Sadie J. Ryan

EMERGING PATHOGENS INSTITUTE
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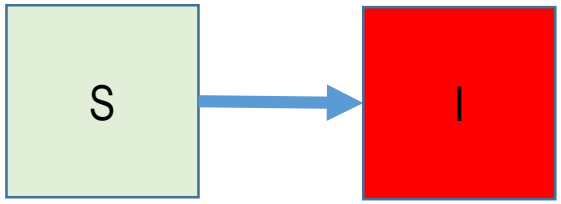
Today's menu

- Introduction to a physiological model for malaria
- Mapping malaria transmission and season
- Adding climate change in Africa & ATLAS project
- Informing interventions

The model continuum

Mechanistic process

Bottom up



$dS/dt = -bSI$

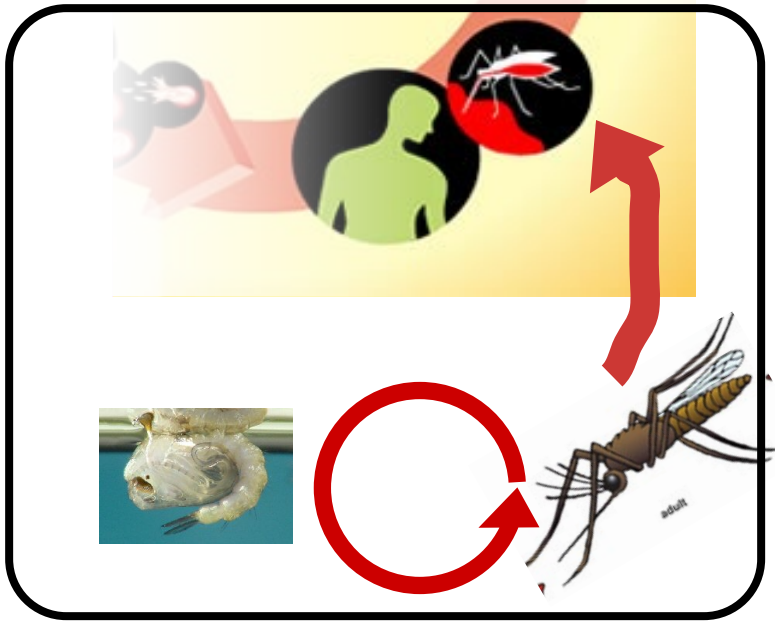
$dI/dt = bSI$

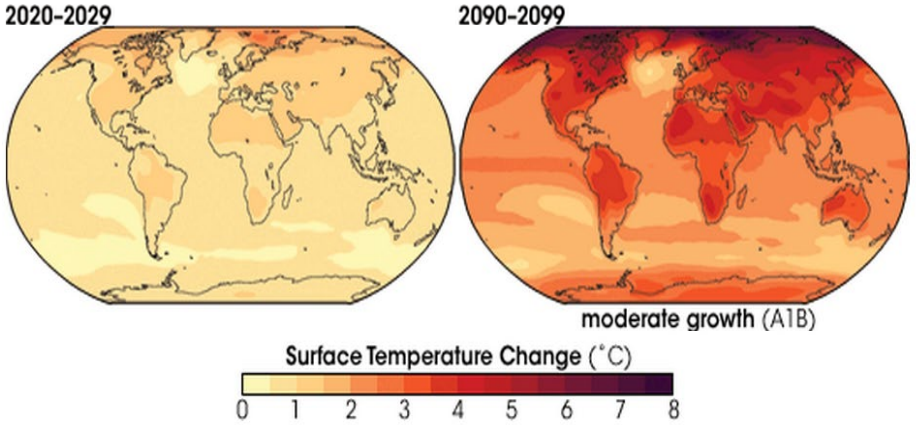
Pattern finding – stats

Top down

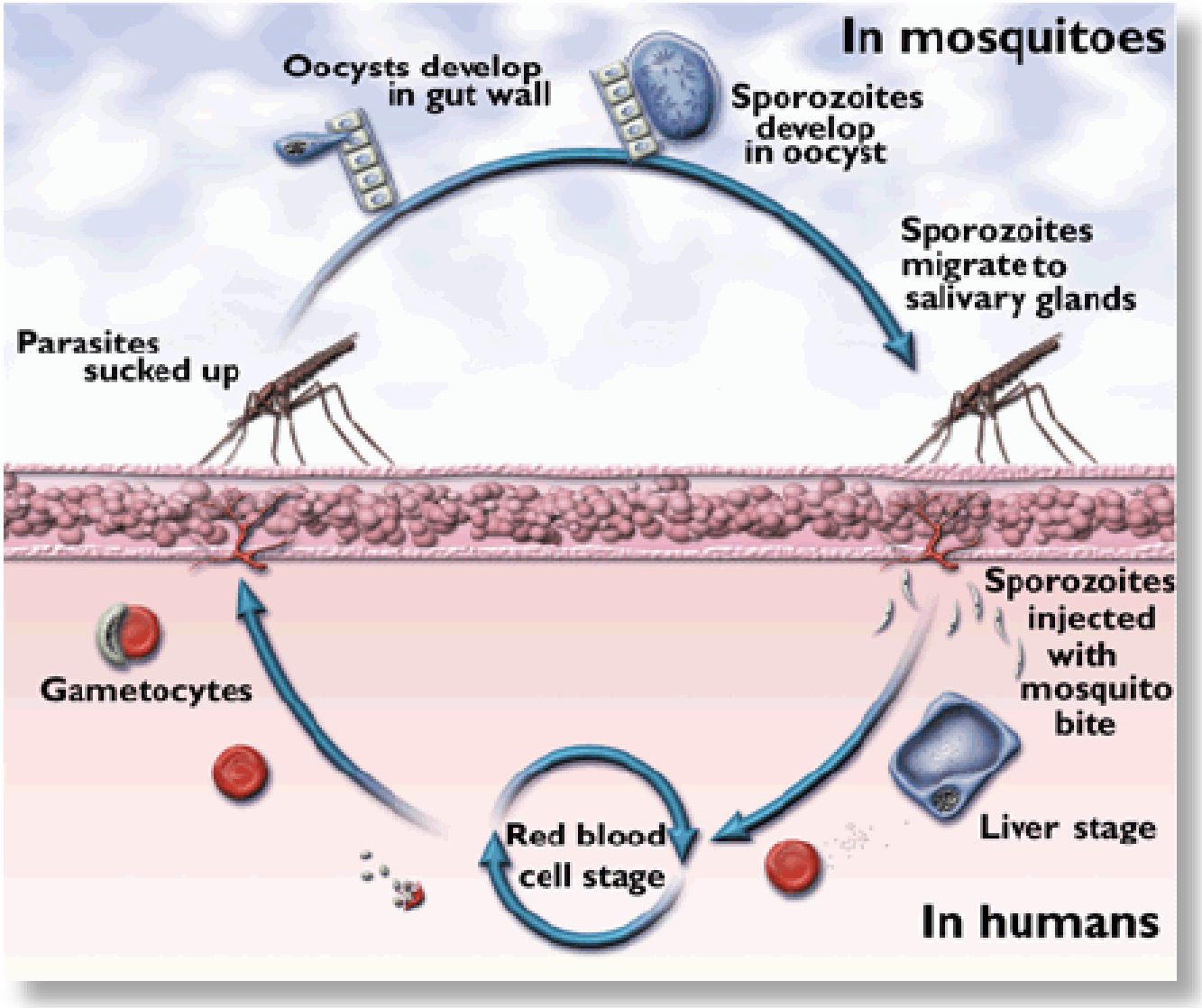
```
Mod <- lmer (x ~
        fever + age + NDVI + temp +
        1|state)
```

Is a warmer world necessarily a sicker world?





How does malaria respond to temperature?



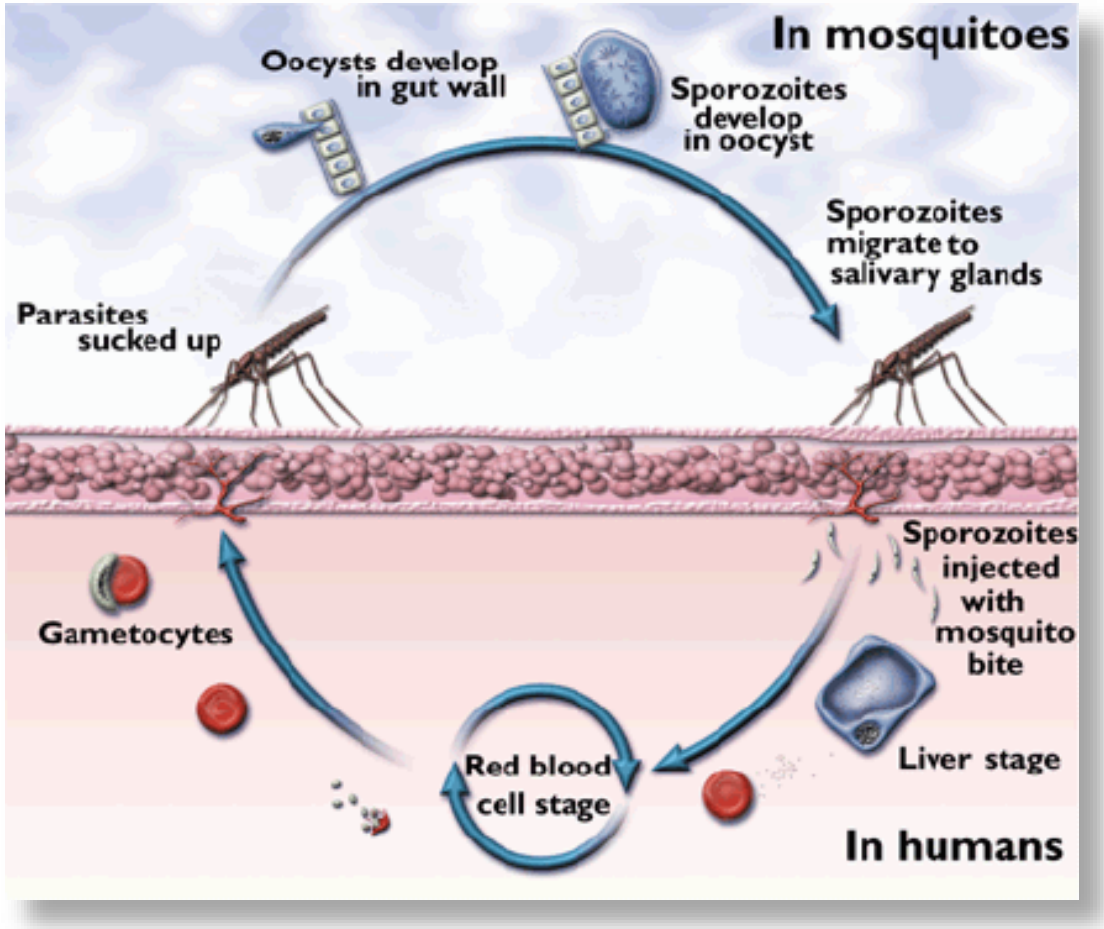
How does malaria respond to temperature?

What Processes Drive Malaria Transmission?

$$R_0 = \sqrt{\frac{ma^2bp^{EIP}}{-r\ln(p)}}$$

MacDonald (1957)

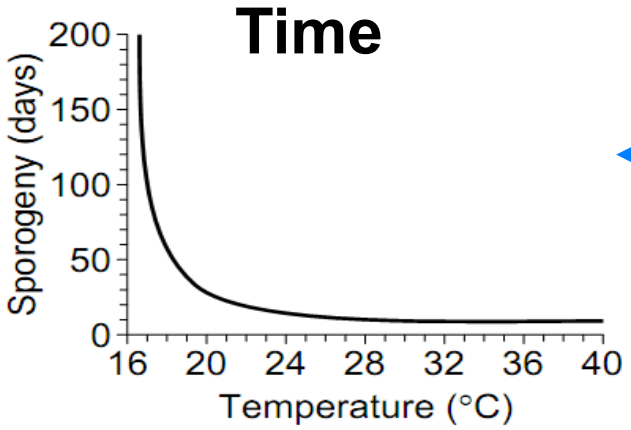
- mosquito density (*m*)
- mosquito biting rate (*a*)
- infectiousness of infected mosquitoes (*b*)
- vector survival (*p*)
- human recovery rate (*r*)

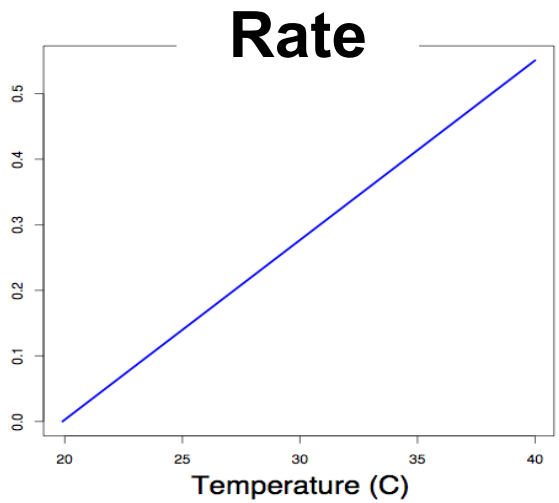


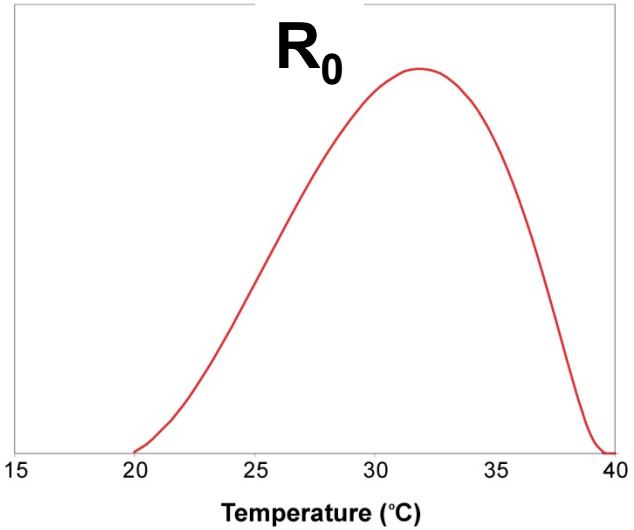
How Does Temperature Drive Biological Processes?

Previous malaria models:

linear or constant rates



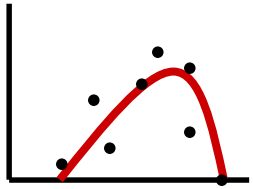




opposing effects of temperature on parasite development and mosquito survival

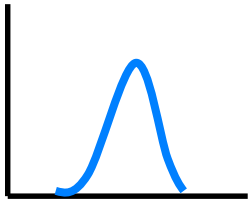
Our approach

Fit physiological responses with data



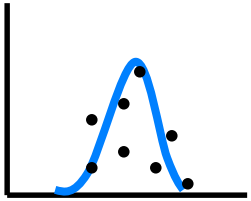
symmetric & asymmetric, linear (for comparison)

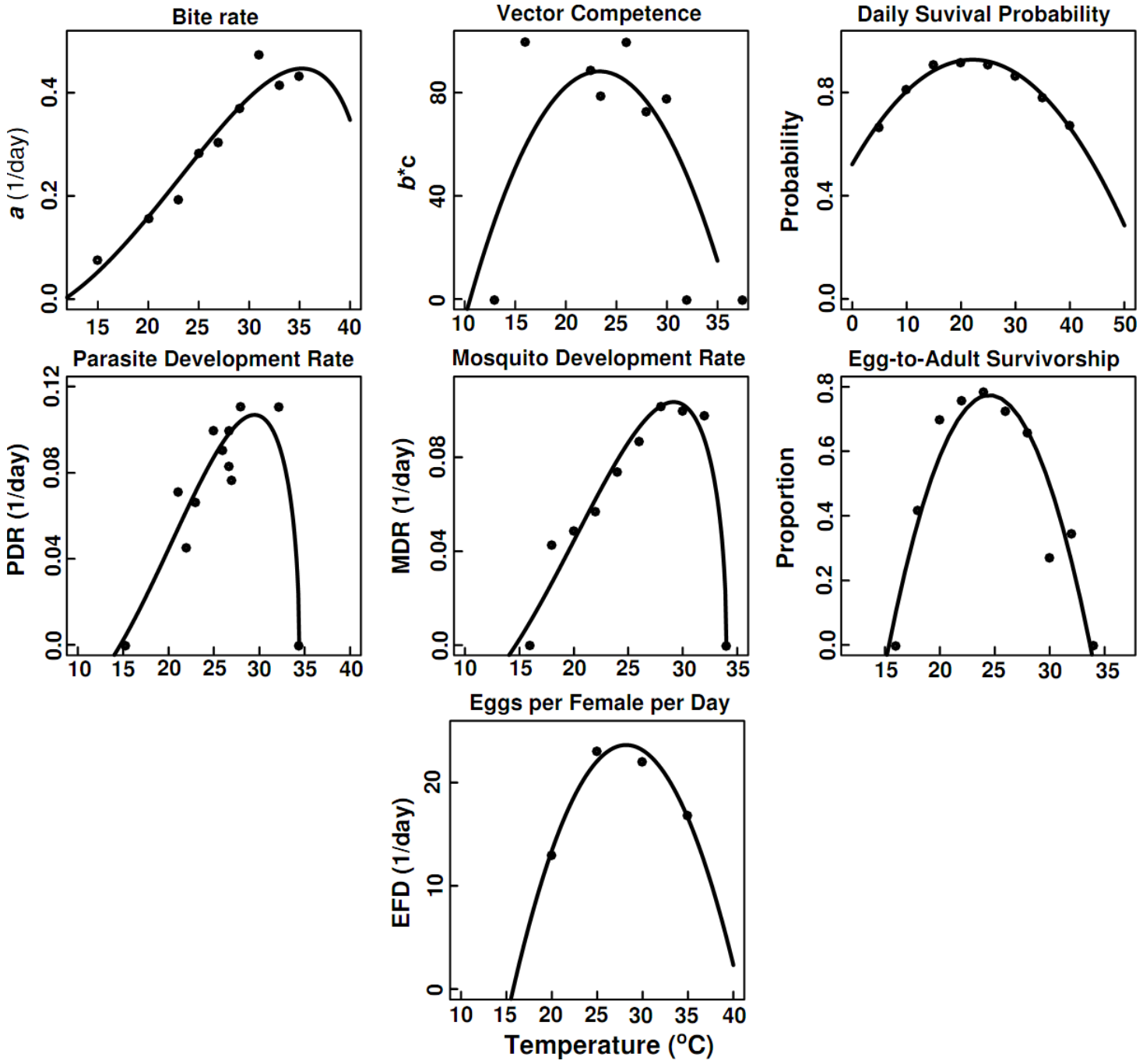
Calculate R_0 vs. T



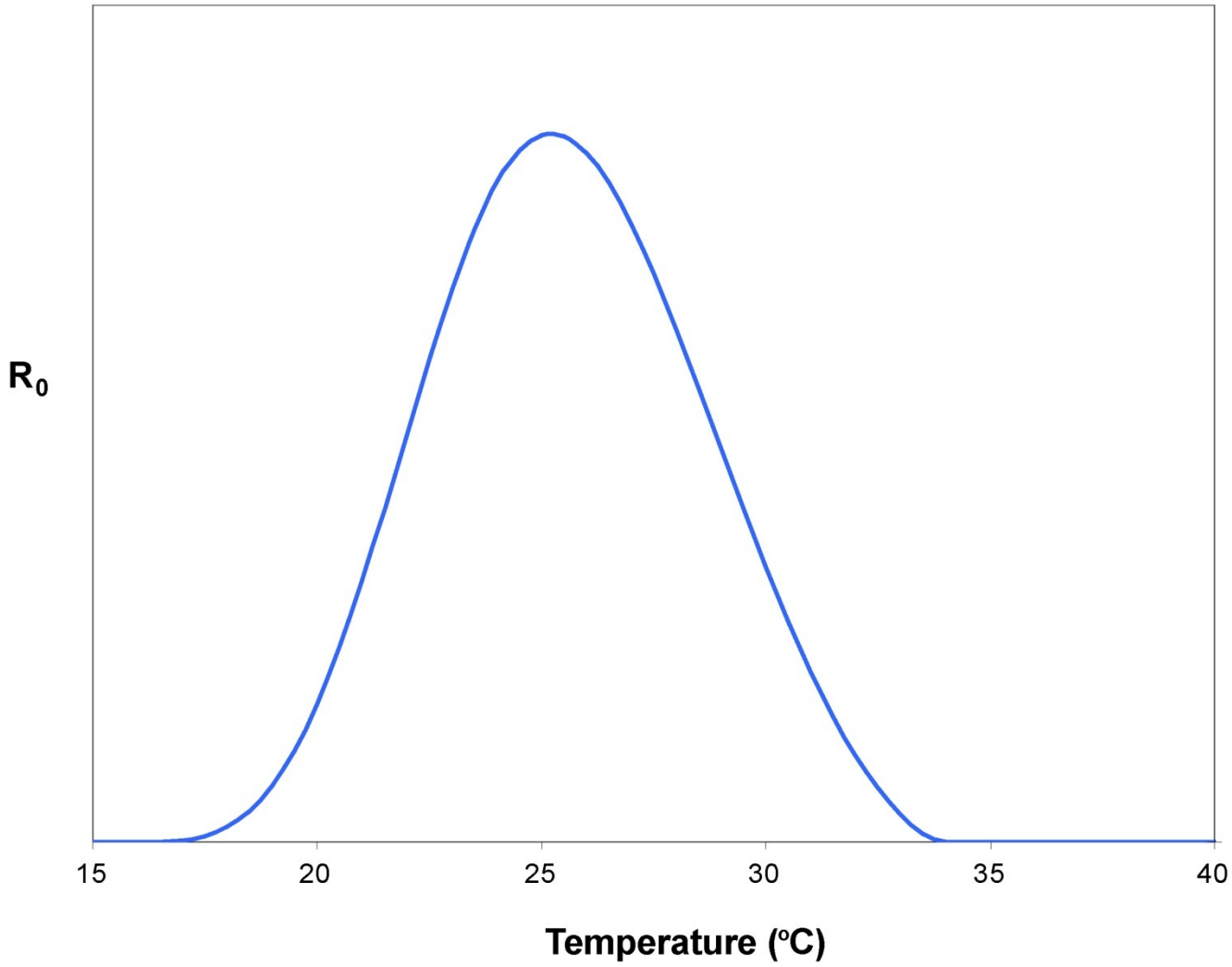
$$R_0 = \sqrt{\frac{a^2 bcmp^T}{(-\ln p)r}}$$

Validate with field data

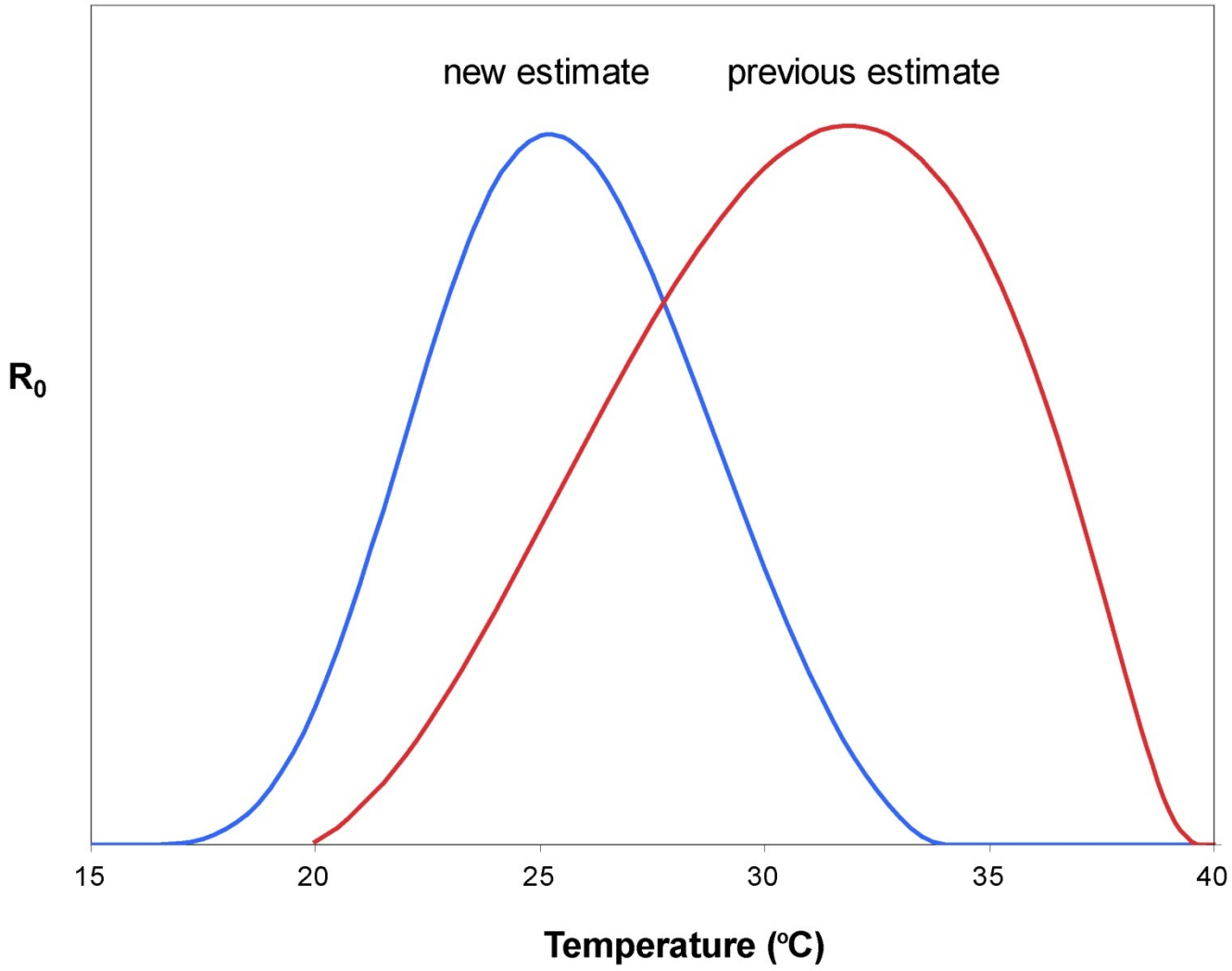



Bite rate
a (1/day)
0.0
0.2
0.4
15
20
25
30
35
40
Vector Competence
b*c
0
40
80
10
15
20
25
30
35
Daily Suvival Probability
Probability
0.0
0.4
0.8
0
10
20
30
40
50
Parasite Development Rate
PDR (1/day)
0.0
0.04
0.08
0.12
10
15
20
25
30
35
40
Mosquito Development Rate
MDR (1/day)
0.0
0.04
0.08
10
15
20
25
30
35
Egg-to-Adult Survivorship
Proportion
0.0
0.2
0.4
0.6
0.8
15
20
25
30
35
Eggs per Female per Day
EFD (1/day)
0
10
20
10
15
20
25
30
35
40
Temperature (°C)

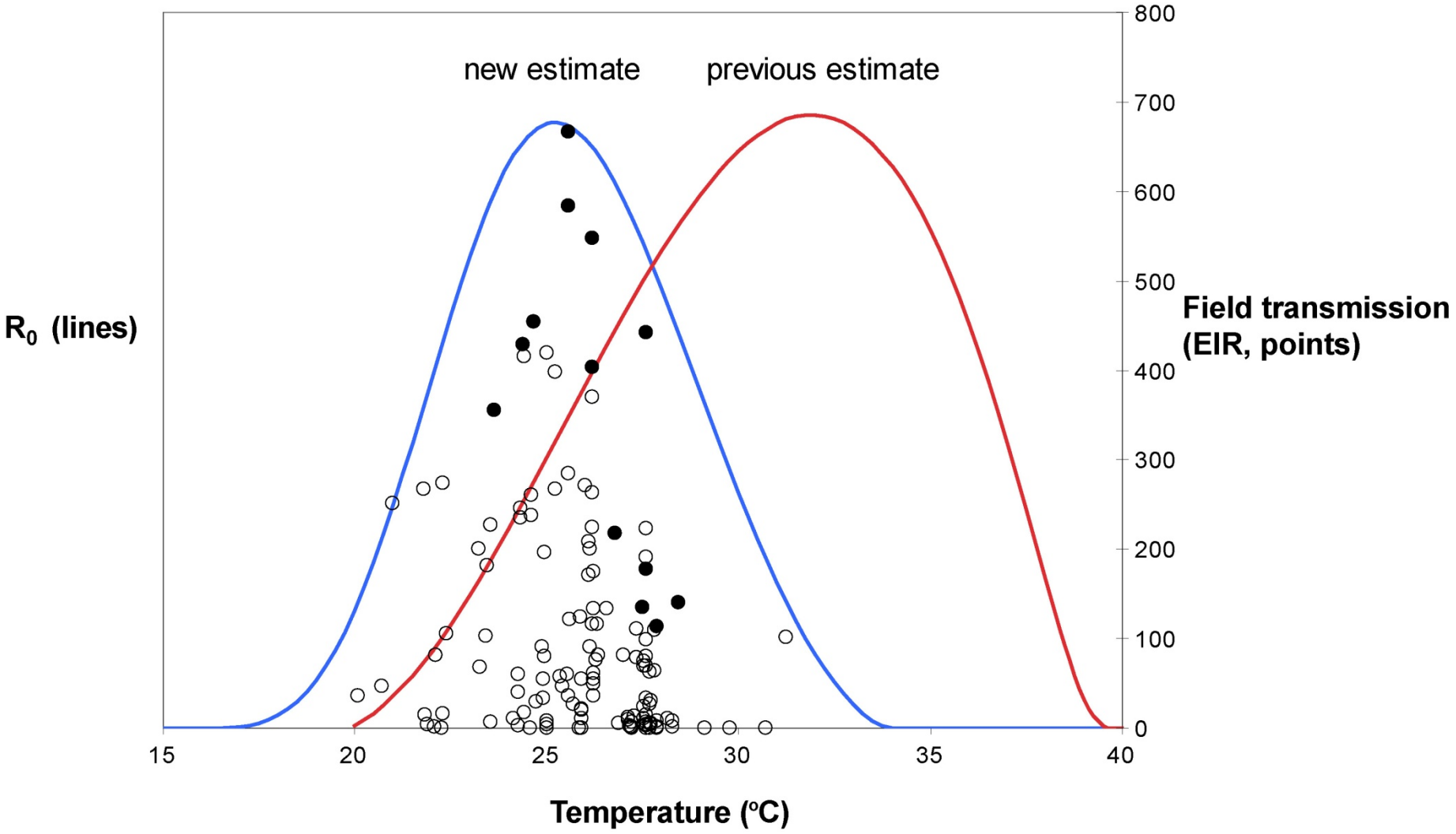
R_0 vs. Temperature



6°C cooler


new estimate
previous estimate
R_0
15
20
25
30
35
40
Temperature (°C)

Matches field data



Field data from MARA project and ERA-40 project

ECOLOGY LETTERS

Ecology Letters, (2012) doi: 10.1111/ele.12015

LETTER

Optimal temperature for malaria transmission is dramatically lower than previously predicted

Erin A. Mordecai,[1,*] Krijn P. Paaijmans,[2] Leah R. Johnson,[3] Christian Balzer,[1,†] Tal Ben-Horin,[4] Emilyde Moor,[5] Amy McNally,[5] Samraat Pawar,[6] Sadie J. Ryan,[7] Thomas C. Smith[1] and Kevin D. Lafferty[1,8]

Abstract

The ecology of mosquito vectors and malaria parasites affect the incidence, seasonal transmission and geographical range of malaria. Most malaria models to date assume constant or linear responses of mosquito and parasite life-history traits to temperature, predicting optimal transmission at 31 °C. These models are at odds with field observations of transmission dating back nearly a century. We build a model with more realistic ecological assumptions about the thermal physiology of insects. Our model, which includes empirically derived nonlinear thermal responses, predicts optimal malaria transmission at 25 °C (6 °C lower than previous models). Moreover, the model predicts that transmission decreases dramatically at temperatures > 28 °C, altering predictions about how climate change will affect malaria. A large data set on malaria transmission risk in Africa validates both the 25 °C optimum and the decline above 28 °C. Using these more accurate nonlinear thermal-response models will aid in understanding the effects of current and future temperature regimes on disease transmission.

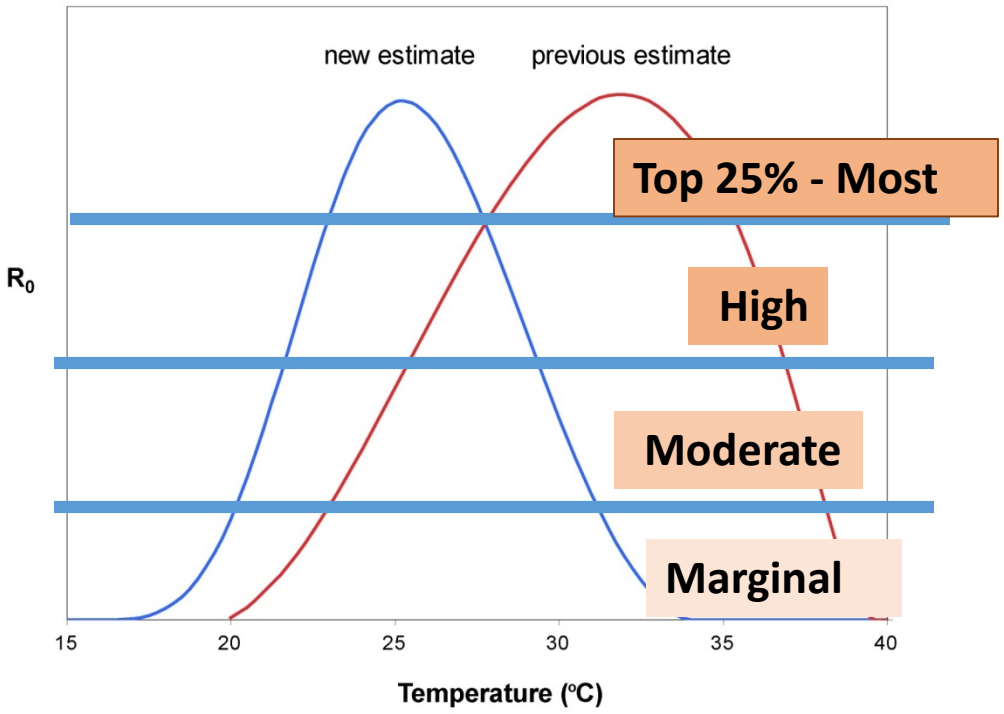
Keywords

Anopheles, climate change, disease ecology, malaria, *Plasmodium falciparum*, temperature.

Ecology Letters (2012)

How do we tell people? People like maps

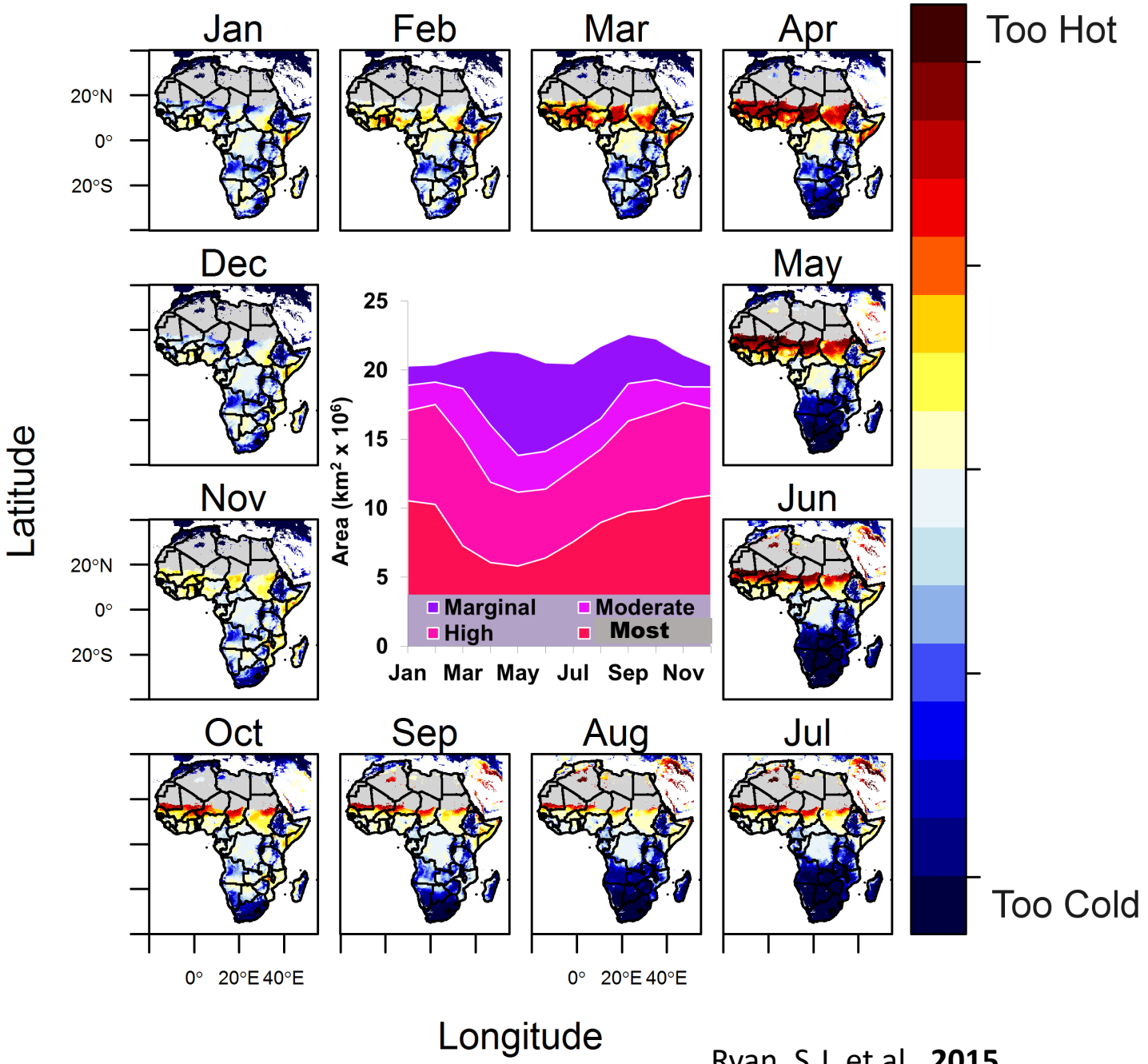
- The question of “where” is very important for control
- Prevention for travelers
- Anticipating shifts of transmissibility and seasons



Ryan, S.J. et al., 2015

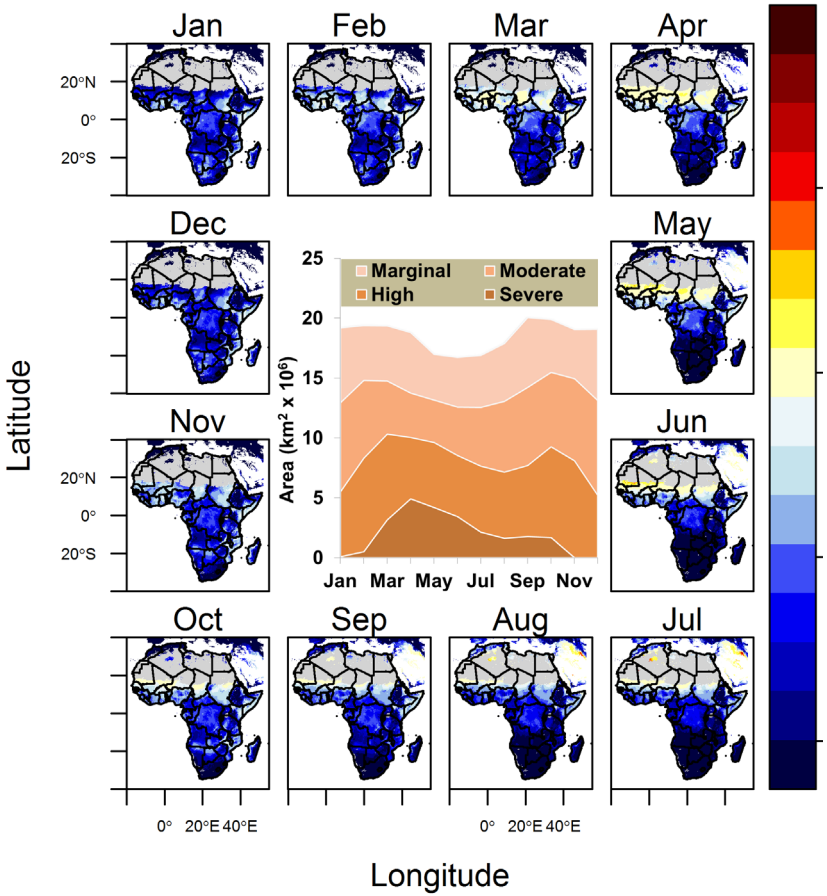
WorldClim data
Temperature
Agg: 10km^2

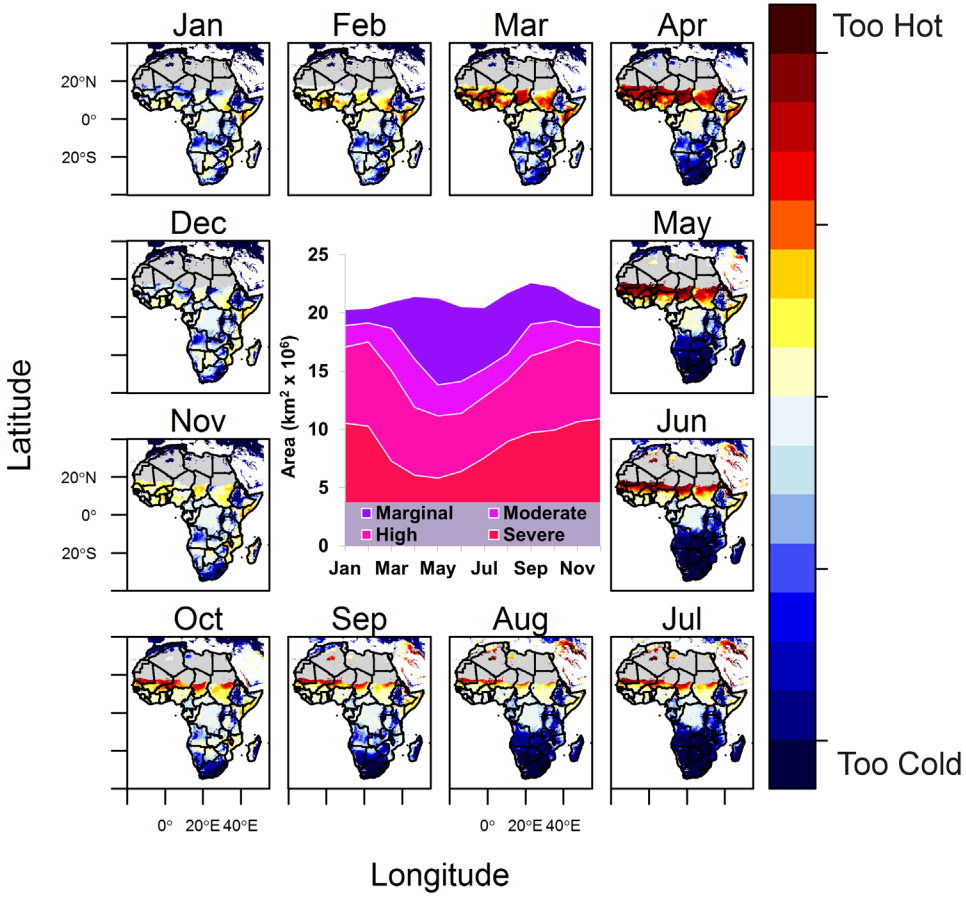
Aridity mask
MODIS NDVI



Ryan, S.J. et al., **2015**

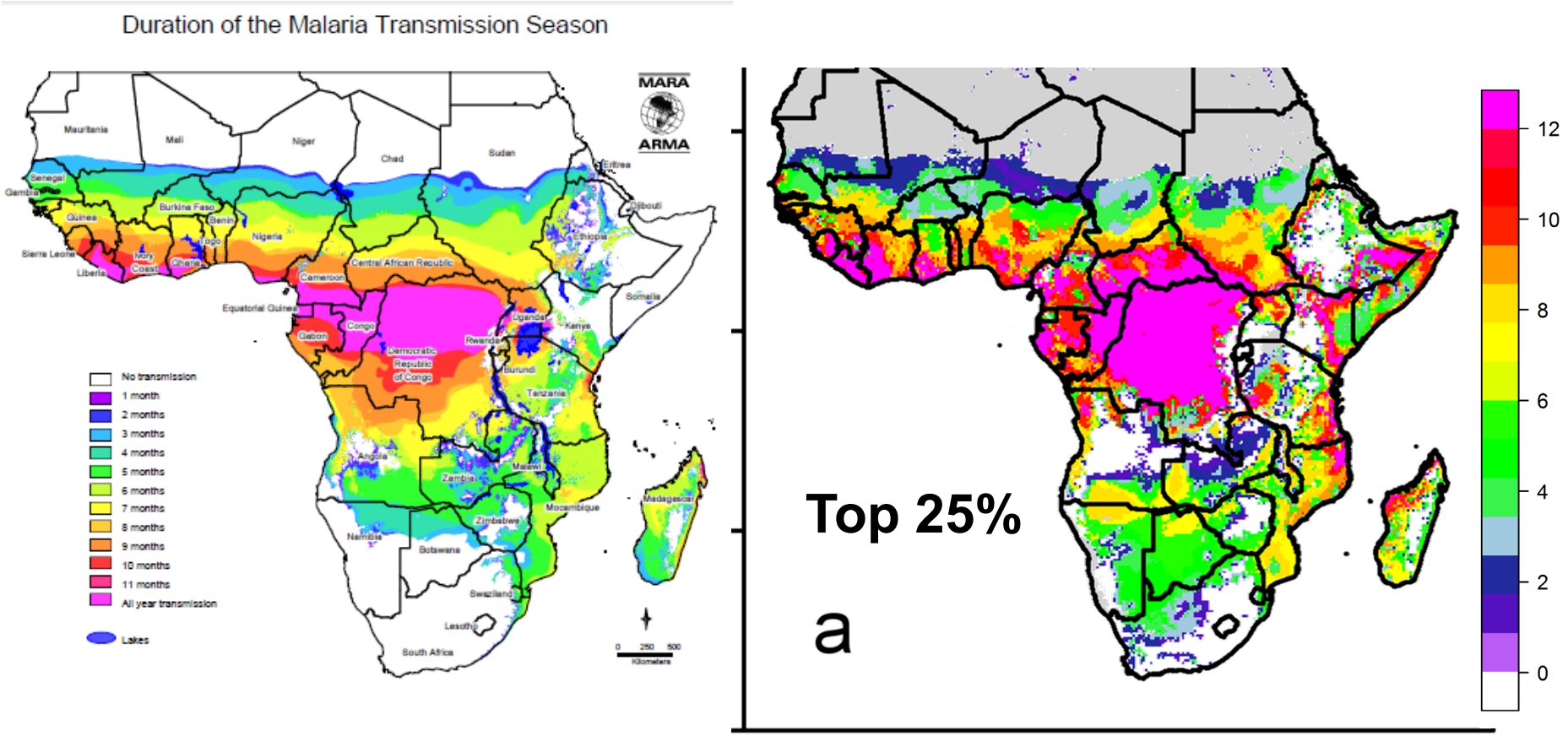
Old and New





Ryan, S.J. et al., **2015**

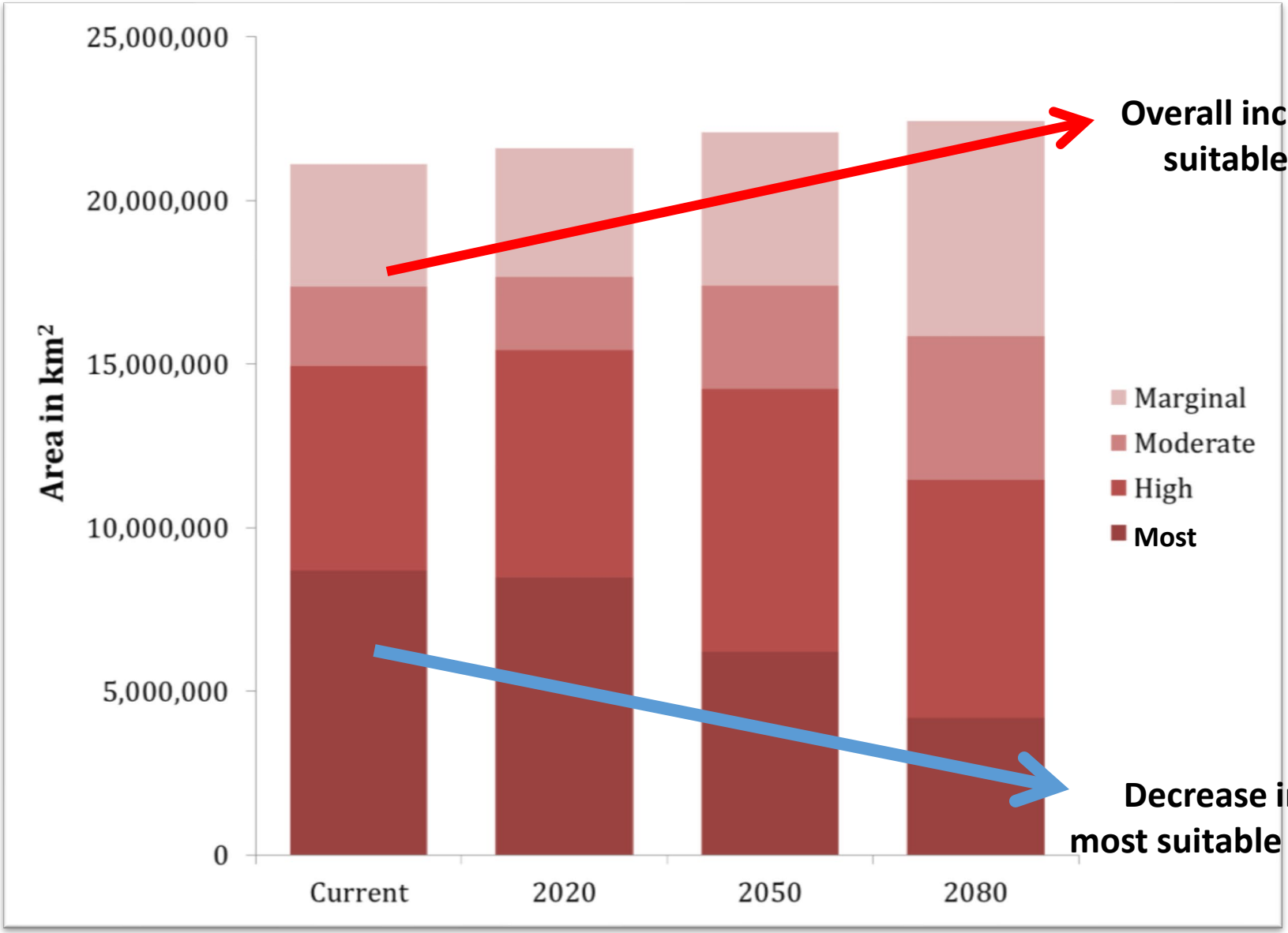
Seasonality – duration of season



Maps are useful for planning and intervention

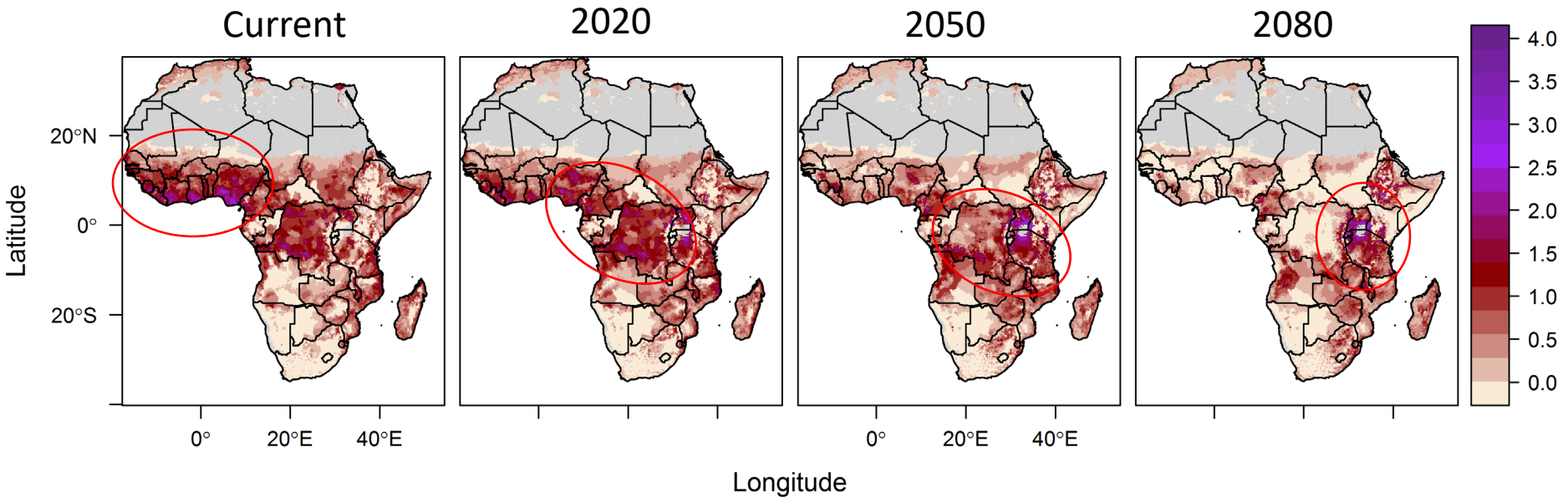
Ryan, S.J. et al., **2015**

Warm it up – scenario A1B



Ryan, S.J. et al., **2015**

Risk – population and suitability



*Population density estimates for 2015 * severe suitability quantile under HadCM3*

Ryan, S.J. et al., **2015**

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Carol Pearson
December 10, 2015 10:20 PM

WASHINGTON—U.S. health agencies have been monitoring climate change for some time. So have researchers at universities across the country. What they've found might help people protect their health as weather conditions change.

Climate change is not just a change in the global temperature; it is also a change in the weather. George

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ENGINEERED PROTEIN MAY OFFER SAFE WAY TO TREAT OSTEOPOROSIS

Malaria will arrive in new areas, posing a risk to new populations, says Sadie Ryan, and the shift of endemic and epidemic areas will require changes to public health management. (Credit: United Nations Development Programme/Flickr)

SPOTS IN AFRICA COULD GET TOO HOT FOR MALARIA

UNIVERSITY OF FLORIDA → Original Study

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ATLAS aims to improve the quality and effectiveness of climate risk reduction in development programs through tested, harmonized approaches to adaptation assessments; thought leadership; and by building the capacity of USAID and its partners. By integrating adaptation into development investments, ATLAS helps to safeguard and promote sustainable, climate resilient growth.

As awareness of the socioeconomic consequences of climate change grows, USAID Missions and partner governments are increasingly looking for support in assessing climate change vulnerability and improving climate-related decision making. Through new methodologies and tools

USAID Adaptation Community Meeting Series

Decisions will be made

SHIFTING BURDENS: MALARIA RISK UNDER A CHANGING CLIMATE

Adaptation Thought Leadership and Assessments (ATLAS) Project

USAID
FROM THE AMERICAN PEOPLE

OBJECTIVE OF STUDY

Provide decision makers and stakeholders who implement malaria control programs (governments, NGOs, donors, etc.) with **targeted, detailed information** on *when* and *where* malaria suitability will shift in response to rising temperatures.

RESEARCH QUESTIONS

- Where are **new areas** of endemic and seasonal suitability going to emerge where malaria was previously unsuitable?
- Where will **suitability increase?**
  - Seasonal areas becoming endemic
  - Moderately or marginally suitable areas becoming seasonal or endemic
- Where will **suitability decrease?**
  - Endemic areas becoming seasonal

When will these changes take place?

How many people will be at risk from these changes?

METHODOLOGY

Approach
Explore vector suitability in light of future climate model-based projections

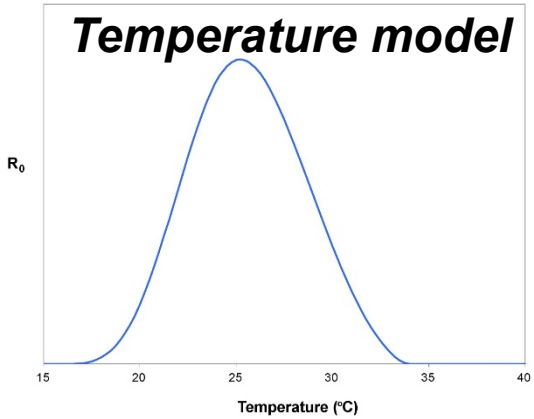
Mosquito species: *Anopheles gambiae*

Malaria pathogen: *Plasmodium falciparum*

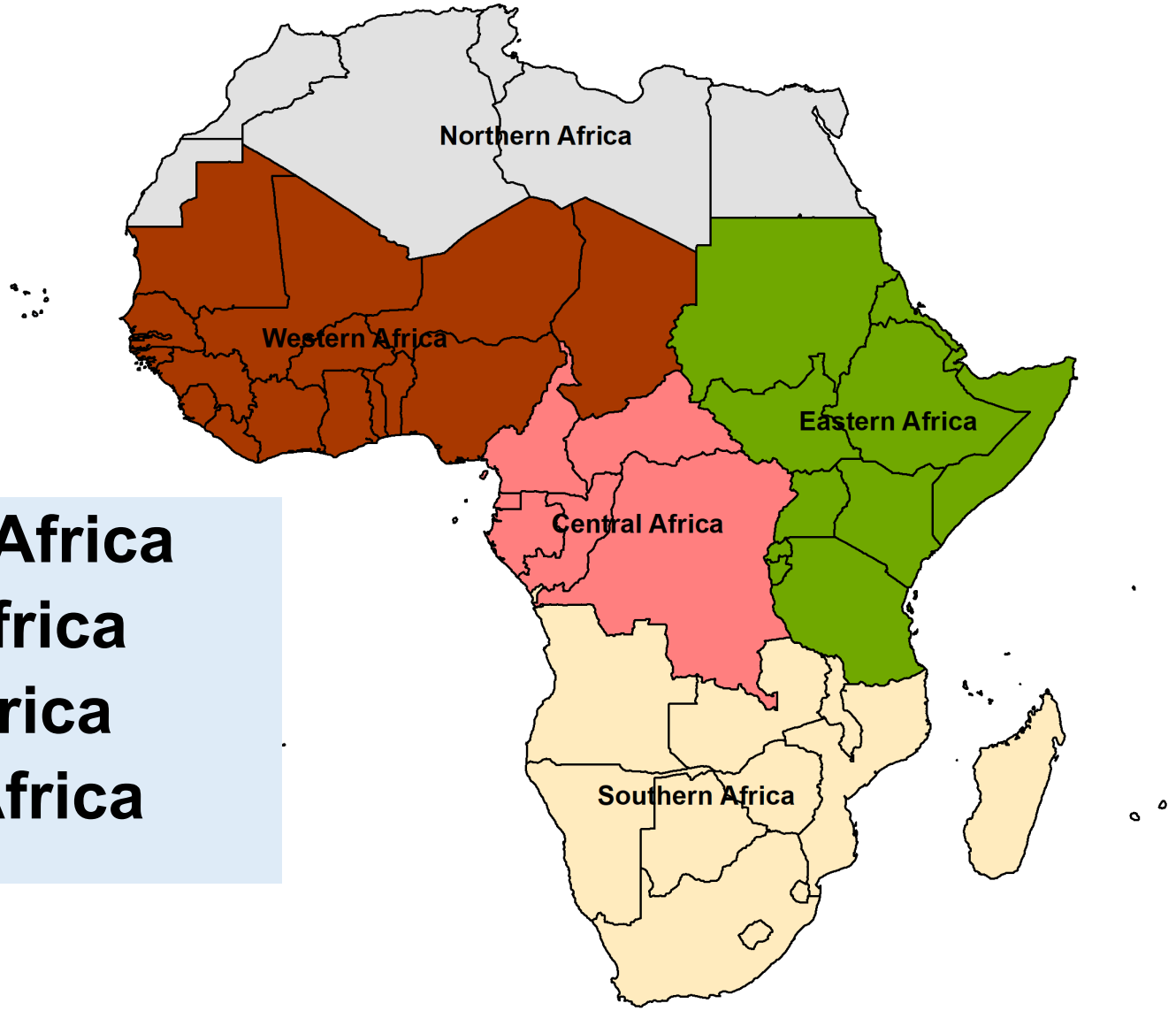
Climate model: multi-model ensemble (CMIP5)

Climate projections: RCP 4.5 and RCP 8.5

Time period: 2030, 2050 and 2080



A Regional Approach – Sub-Saharan Africa



- Southern Africa
- Eastern Africa
- Central Africa
- Western Africa

Suitability, People, and Climate Changes

Defining seasonality

Endemic: 10-12 months

Seasonal: 7- 9 months

Moderate: 4-6 months

Marginal: 1-3 months

Combined

People At Risk (PAR)

People living in areas defined suitable

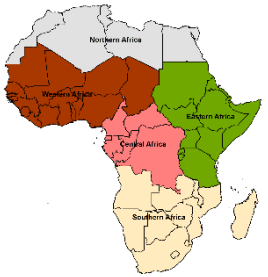
GPW 2010 and 2020

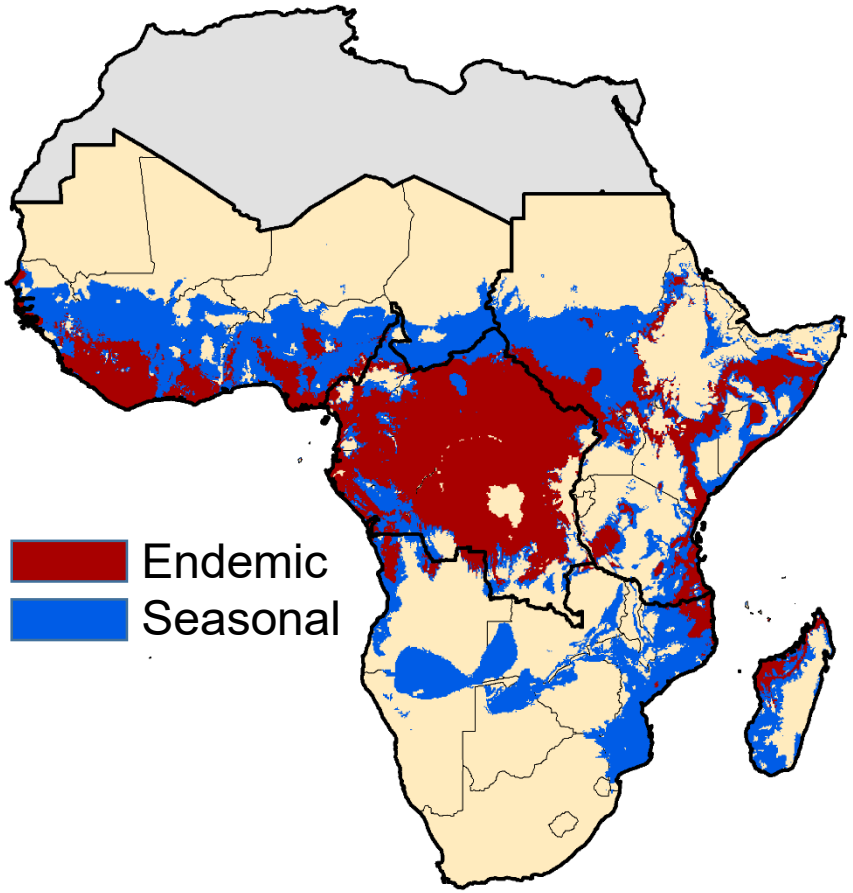
(Gridded Population of the World v4.11)

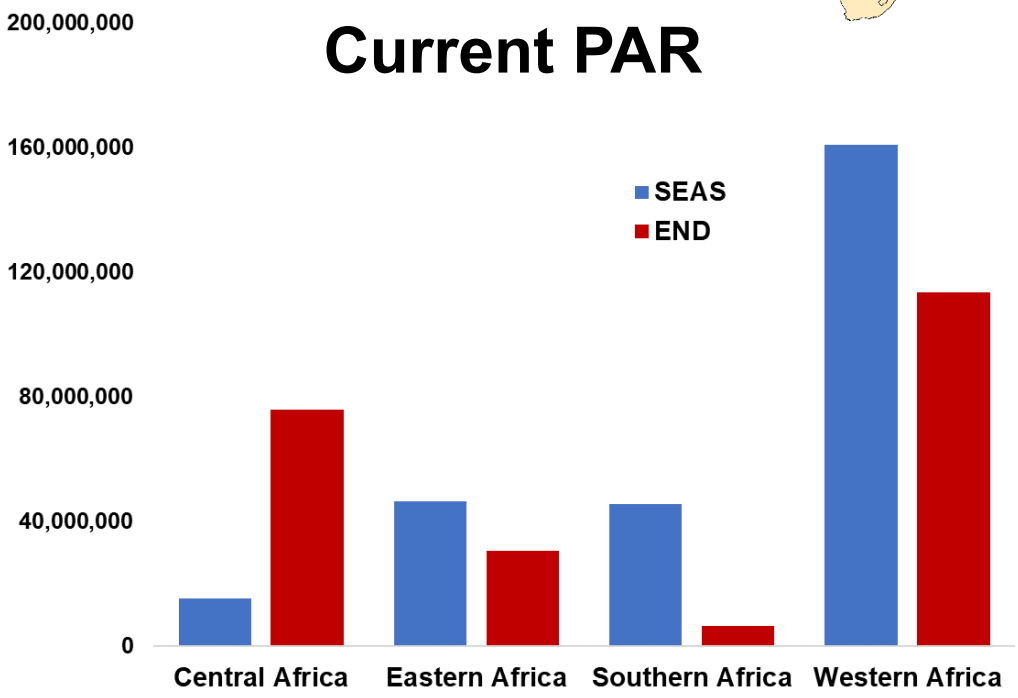
Average annual temperature increases (°C) from baseline (1960–1990) by region, RCP, and time period

Region	2030s		2050s		2080s	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
West Africa	1.32	1.57	2.29	2.32	2.84	4.38
East Africa	1.32	1.63	1.90	2.32	2.96	4.38
Central Africa	1.10	1.42	1.63	2.07	2.69	4.04
Southern Africa	0.94	1.28	1.33	2.01	2.51	4.08

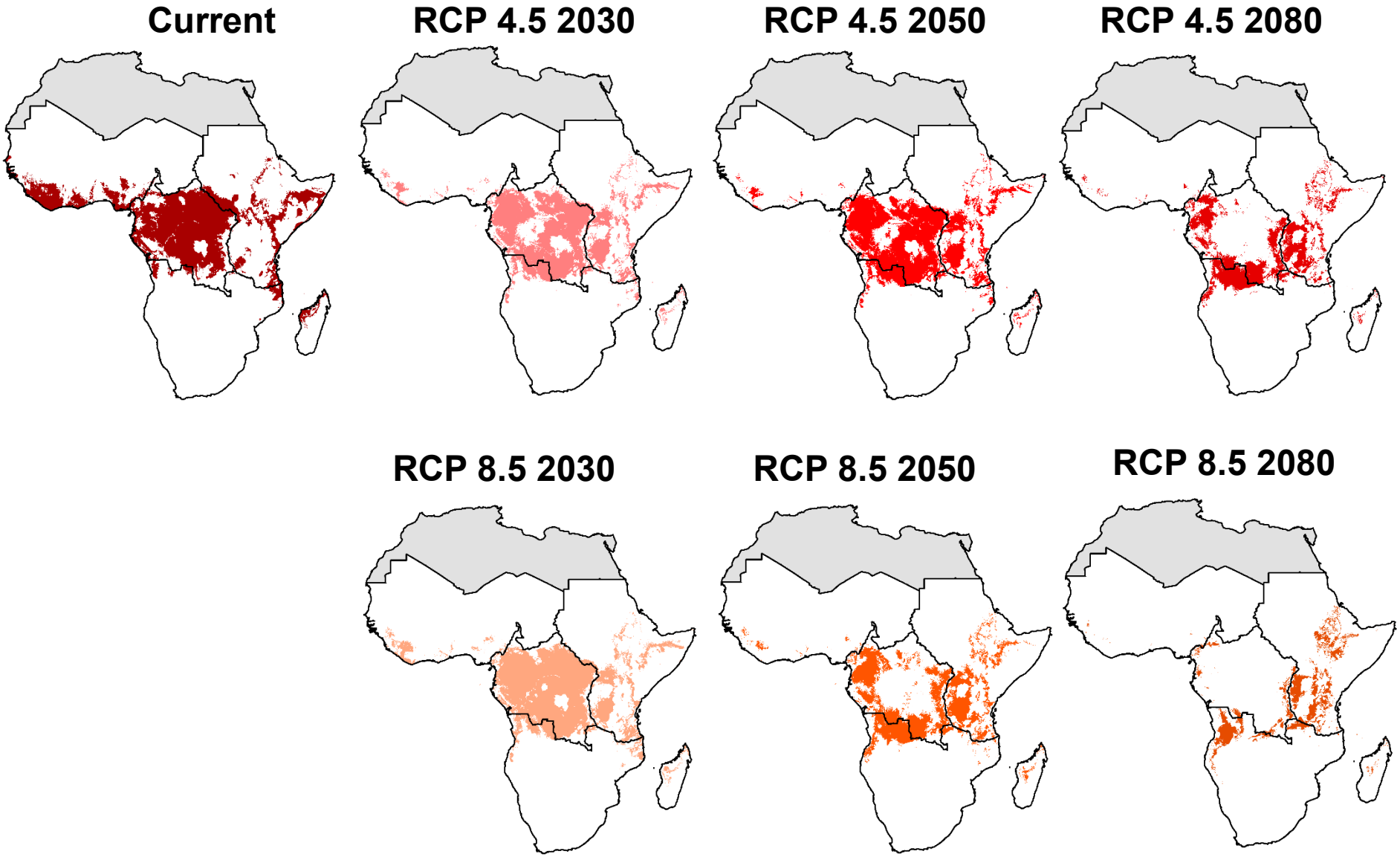
Current seasonal and endemic suitable areas for malaria transmission



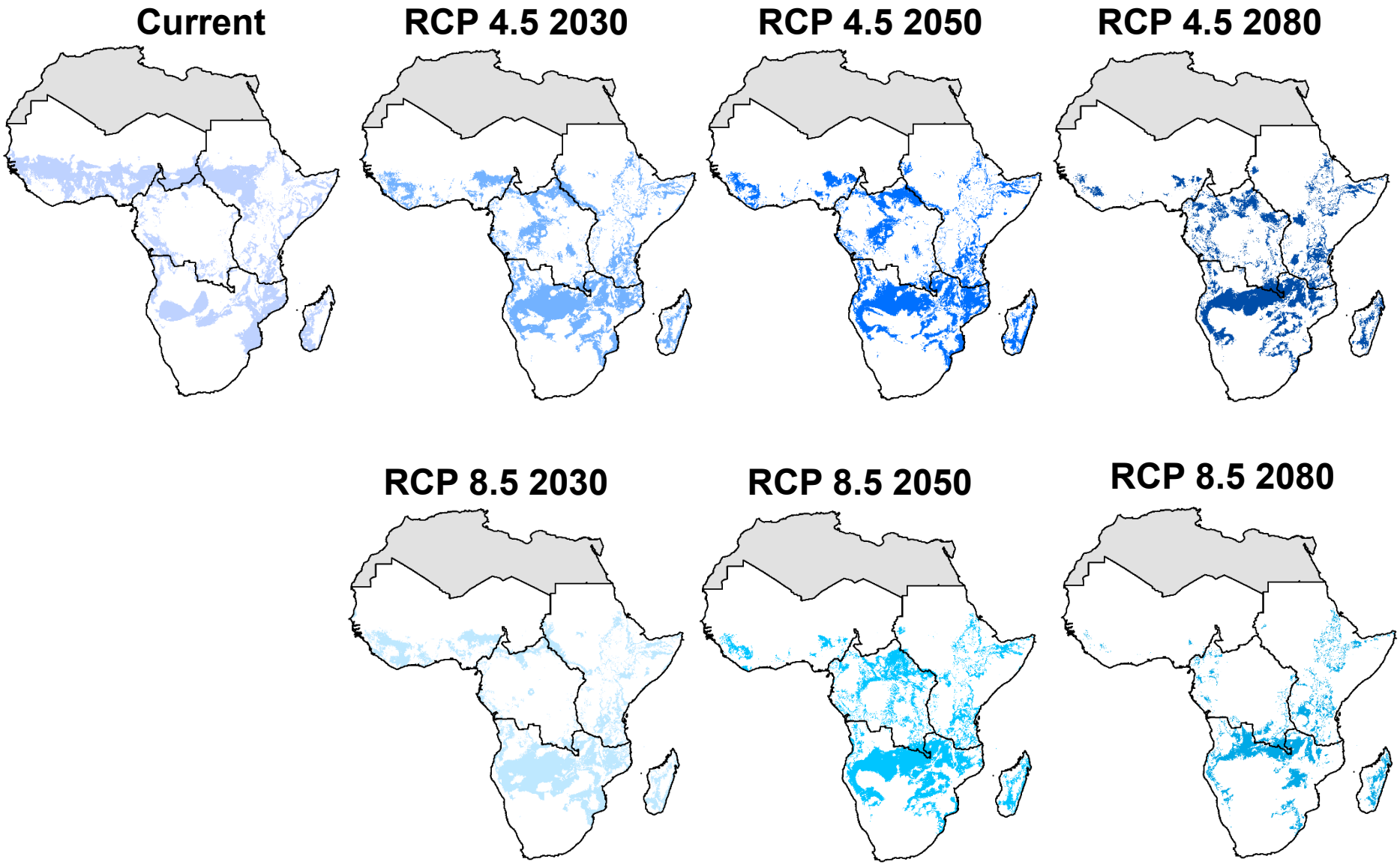




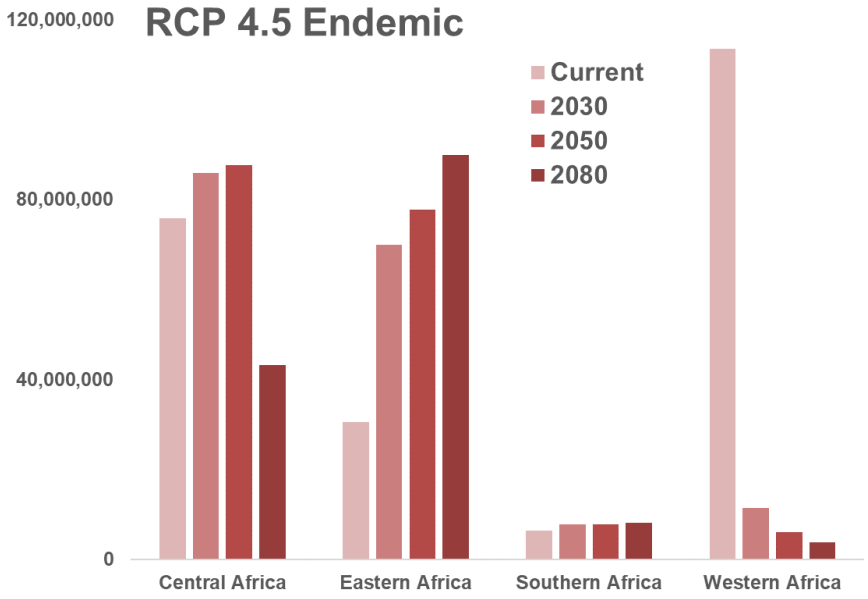
Current and futures- endemic

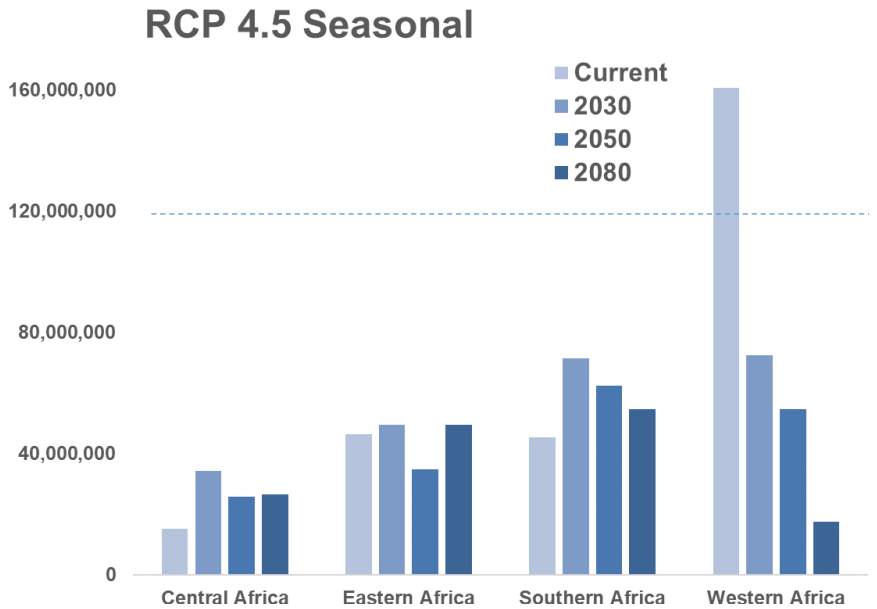


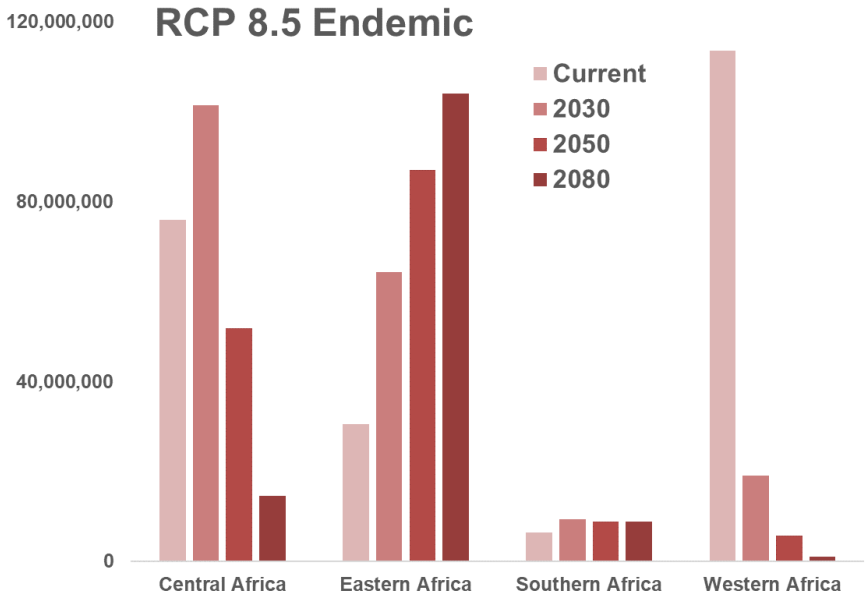
Current and futures - seasonal

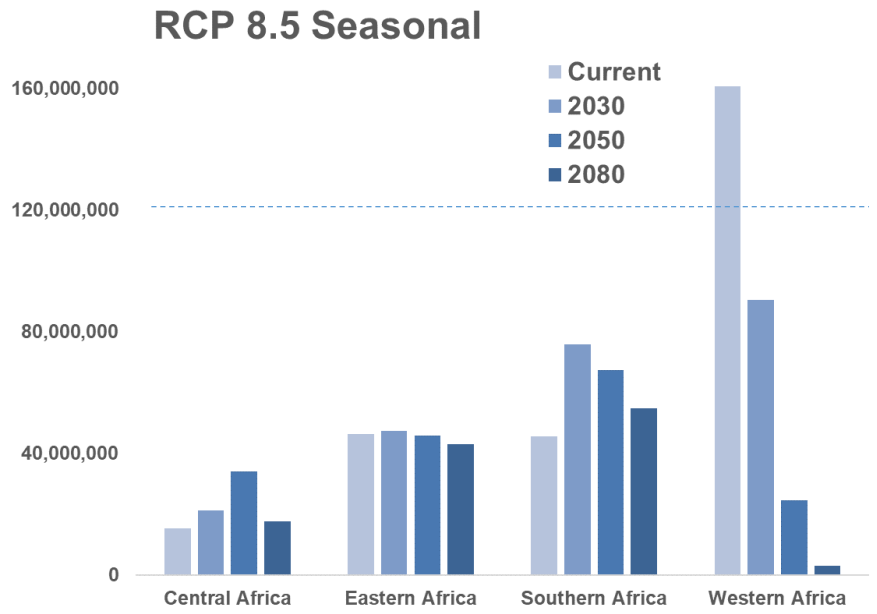


People at Risk - PAR









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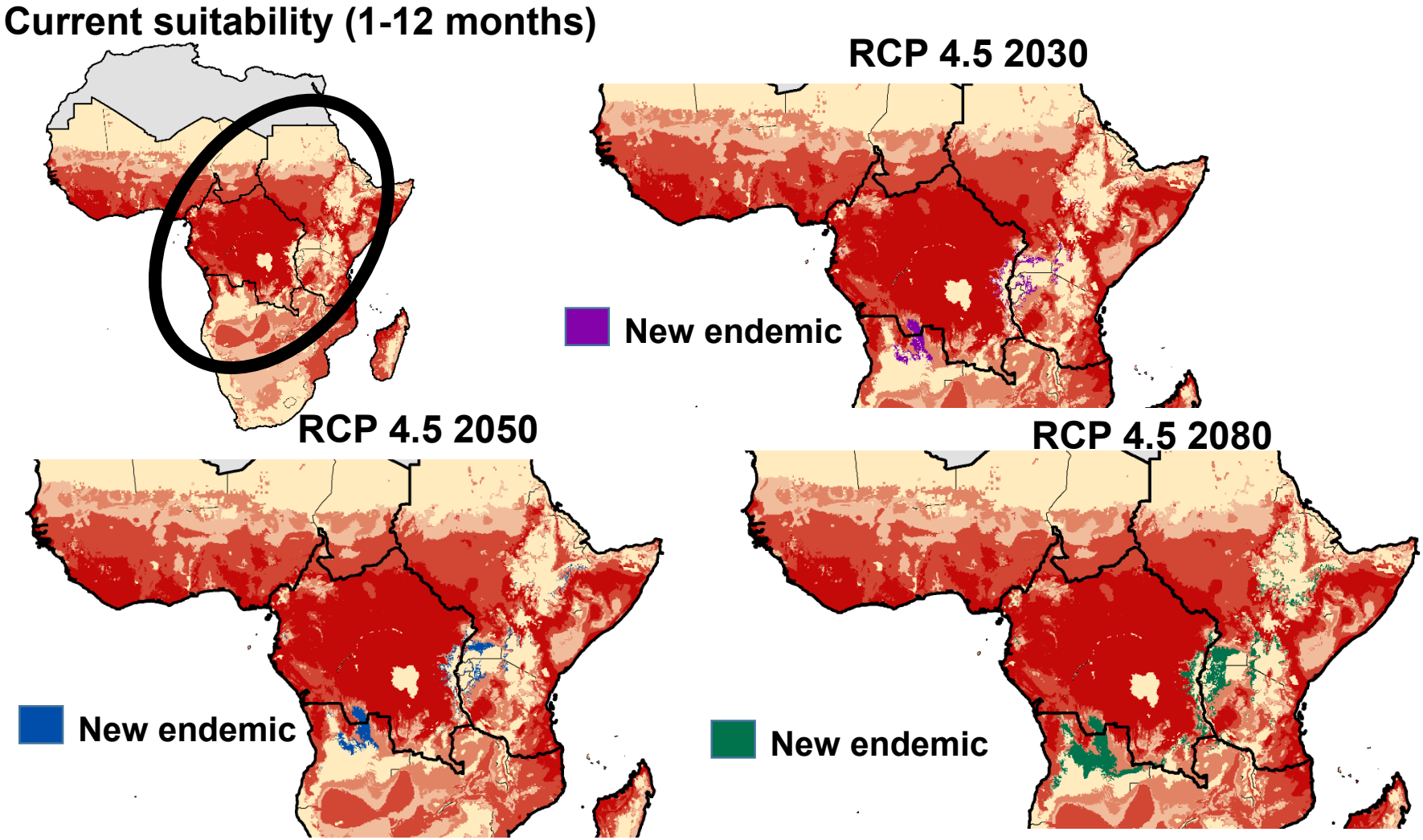
- Where will **suitability decrease?**
  - Endemic areas becoming seasonal

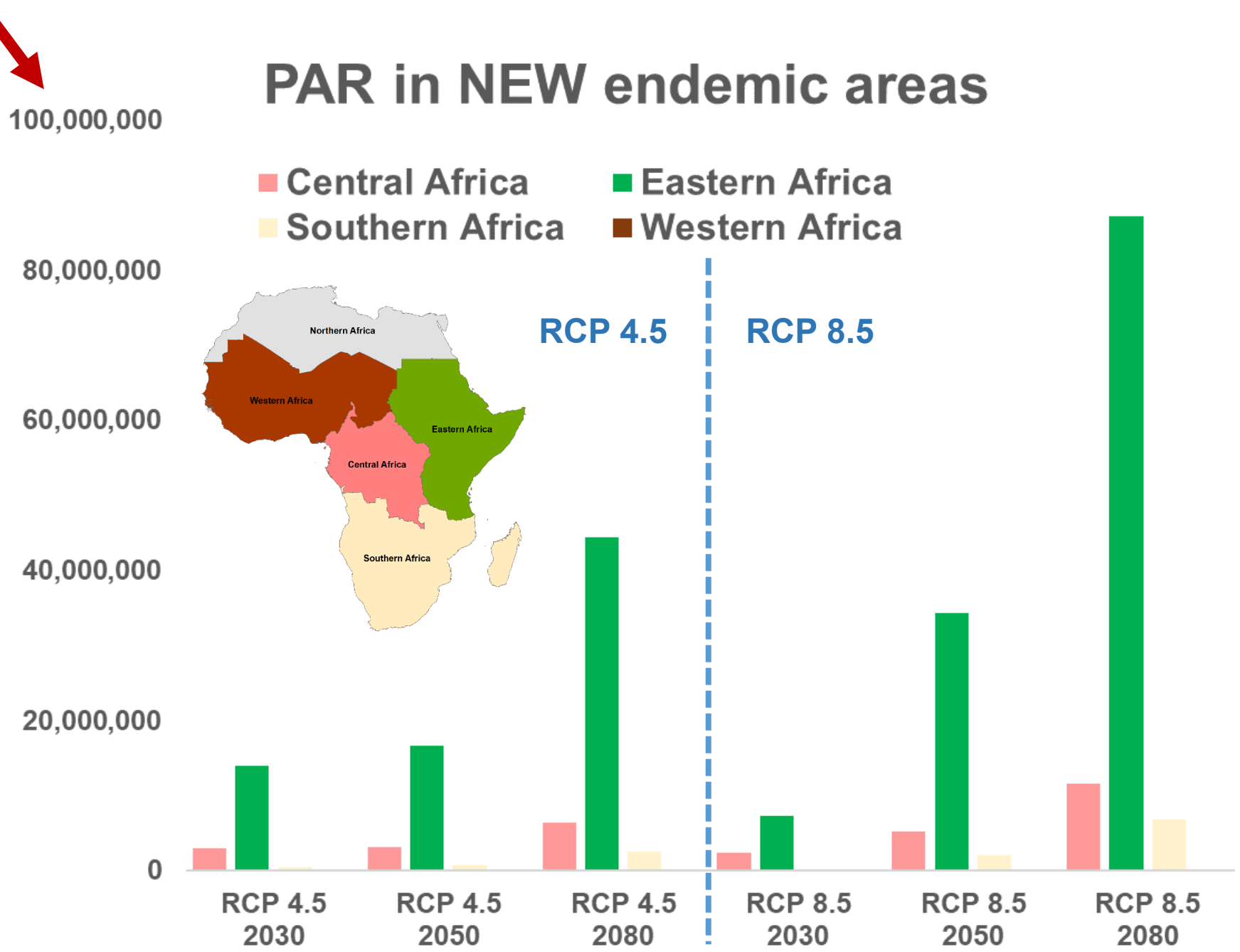
When will these changes take place?

How many people will be at risk from these changes?

NEW areas – unsuitable to endemic (RCP 4.5)

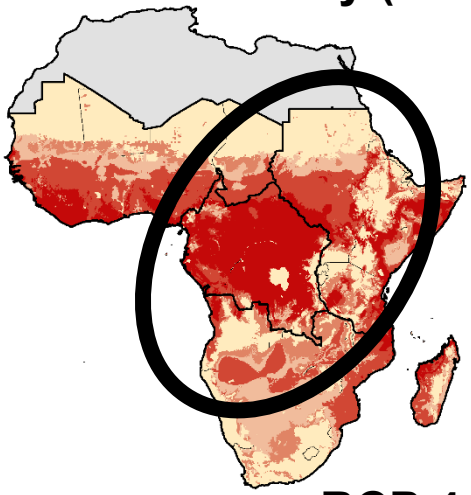


PAR in NEW endemic areas

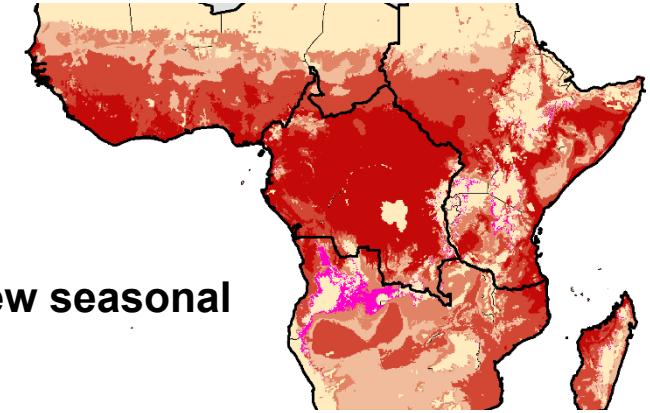


NEW areas – unsuitable to seasonal (RCP 4.5)

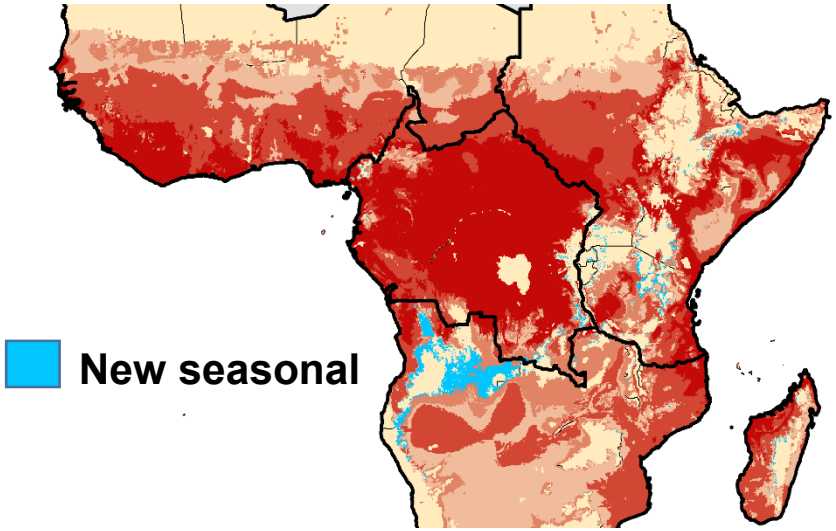
Current suitability (1-12 months)



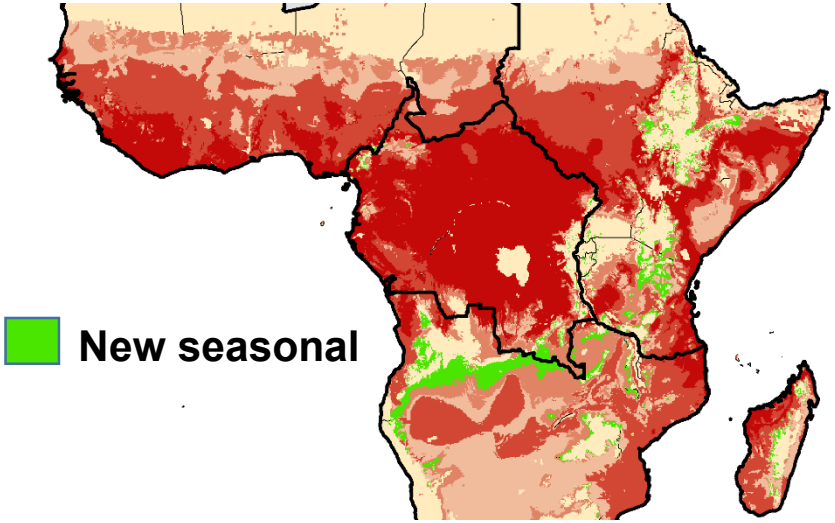
RCP 4.5 2030



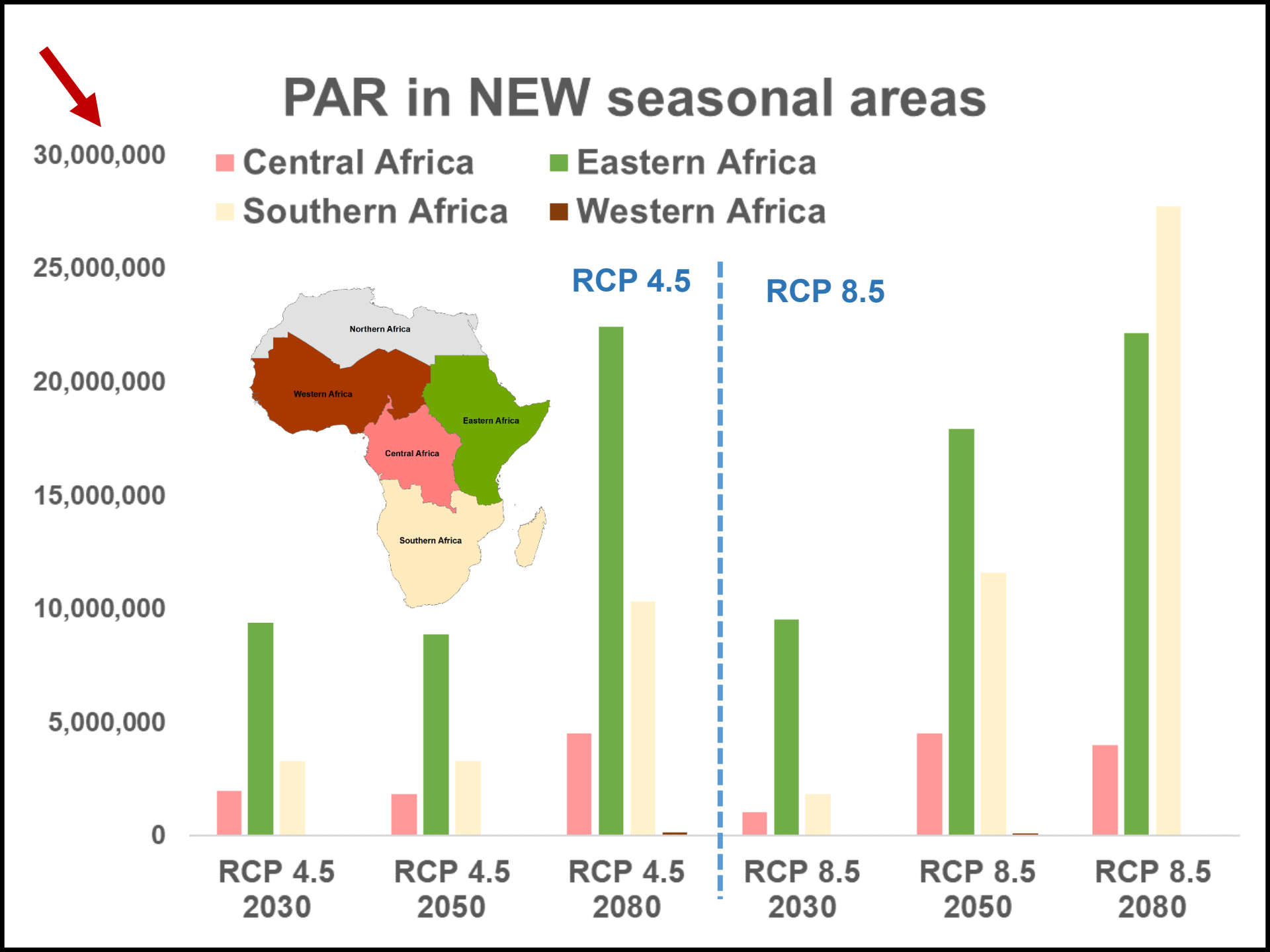
RCP 4.5 2050



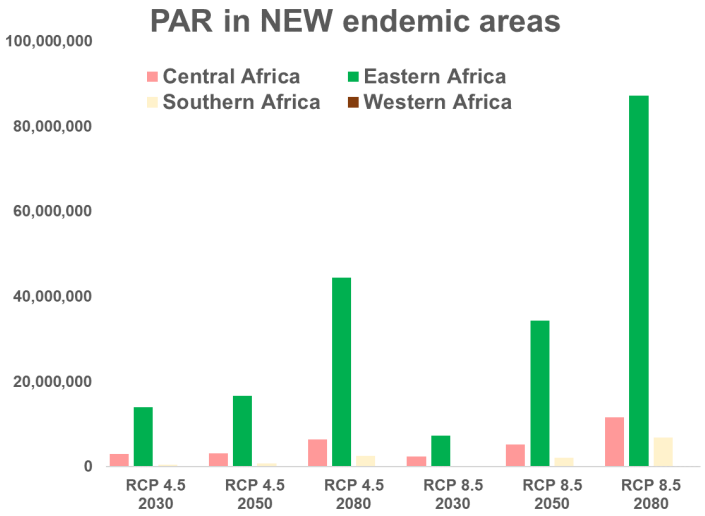
RCP 4.5 2080

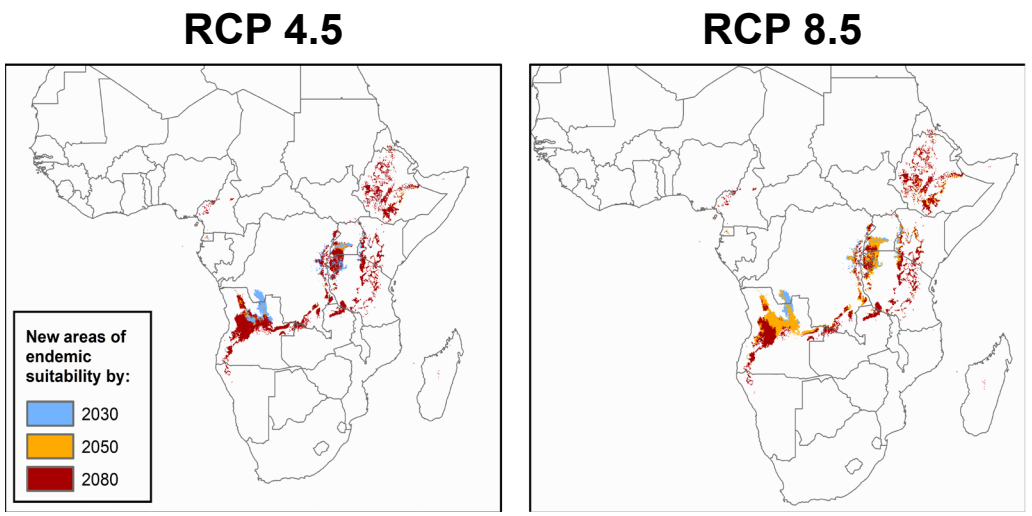


PAR in NEW seasonal areas



Big Messages?





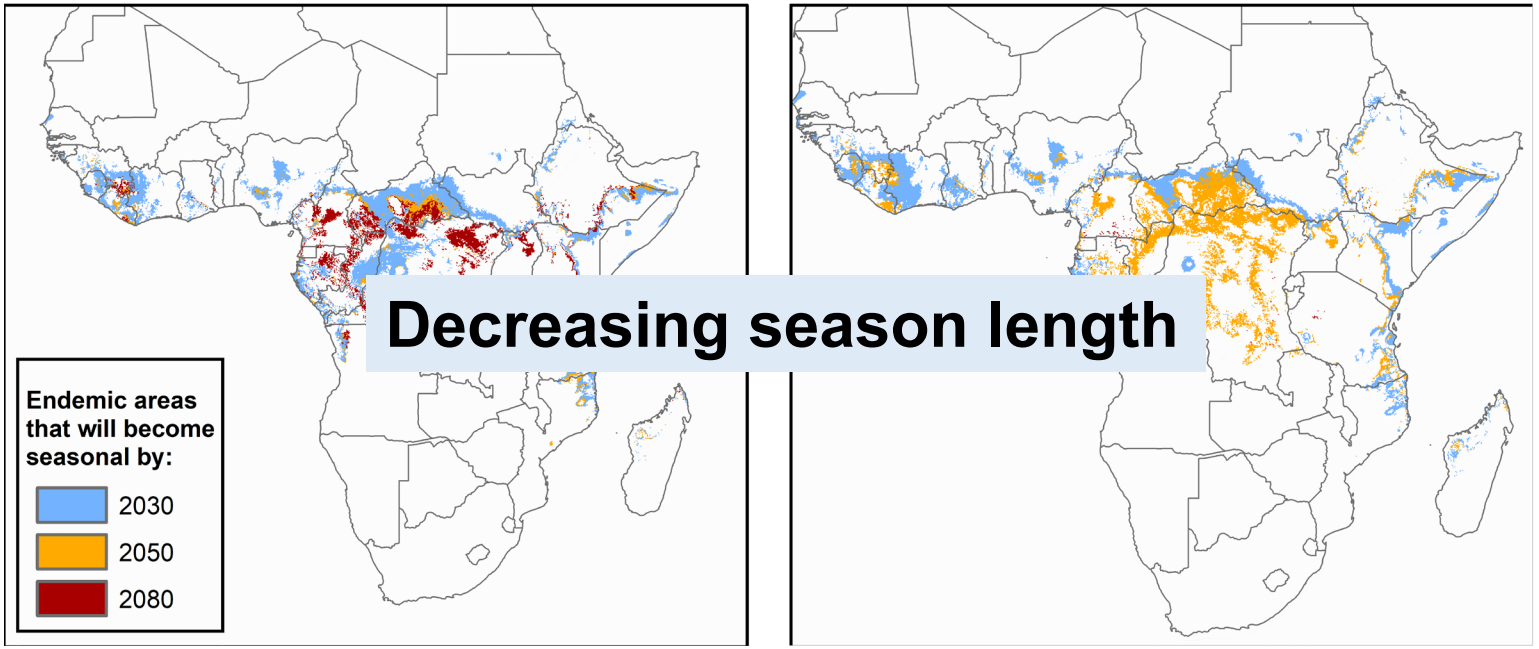
An additional 16 to 18 million people will shift from areas of ***no suitability*** risk (0 months) to ***endemic*** (10-12 months) malaria exposure in Sub-Saharan Africa **by the 2030s**, with a significant portion of these located in East Africa.

Big Messages?

Too hot for malaria?

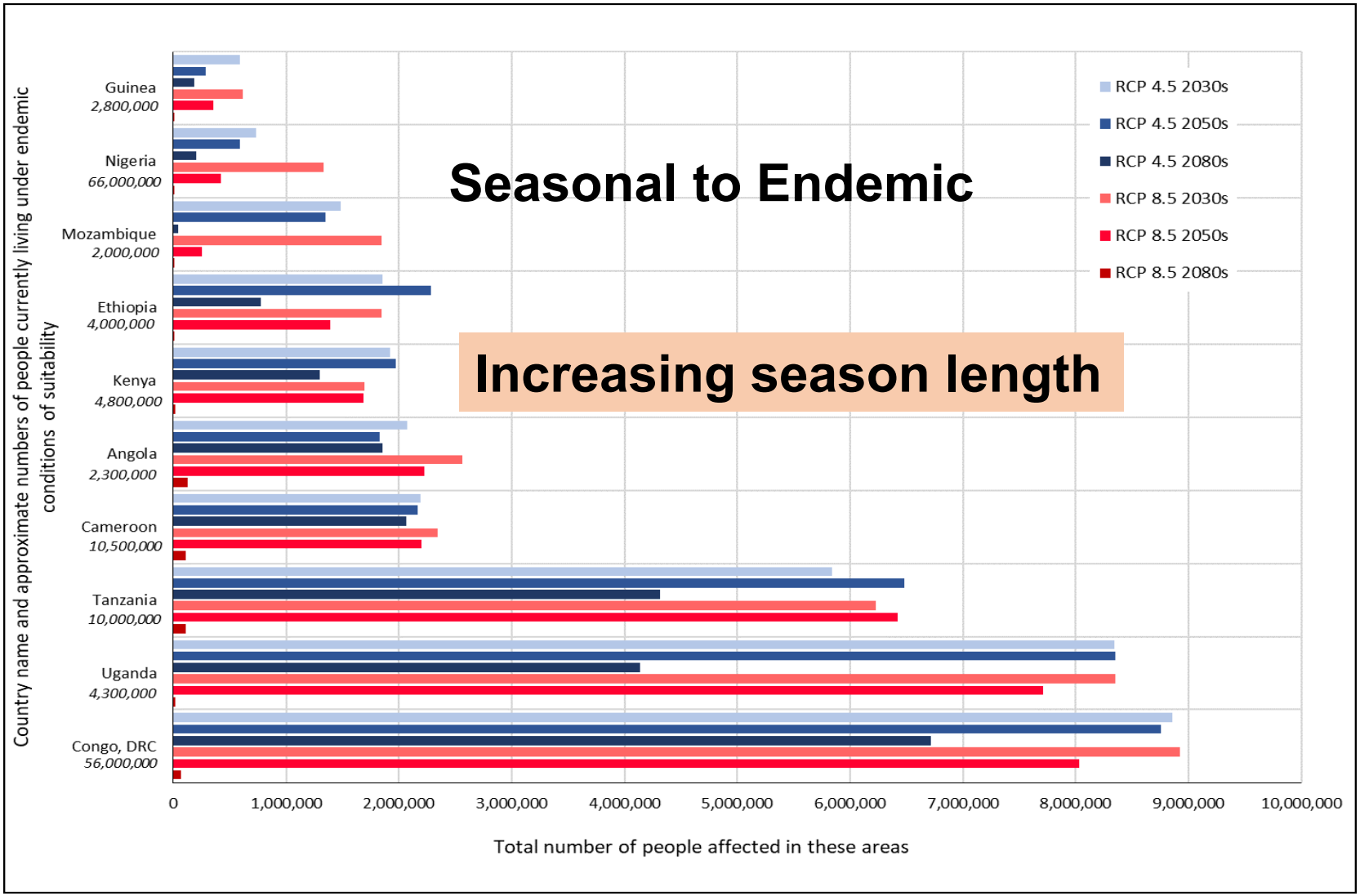
RCP 4.5

RCP 8.5



- **Approximately 47 to 58 million people will see reduced endemic (10-12 months) risk but will still experience marginal to moderate risk (1-6 months), in Western Africa due to the exceedance of thermal thresholds for mosquitoes.**
- **The net change in numbers of people at any risk of malaria transmission (those moving from endemic, seasonal or no suitability to marginal/moderate malaria exposure) in West Africa will be an increase of approximately 65 million people by the 2030s under the best-case scenario (RCP 4.5).**

Big Messages?

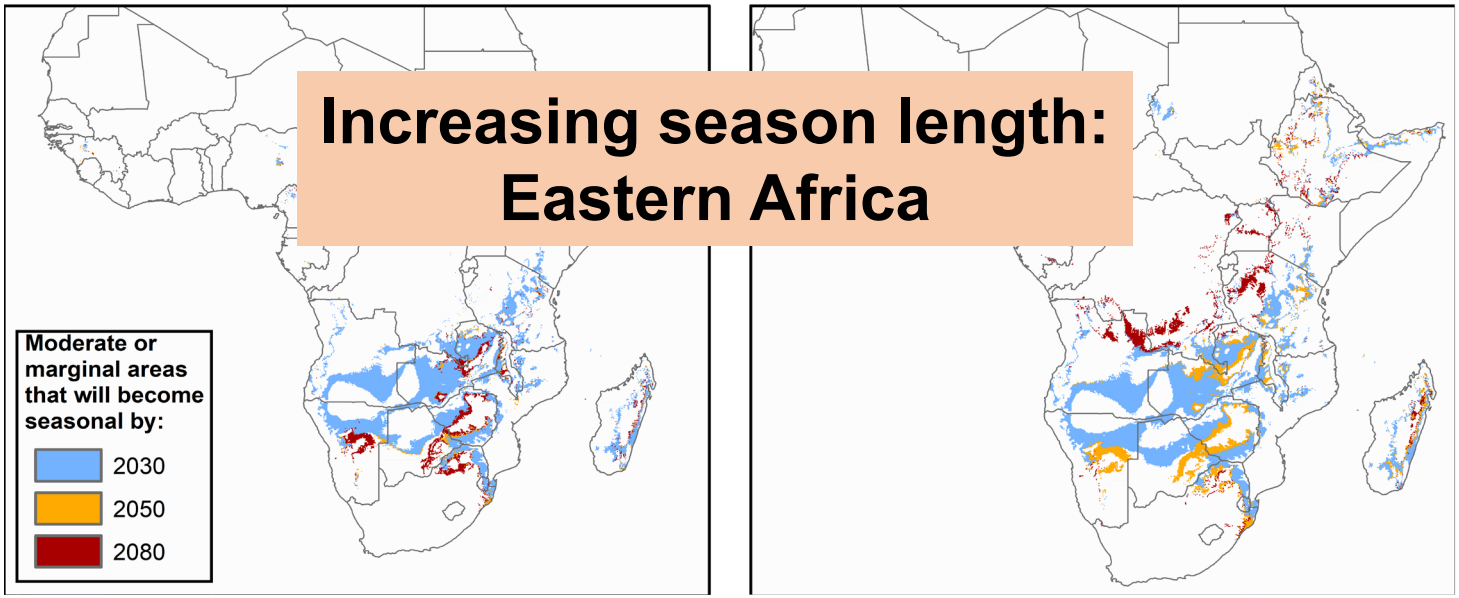


Big Messages?

Areas that are currently moderately or marginally suitable (1-6 months) for transmission but will shift to seasonally suitable (7-9 months) are found mainly in Eastern Africa.

RCP 4.5

RCP 8.5

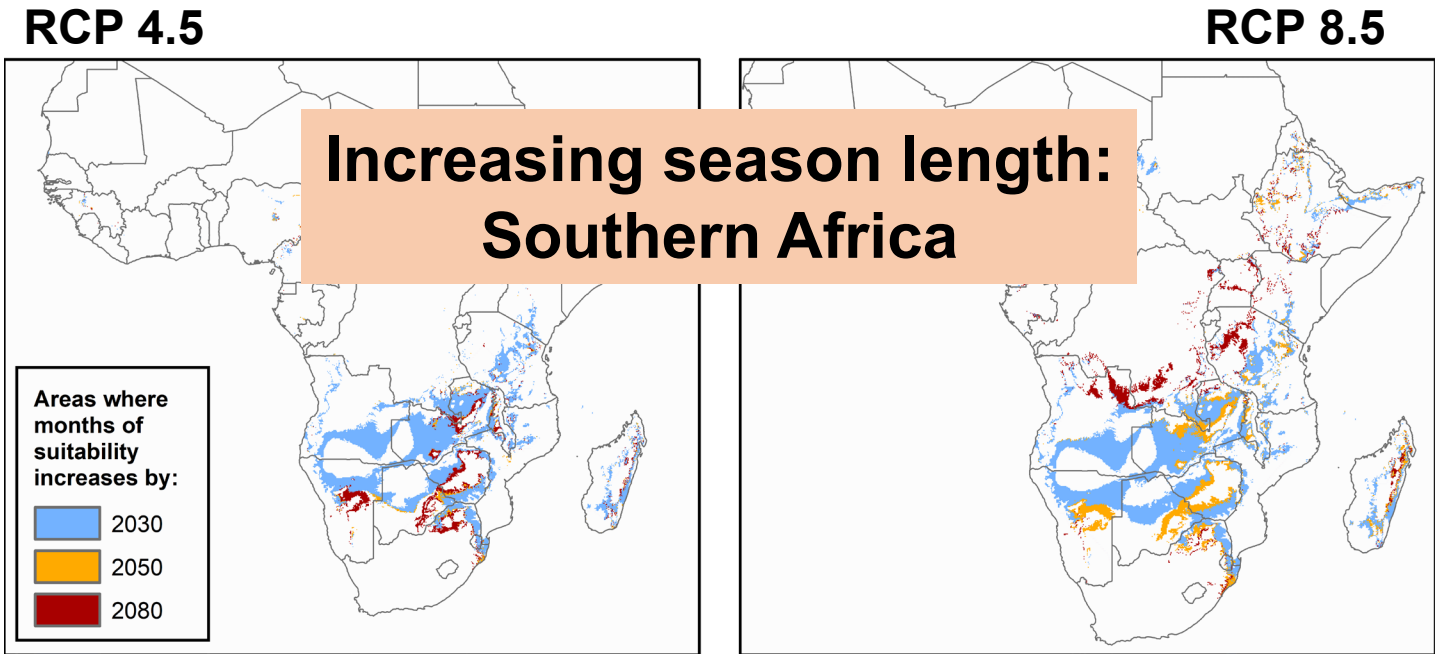


Increasing season length: Eastern Africa

This includes large portions of Tanzania and Uganda

Big Messages?

Areas where moderate or marginal suitability will become seasonal include the Southern Africa region: Zambia, Malawi, eastern South Africa, Botswana, the highlands of Zimbabwe, northern Mozambique, and the Zambezi River Basin.



- **These changes will put approximately 17 to 21 million people at increased risk from transmission in Southern Africa under the best case scenario (RCP4.5) by 2030.**

- **In Zambia alone, this adds an additional ~9 to 12 million people (across climate scenarios) to those currently living in seasonal risk.**

IMPLICATIONS FOR POLICY AND RESPONSE
FOR NEW AREAS OF EMERGING SUITABILITY

What's at risk?

Malaria outbreaks where people have little or no immunity to the disease can often lead to epidemic conditions, especially among vulnerable groups such as women and children.

What's the opportunity?

Targeted and concentrated surveillance at the edge of malaria's range offers the opportunity to control potential epidemic outbreaks as they happen and can reduce the risk of novel outbreaks.

IMPLICATIONS FOR POLICY AND RESPONSE
FOR AREAS WHERE MONTHS OF SUITABILITY INCREASE

What's at risk?

One key concern is where and how increased temperatures will lengthen the period of the year during which diseases can be established and transmitted. Current management and control interventions may need to be reviewed and revised to account for likely increased incidence.

What's the opportunity?

Malaria response programs will need to be extended, planning for increasing resource needs (e.g. staff time, medicines) as well as costs, and requiring an ***extended investment pipeline***.

IMPLICATIONS FOR POLICY AND RESPONSE
FOR AREAS WHERE MONTHS OF SUITABILITY ARE REDUCED

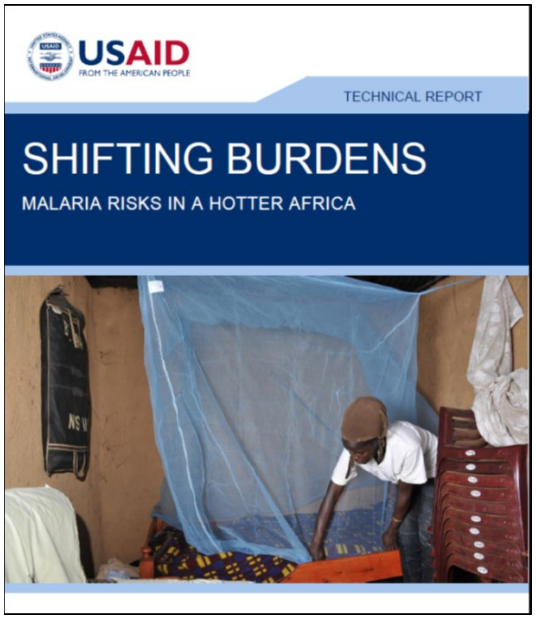
What's the opportunity?

Seasonal response can be refined and targeted – either reducing the cost of interventions or potentially eradicating malaria exposure in these areas.

Decisions will be made…

- Target on-ground surveillance and responses to changing epidemiology
- Improve a country's capacity for collecting and using information at the national level
- Build capacity in health systems
- Refine country selection and strategic budgeting for international programs
- Develop regional approaches and partnerships

Thank you



Technical report coming soon to Climatelinks.org

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