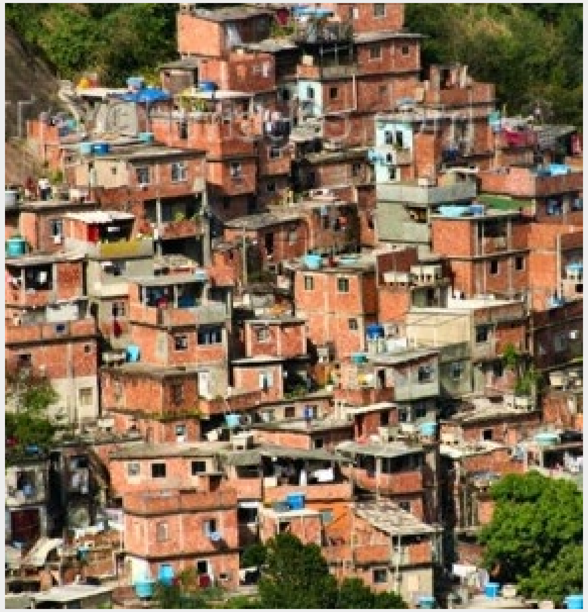
Human-environment dynamics in the Sonoran Desert and *Ae. aegypti*, the vector of dengue, Zika and chikungunya



Kacey C. Ernst, PhD MPH

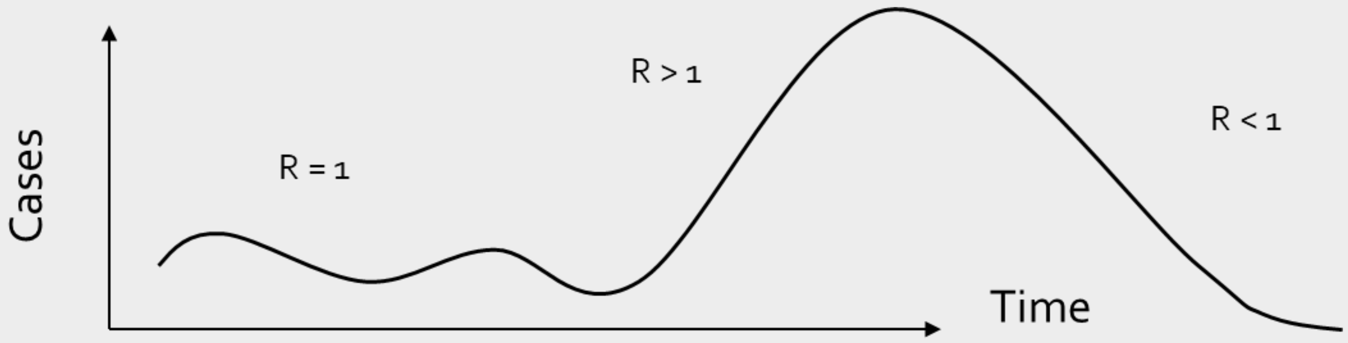
Associate Professor and Program Director Epidemiology, College of Public Health

WRRC Brown Bag, 4/8/2020

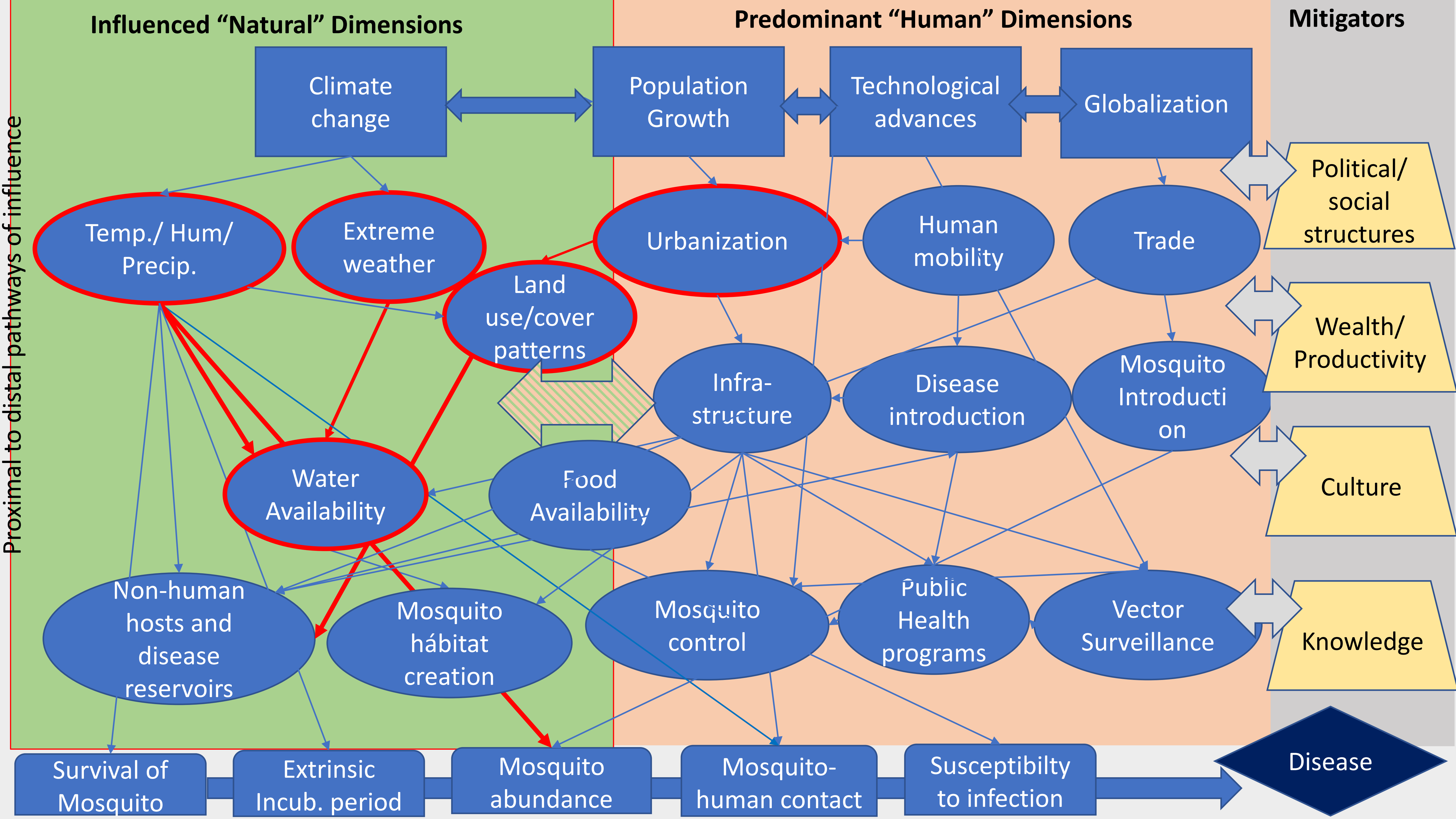
Potential for transmission

Reproductive number for mosquito-borne diseases (modification of the vectorial capacity equation)

$$R_0 = \frac{ma^2bc\,p^n}{(-\ln(p))r}$$



m: ratio of mosquitoes to humans
a: mosquito biting rate (on humans)
b and c: pathogen transmission efficiencies (human to mosquito and mosquito to human)
p: daily survival rate of mosquitoes
r: the recovery rate in humans (i.e., the reciprocal of the infective period of the human host)
n: the duration of the extrinsic incubation period (EIP).

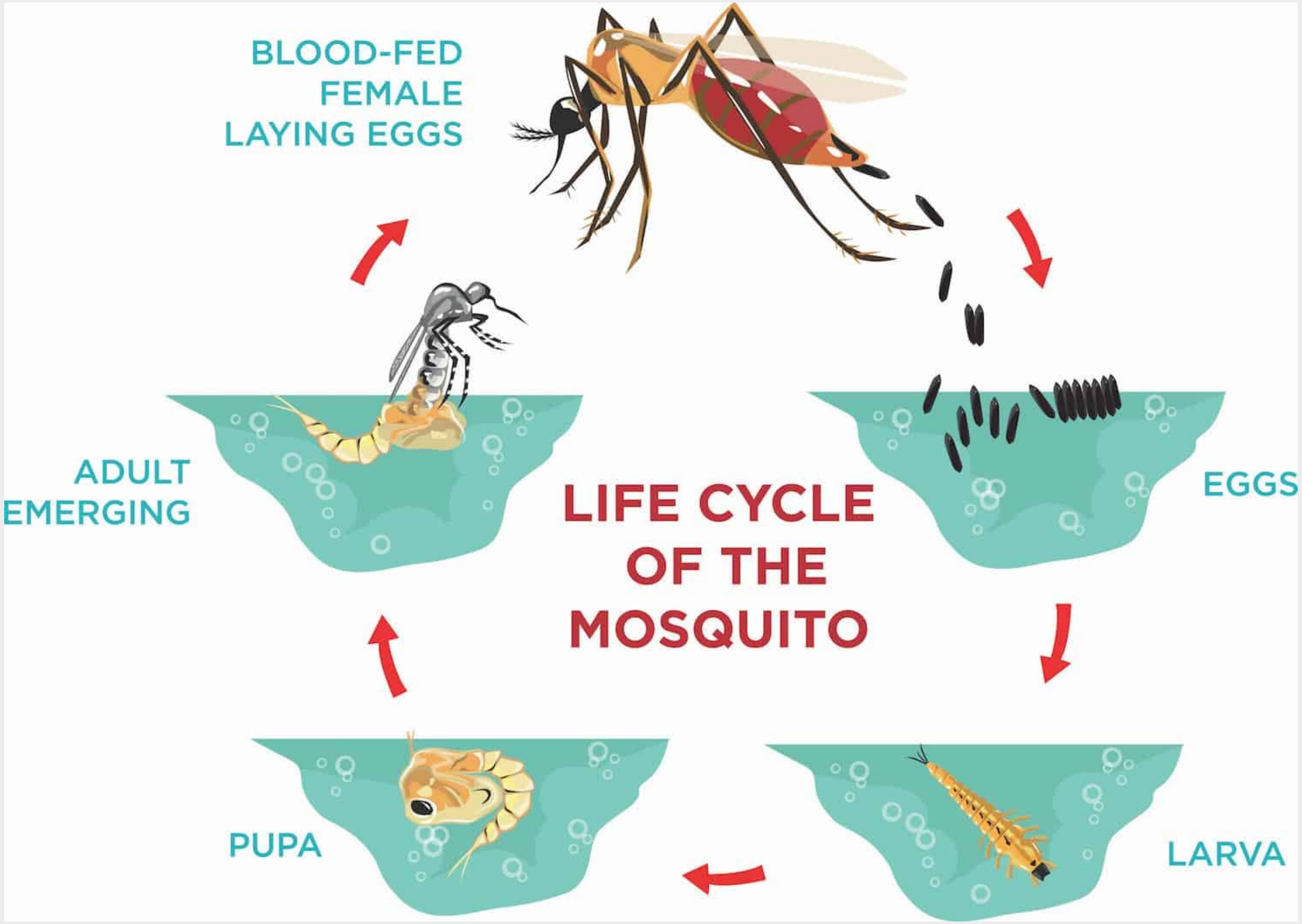


Influenced "Natural" Dimensions
Predominant "Human" Dimensions
Mitigators
Proximal to distal pathways of influence
Climate change
Population Growth
Technological advances
Globalization
Temp./ Hum/ Precip.
Extreme weather
Urbanization
Human mobility
Trade
Political/ social structures
Land use/cover patterns
Infra-structure
Disease introduction
Mosquito Introducti on
Wealth/ Productivity
Water Availability
Food Availability
Culture
Non-human hosts and disease reservoirs
Mosquito hábitat creation
Mosquito control
Public Health programs
Vector Surveillance
Knowledge
Survival of Mosquito
Extrinsic Incub. period
Mosquito abundance
Mosquito-human contact
Susceptibilty to infection
Disease

Aedes aegypti aka
"The Yellow Fever Mosquito"

- Highly adaptable
- Human commensal
- Day-biter (bednets less useful)
- Transmits
- • Yellow fever virus
- • Dengue viruses
- • Chikungunya virus
- • Zika virus
- • Mayora virus

Mosquito life-cycle

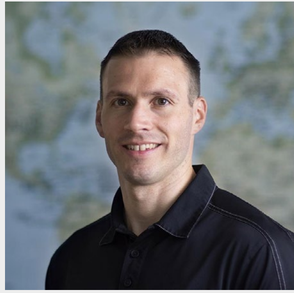


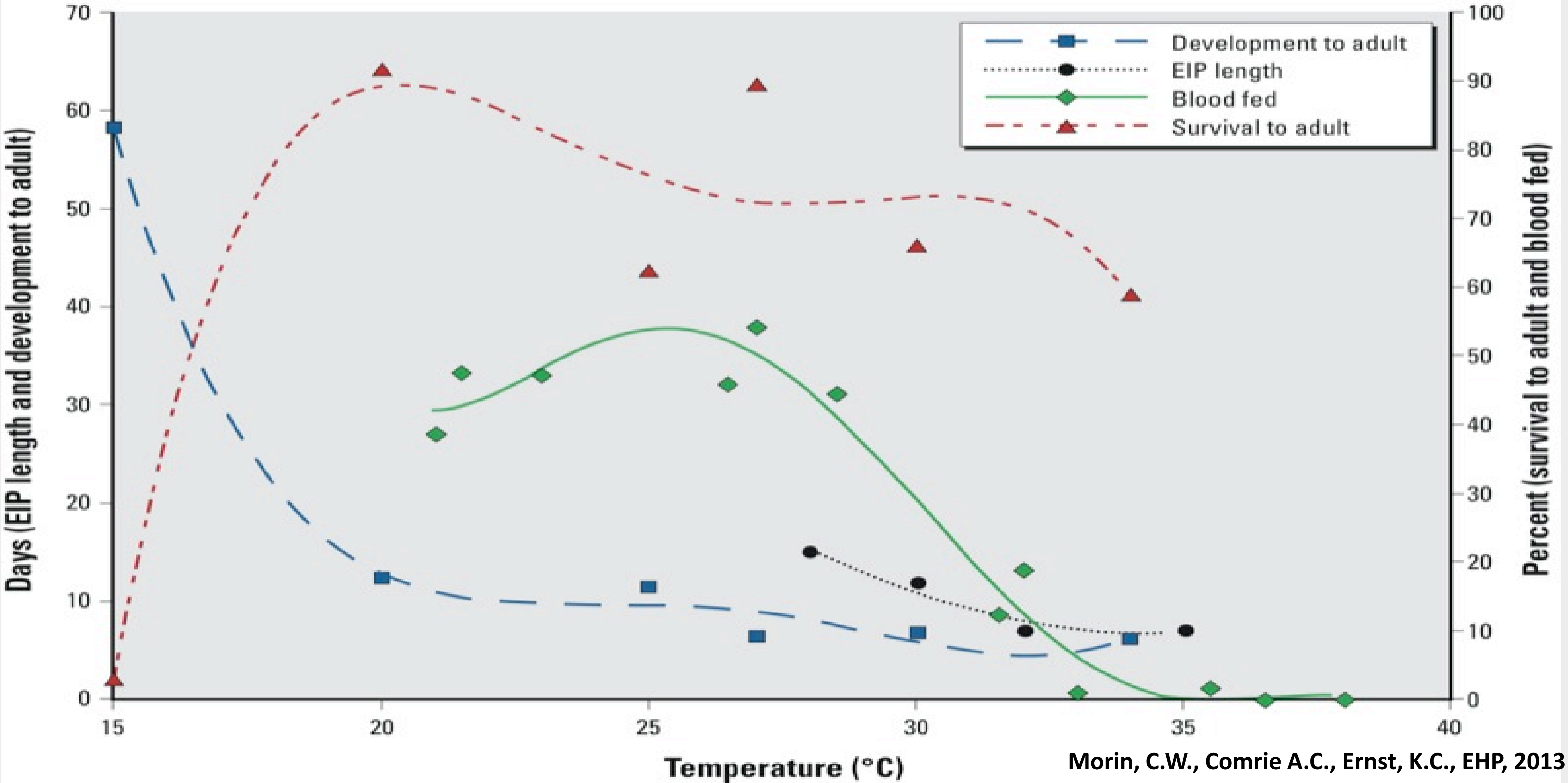
Oviposition sites

Precipitation Driven

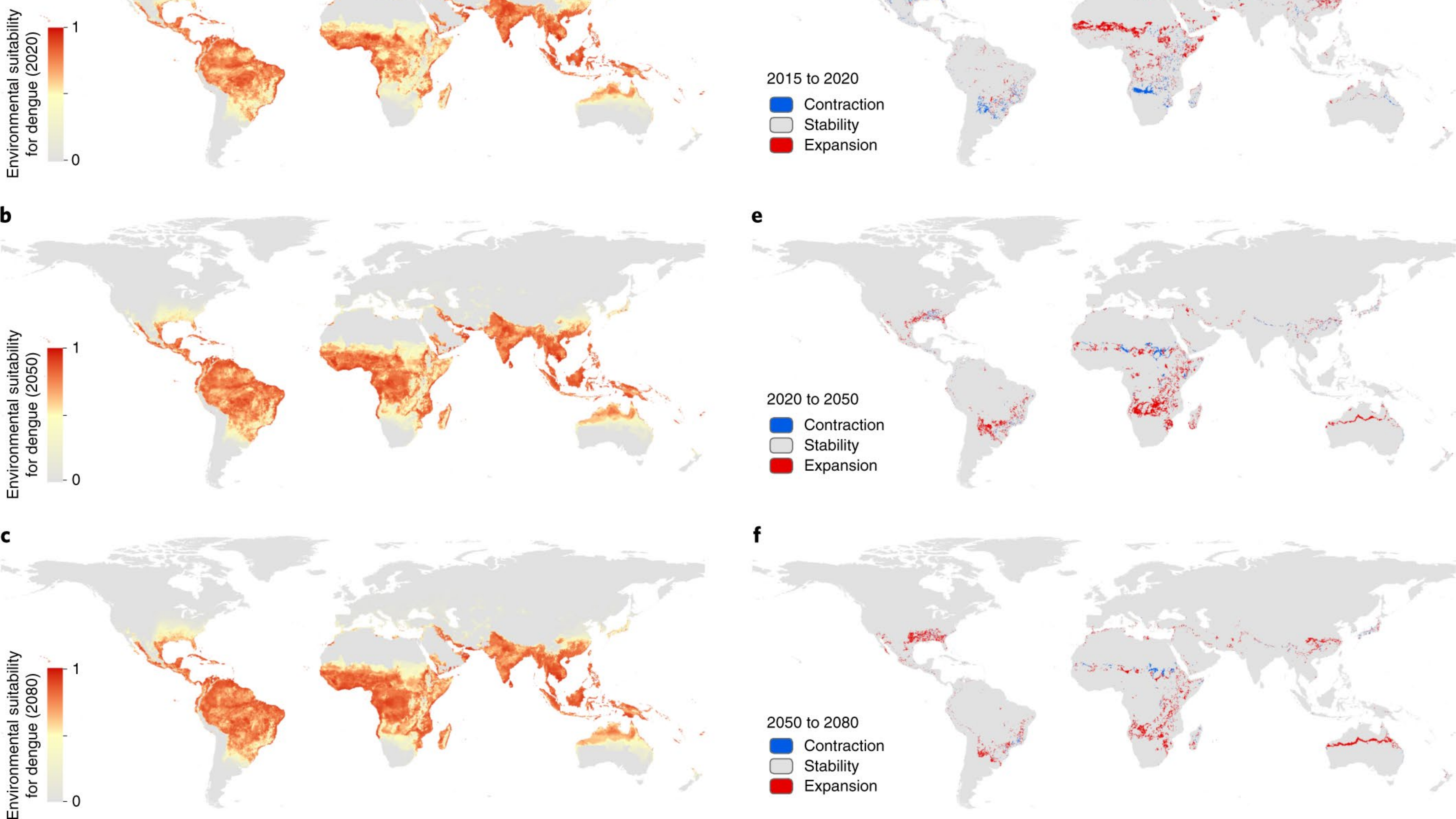
Anthropogenic water sources

1. Shifting climate patterns may influence disease dynamics





Morin, C.W., Comrie A.C., Ernst, K.C., EHP, 2013

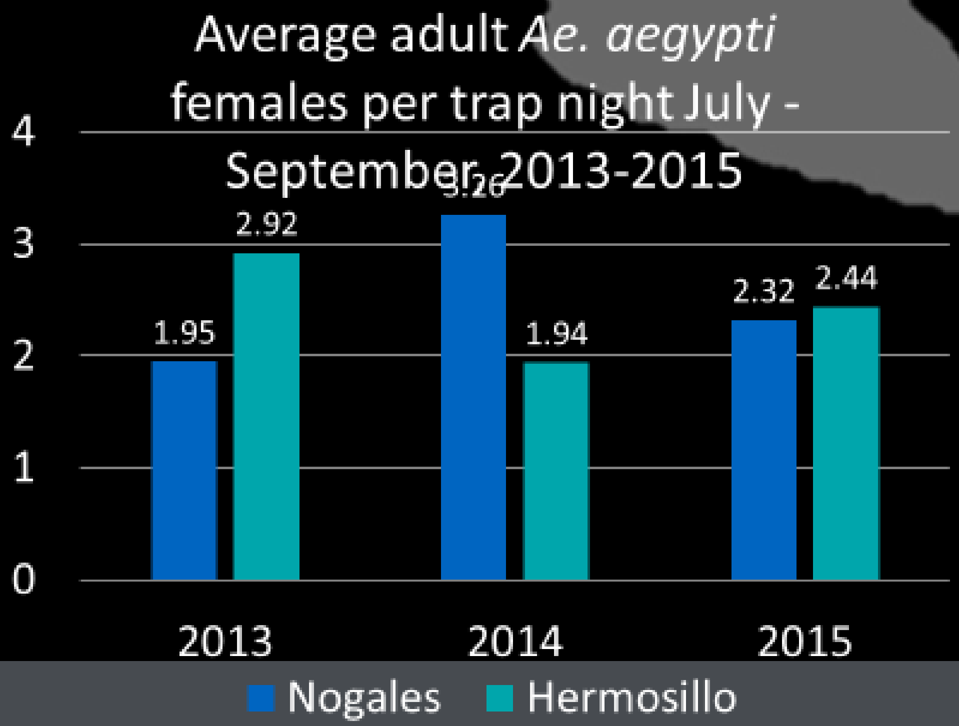

Environmental suitability for dengue (2020)
1
0
2015 to 2020
Contraction
Stability
Expansion
b
Environmental suitability for dengue (2050)
1
0
e
2020 to 2050
Contraction
Stability
Expansion
c
Environmental suitability for dengue (2080)
1
0
f
2050 to 2080
Contraction
Stability
Expansion

Aedes aegypti infest urban areas throughout the Arizona-Sonoran Desert region

Transmission disparities in dengue

Reported yearly incidence of dengue per 100,000

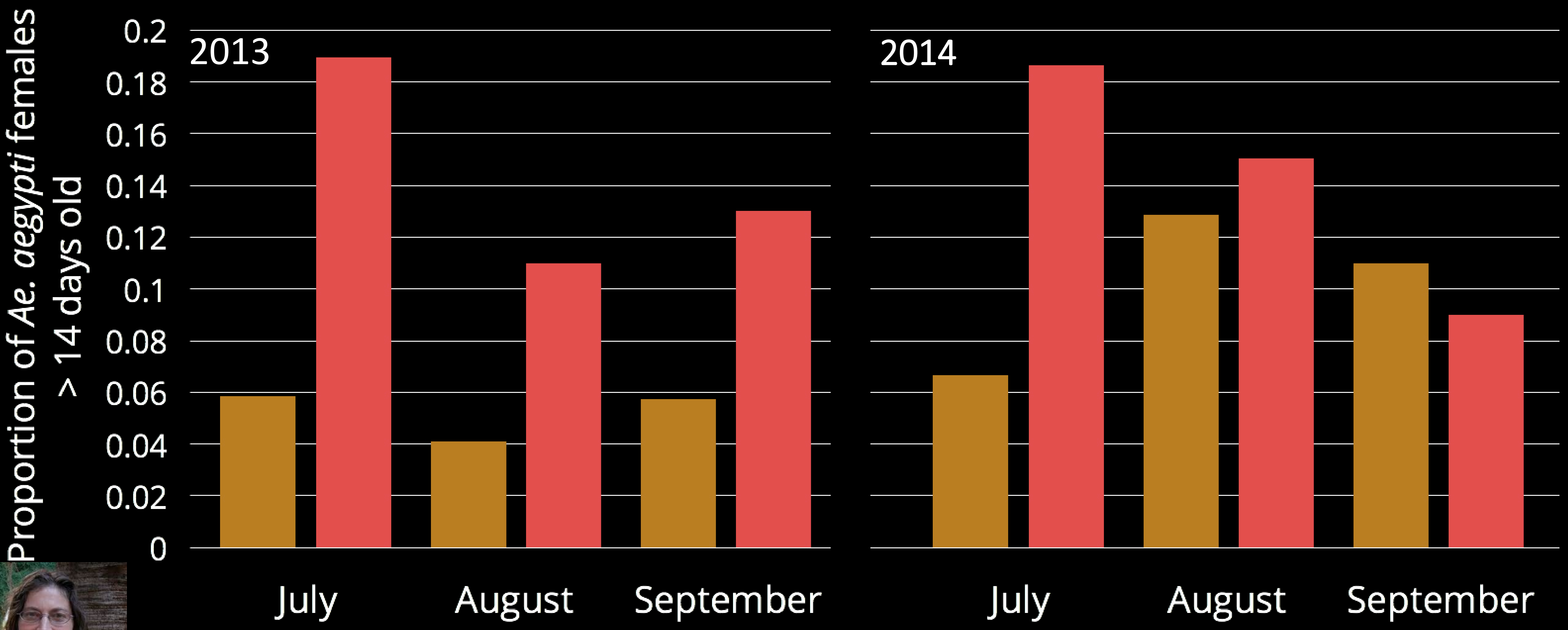
	Hermosillo	Nogales
2006	22.6	1.4
2007	15.4	0.5
2008	92.0	No cases
2009	22.2	1.9
2010	504.0	1.9
2011	26.3	1.0
2012	12.3	0.0
2013	33.1	1.9
2014	155.0	6.6
2015	88.1	1.9



Source: Reyes-Castro, P., *et. al.* 2015

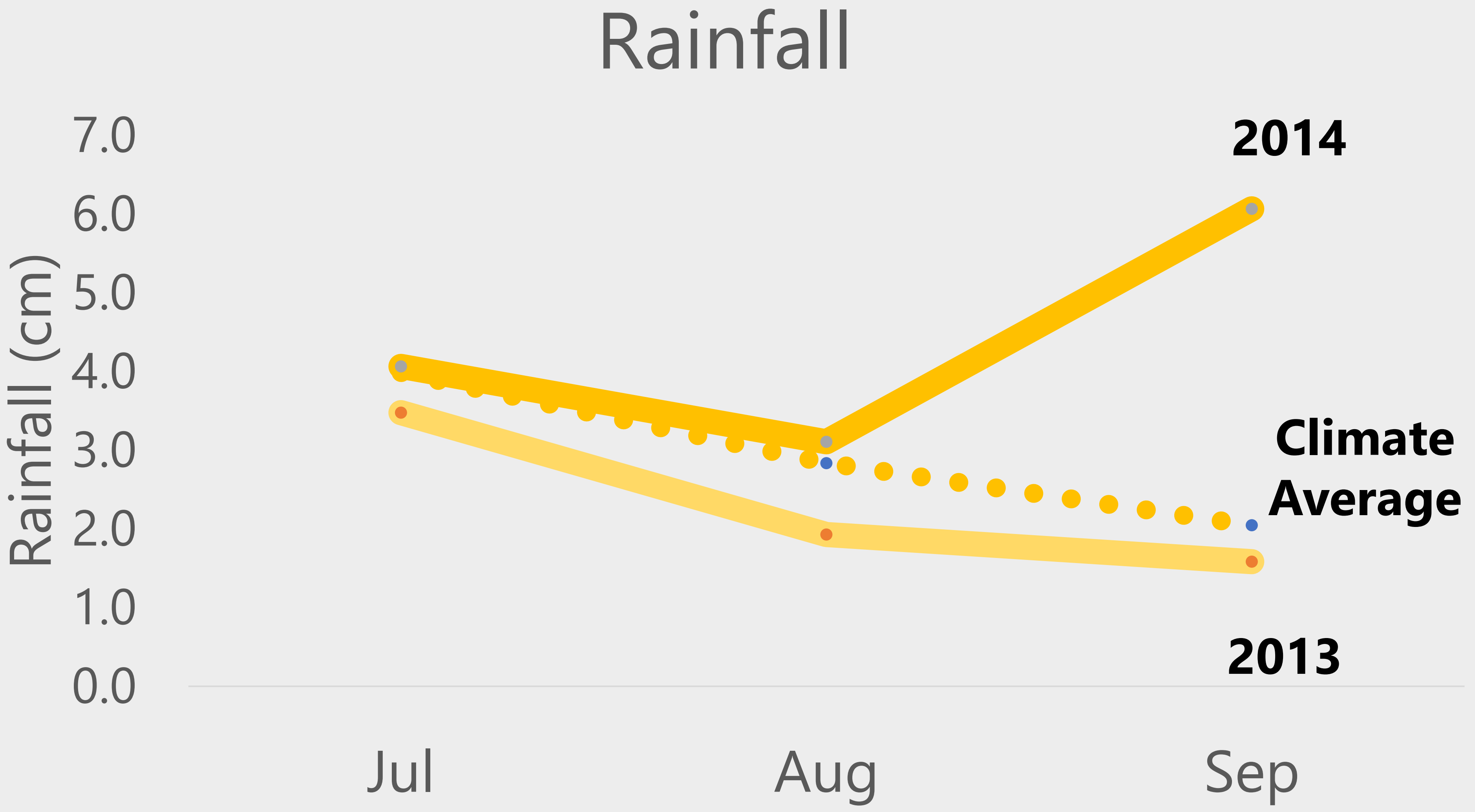
Age structure differences

Avg. percent of *Ae. aegypti*
>14 days old identified in traps



Ernst and Walker et. al. 2017

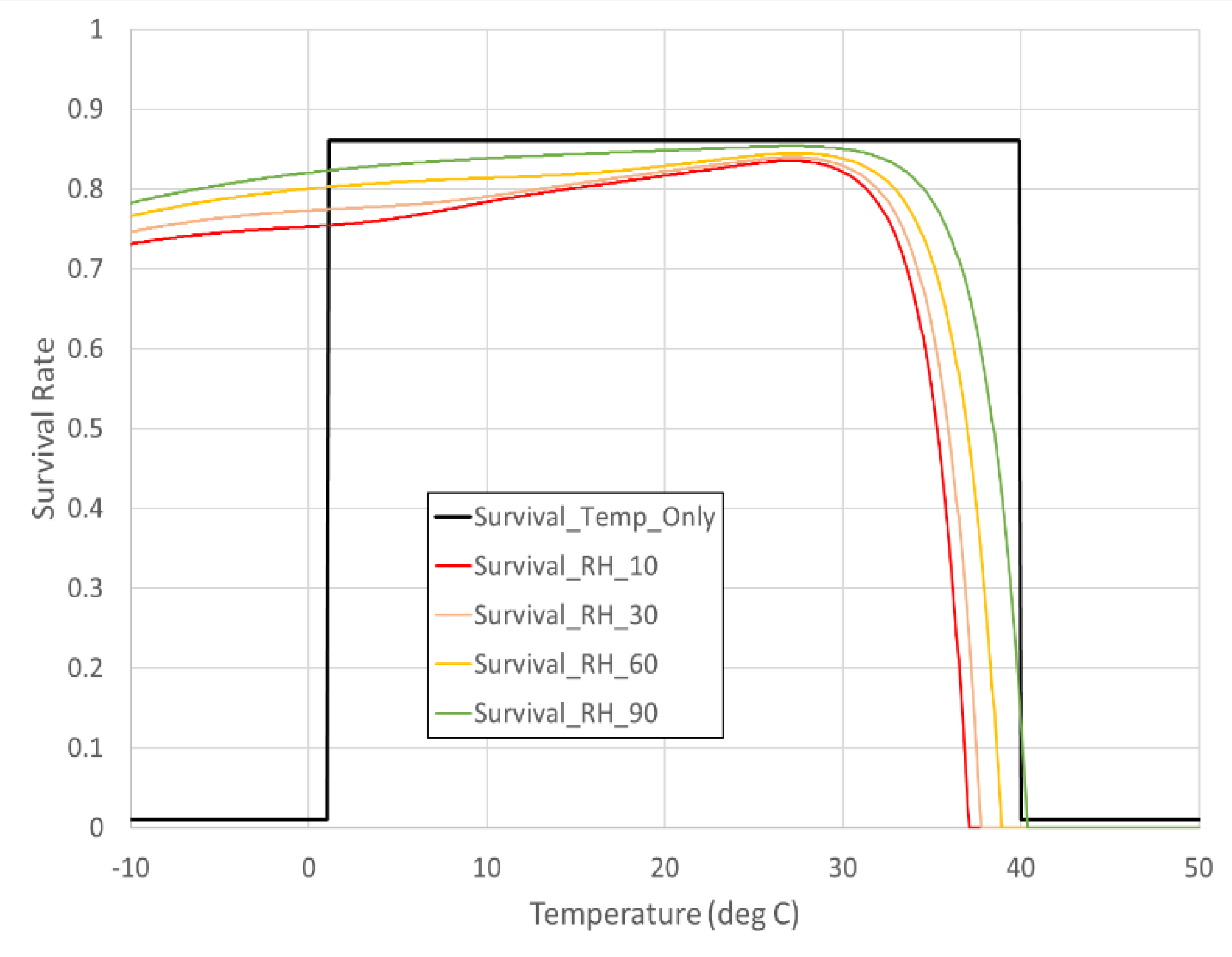
Weather conditions in Nogales



Humidity-temperature interact to influence longevity

- At upper and lower thermal limits humidity plays a significant role in longevity

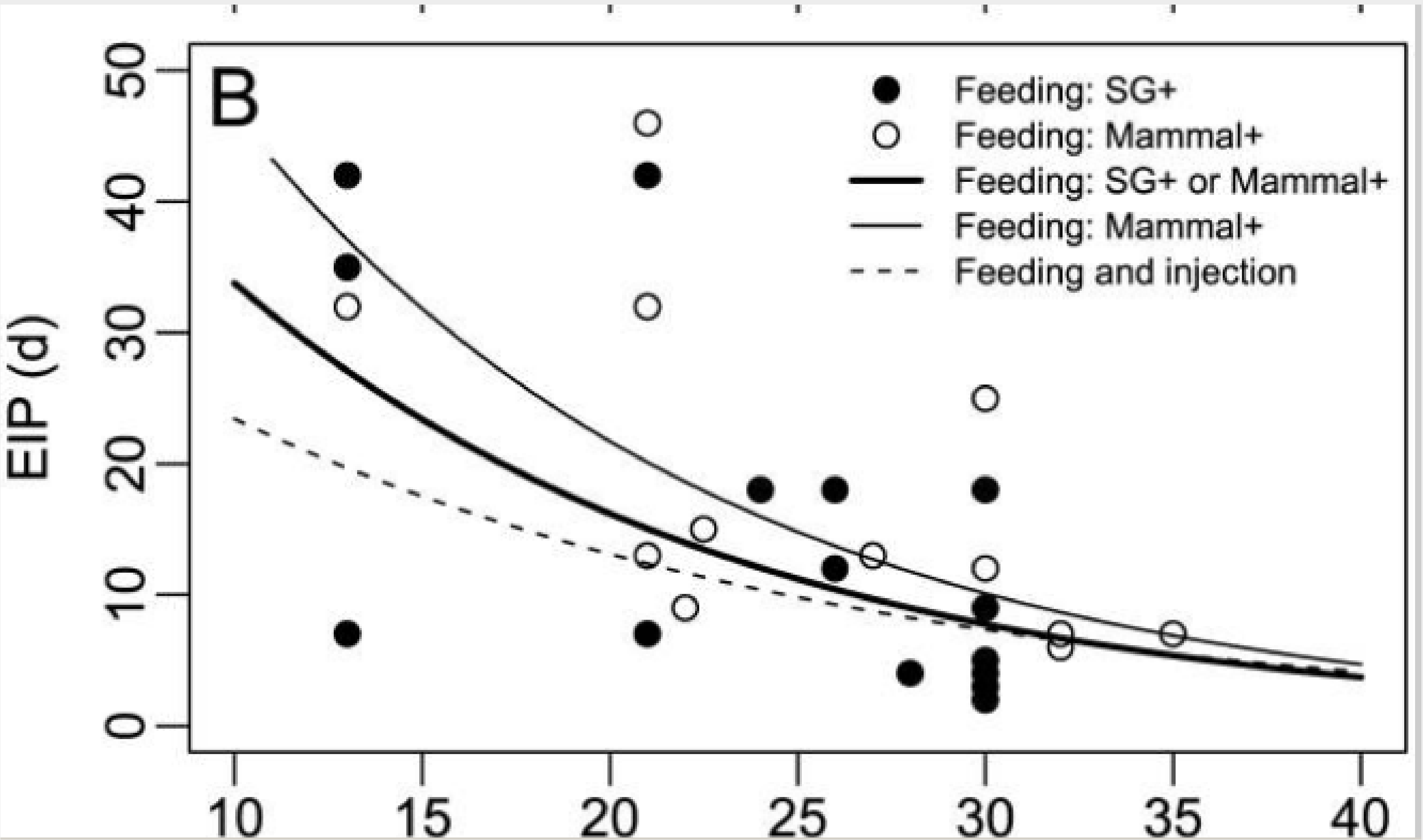
- Example: at 35°C, est. survival per day is roughly 80% at 90% RH to 60% at 10% RH



Comparison of survival rates from the original adult mortality algorithm based on temperature only (black line), and the new algorithm based on both temperature and humidity (colored lines for different values of relative humidity). In this example both algorithms assume a base field mortality of 14% (i.e., a survival rate of 0.86).

Schmidt et. al. Parasites and Vectors 2018
Morin et. al. under revision

Extrinsic incubation period is dependent on temperature



Tjaden *et. al.* PLoS Negl Trop Dis. 2013 Jun; 7(6):

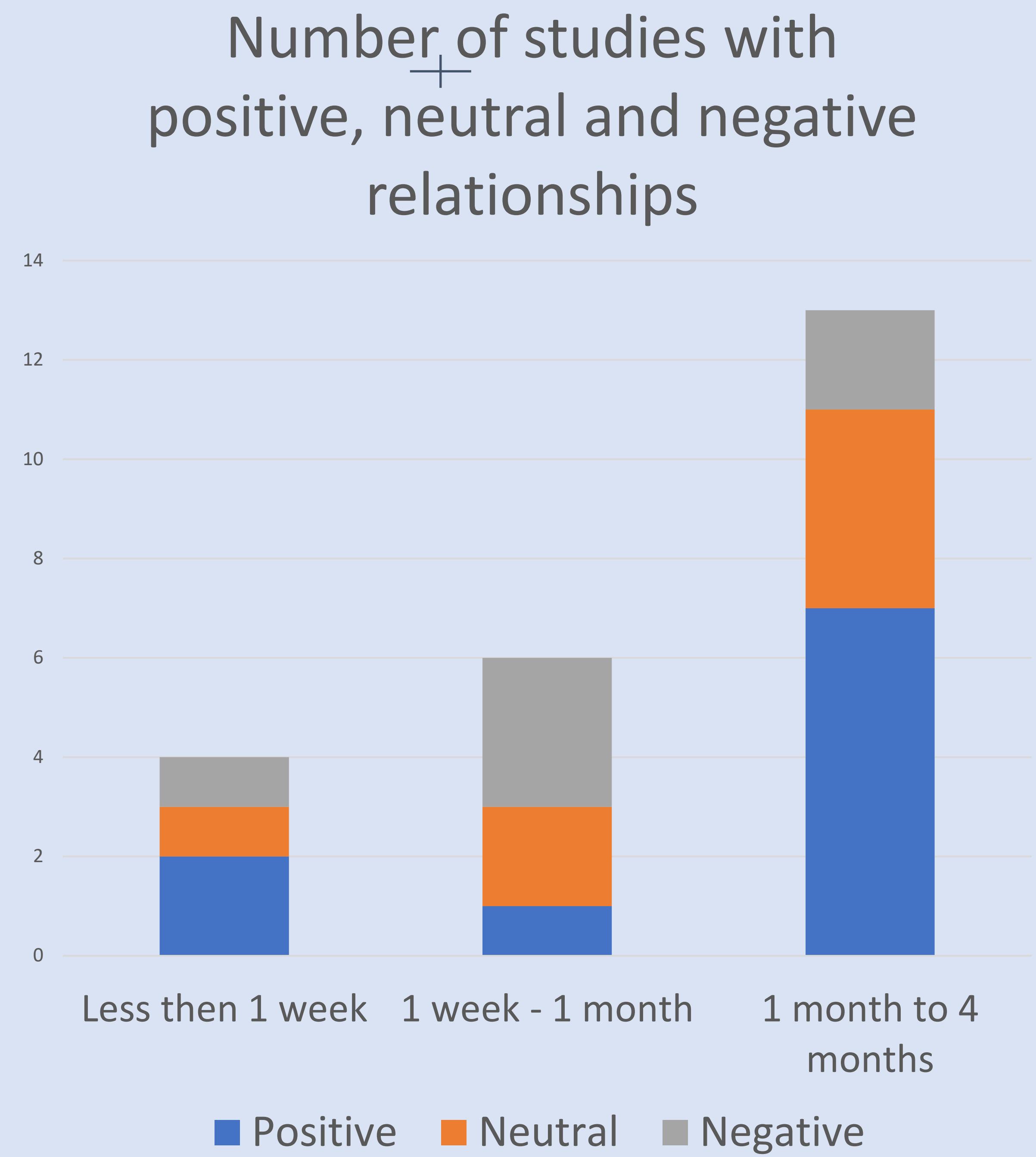
Field collections identify longer EIP and shorter longevity in Nogales may, at least partially, explain variability

Year	City	Proportion Parous	Mean Age, days	Median EIP +2 days	% Exceeds EIP	Mosquito Density (females/ trap/ day)	No. Potential Vectors/ trap/day	RR (95% CI)
2013	Nogales	0.68	6	16.9	0.12	1.95	0.16	ref
	Hermosillo	0.69	7.5	6.3	0.43	2.92	1.14	6.0 (3.5, 10.5)
2014	Nogales	0.66	7.9	19.1	0.14	3.26	0.3	ref
	Hermosillo	0.66	7.7	9	0.43	1.94	0.55	1.9 (1.2, 3.1)
2015	Nogales	0.67	6.9	15.1	0.14	2.32	0.21	ref
	Hermosillo	0.66	6.5	7	0.46	2.44	0.74	3.5 (2.1, 5.9)

- Source: Ernst *et. al.* in preparation, Joy et. al.

2. Extreme weather events

Recent systematic review – Extreme precipitation events and mosquito-borne diseases.



Coalson *et. al.* in prep

3. Landuse/ landcover

Satellite image: Google Maps, accessed Oct 8, 2018

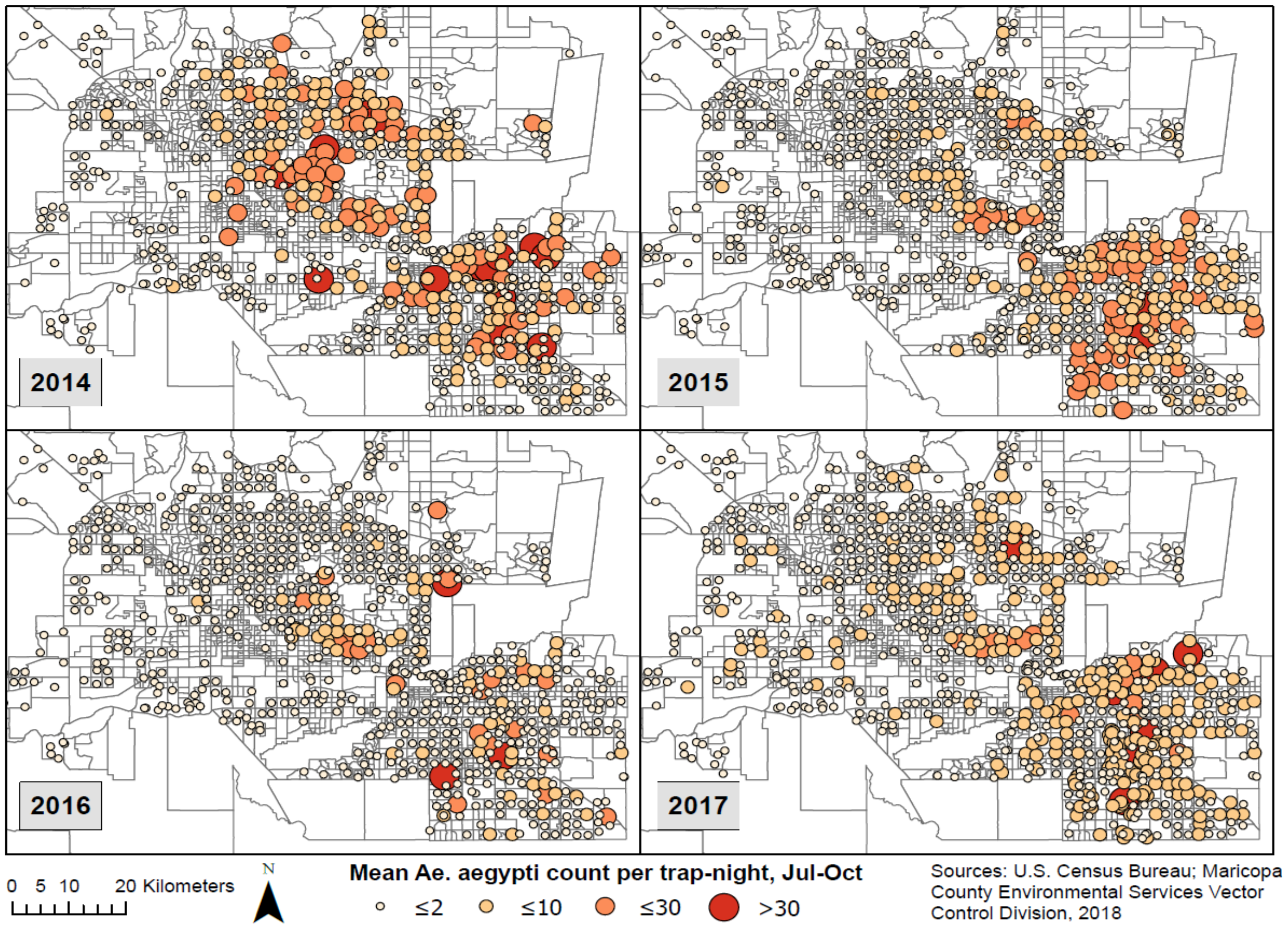
In prep D. Richard and J. Coalson *et. al.*

Methods

- Mosquito counts: Maricopa County Vector Control Division
  - Weekly counts from 700-800 geolocated, CO_2–baited EVS traps
  - Adult female *Ae. aegypti* counts from 2014 – 2017
- Climate data: PRISM Climate Group
  - Monthly avg. temperature
  - Monthly total rainfall
- Potential predictors assessed w/in 50 m of each trap:
  - Sociodemographics: U.S. Census Bureau
  - Land cover/land use: National Agricultural Imagery Program (1 meter resolution)
    - Categories: Pool, Lake, Pavement, Structure, Bare earth, Cactus/shrub, Shadow, **Grass, Trees**
- Data analysis: SAS version 9.4
  - Zero-inflated negative binomial regression of *Ae. aegypti* female counts
  - Multilevel model with random effect for repeat measurements at each trap

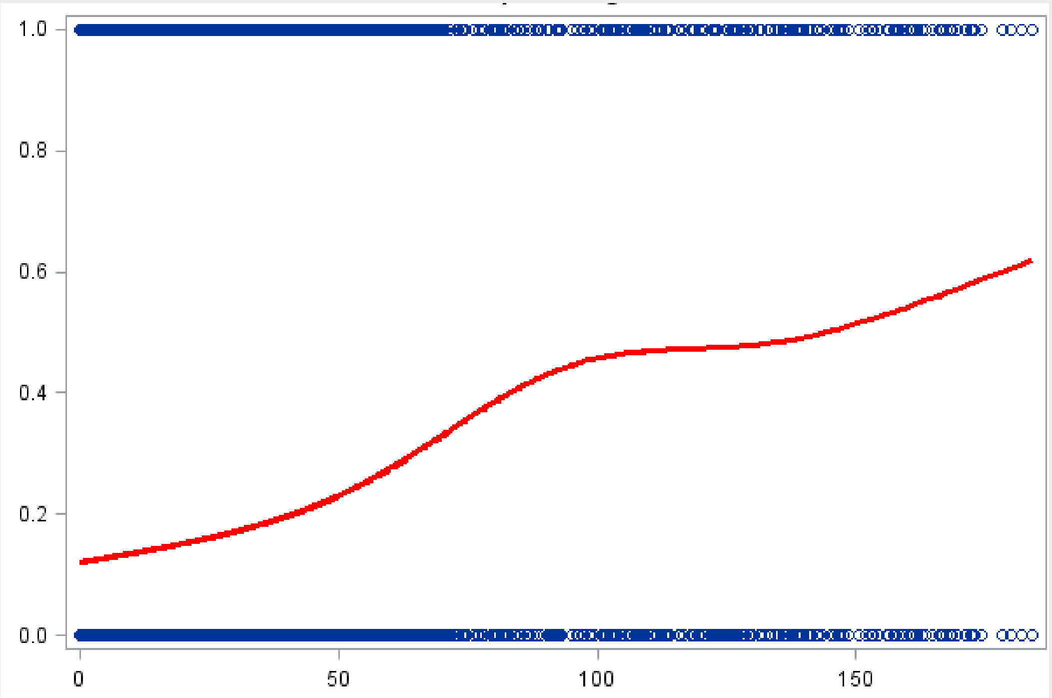
	2014	2015	2016	2017
Number of traps	666	785	794	881
Number of trap-nights	28,131	34,447	38,177	38,972
Ae. aegypti total count	27,208	24,155	28,986	28,934
Trap-nights positive for *Ae. aegypti*	13.6%	16.3%	16.7%	18.3%
Number of females when positive, median (range)	3 (1 – 215)	2 (1 – 375)	2 (1 – 300)	2 (1-325)

Average counts of *Ae. aegypti* females during monsoon season months are higher in southeastern communities and city center

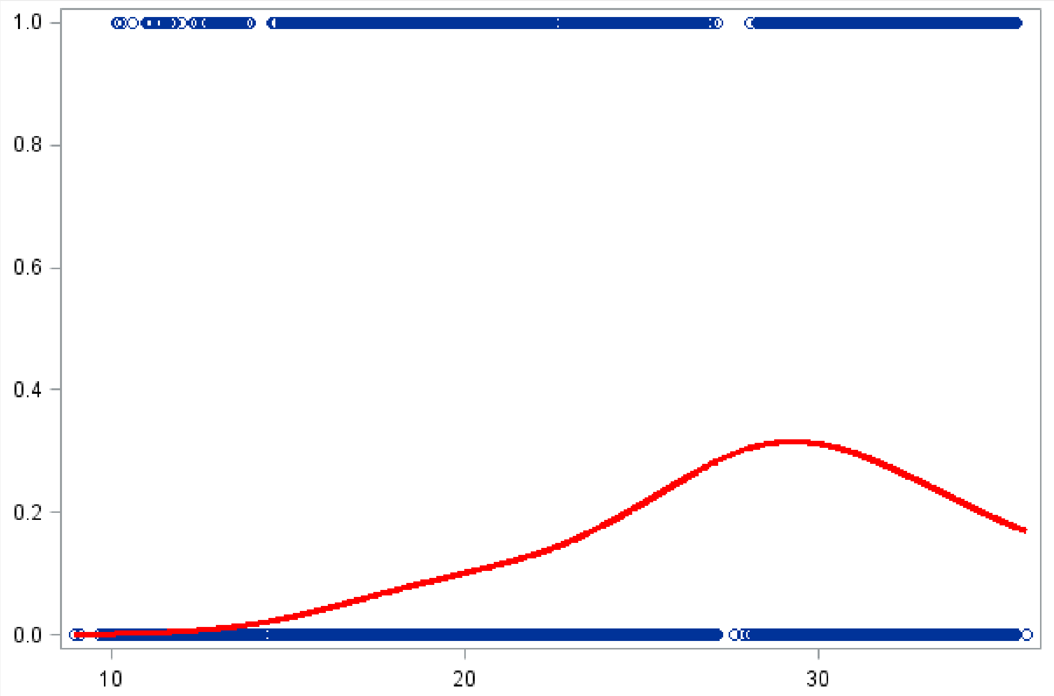


Rainfall and Temperature associations with *Ae. aegypti* presence

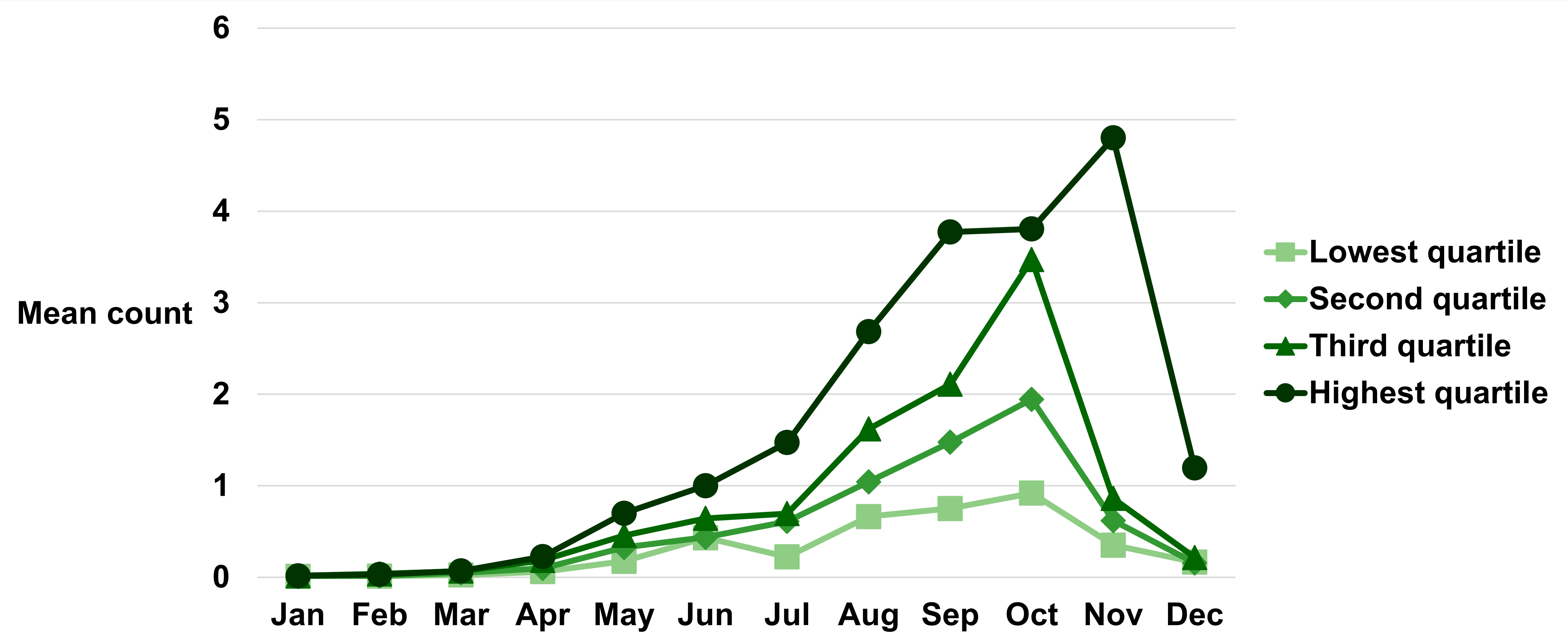
Rainfall (total mm previous month)



Temperature (avg. in Celsius for previous month)



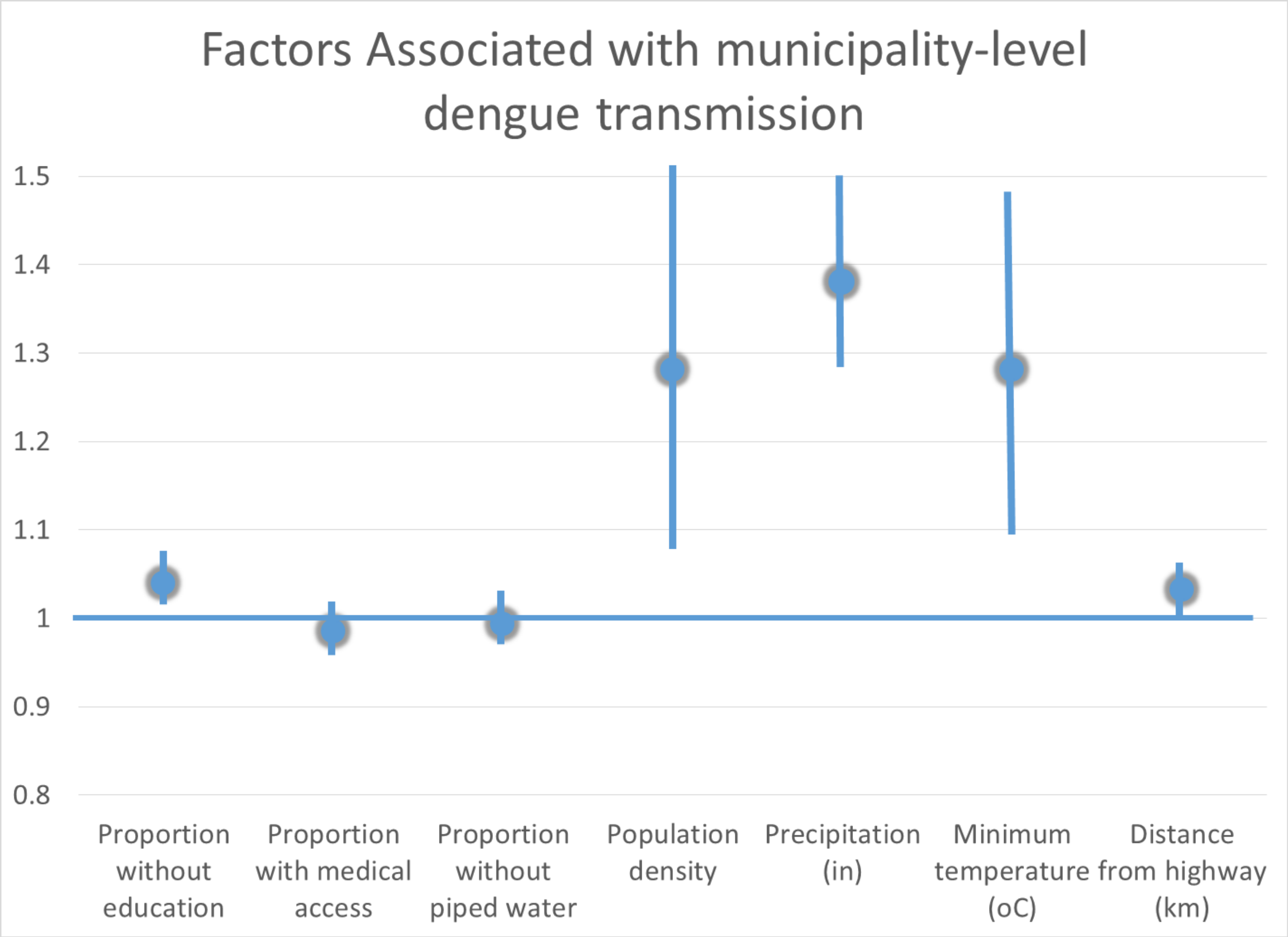
Higher quartiles of tree cover had higher mean counts of *Ae. aegypti*



4. Interplay between social and environmental

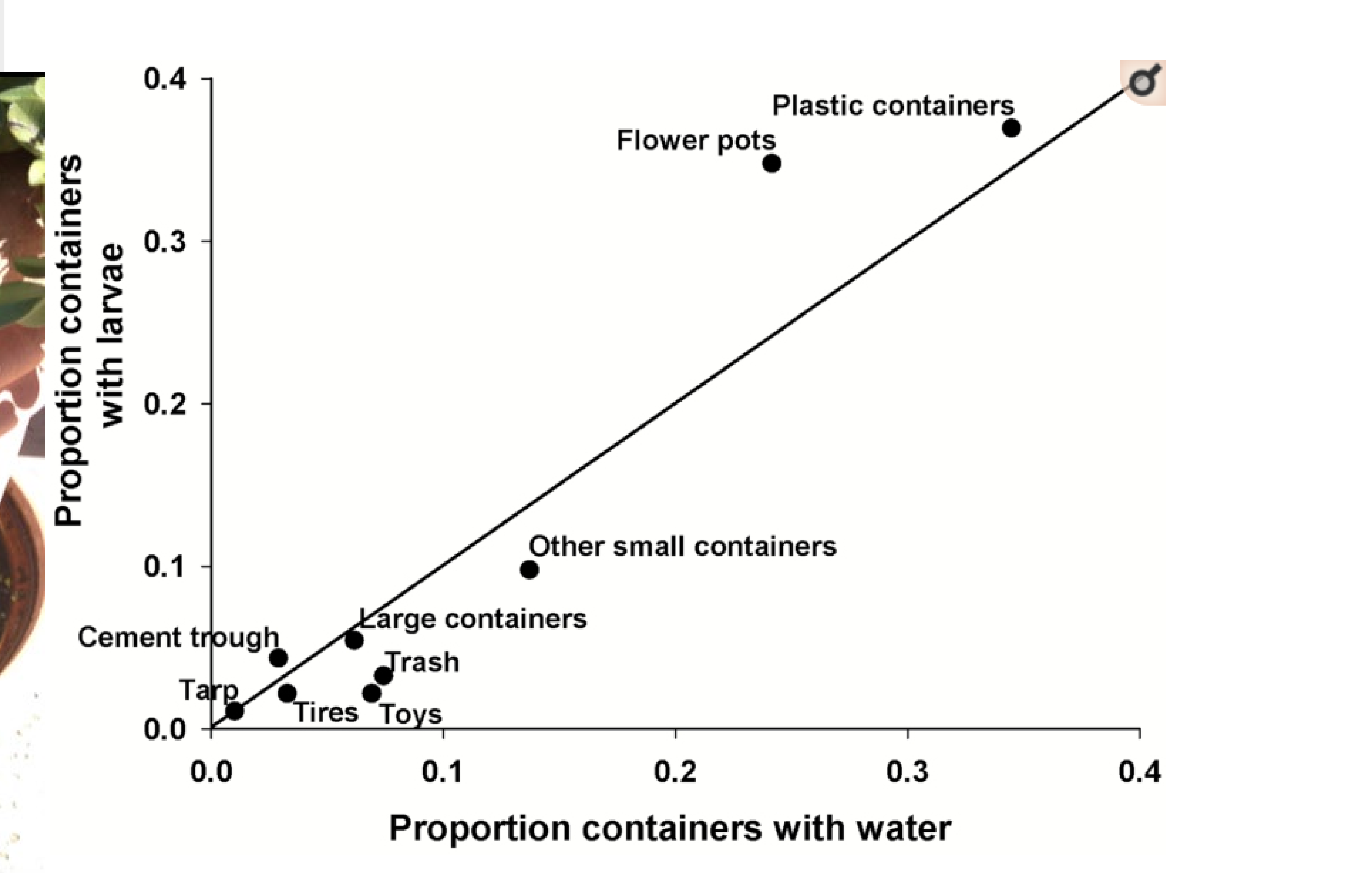
- Municipality level
  - State of Sonora, MX
- NLDAS – climate data
- Census data

- ZINB models



Reyes-Castro, 2015

5. Human dimensions in Tucson – flower pots



Co-benefits and inadvertant consequences- water management

- Drought – water storage – dengue fever
- The case of Australia, Honduras, Brazil

Drought blamed for upsurge in dengue fever in Brazil

Beebe NW et. al.(2009) PLoS NTD 3(5).

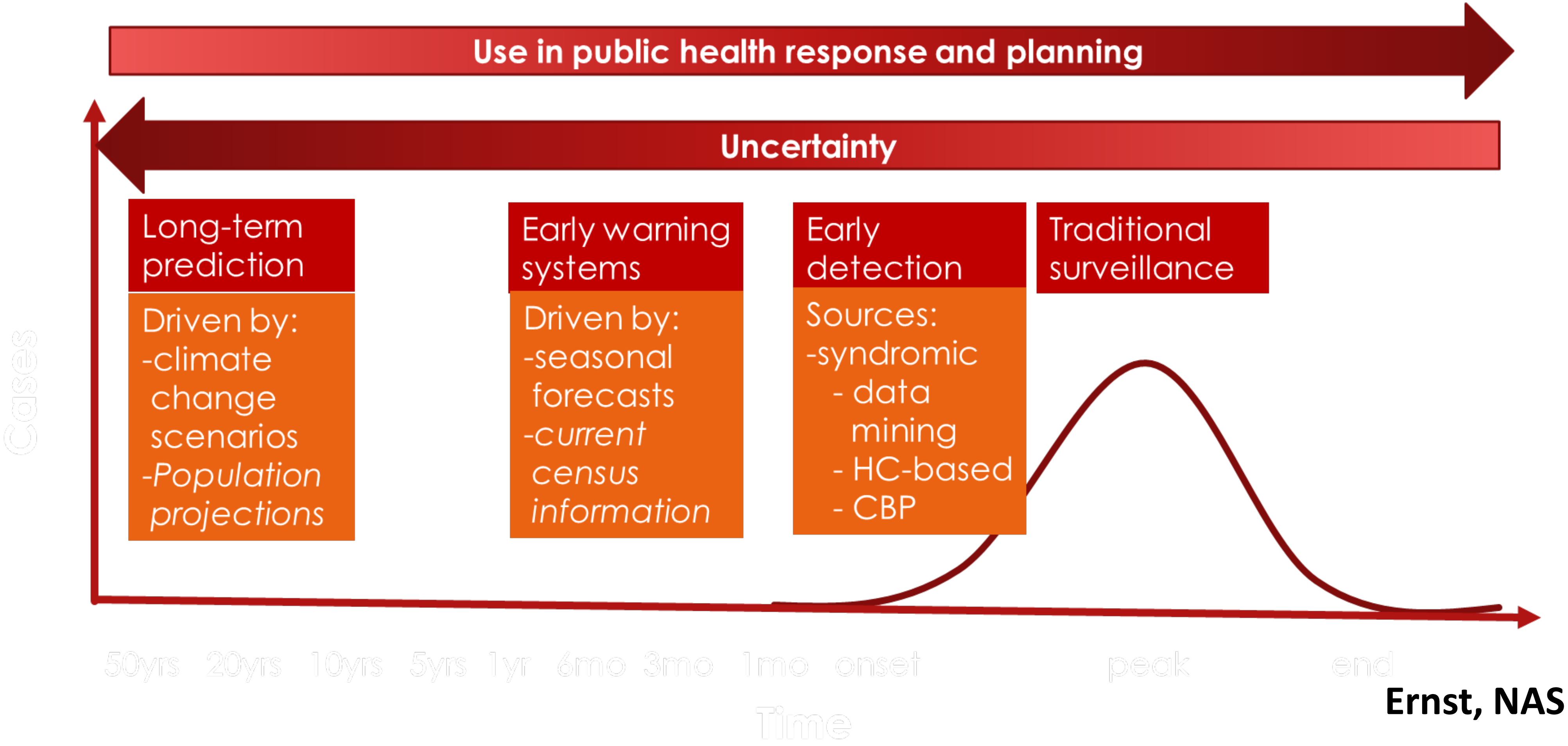
Household level factors

- Household survey
- Tucson
- 387 households – paired with larval survey

Factors associated with *Ae. aegypti* presence

	DF	Chi-2	P-value
House factors			
Neighborhood	19	33.49	0.03
Percent yard vegetated	3	6.48	0.09
Human and behavioral factors			
Number of people in house	1	4.29	0.04
Number of children in house	1	1.42	0.23
Household Income	4	8.91	0.06
Frequency of removing water	5	15.36	0.009

Long term predictions to early warning and early detection



Ernst, NAS Workshop, 2018

Climate Change Activities

Most frequently reported

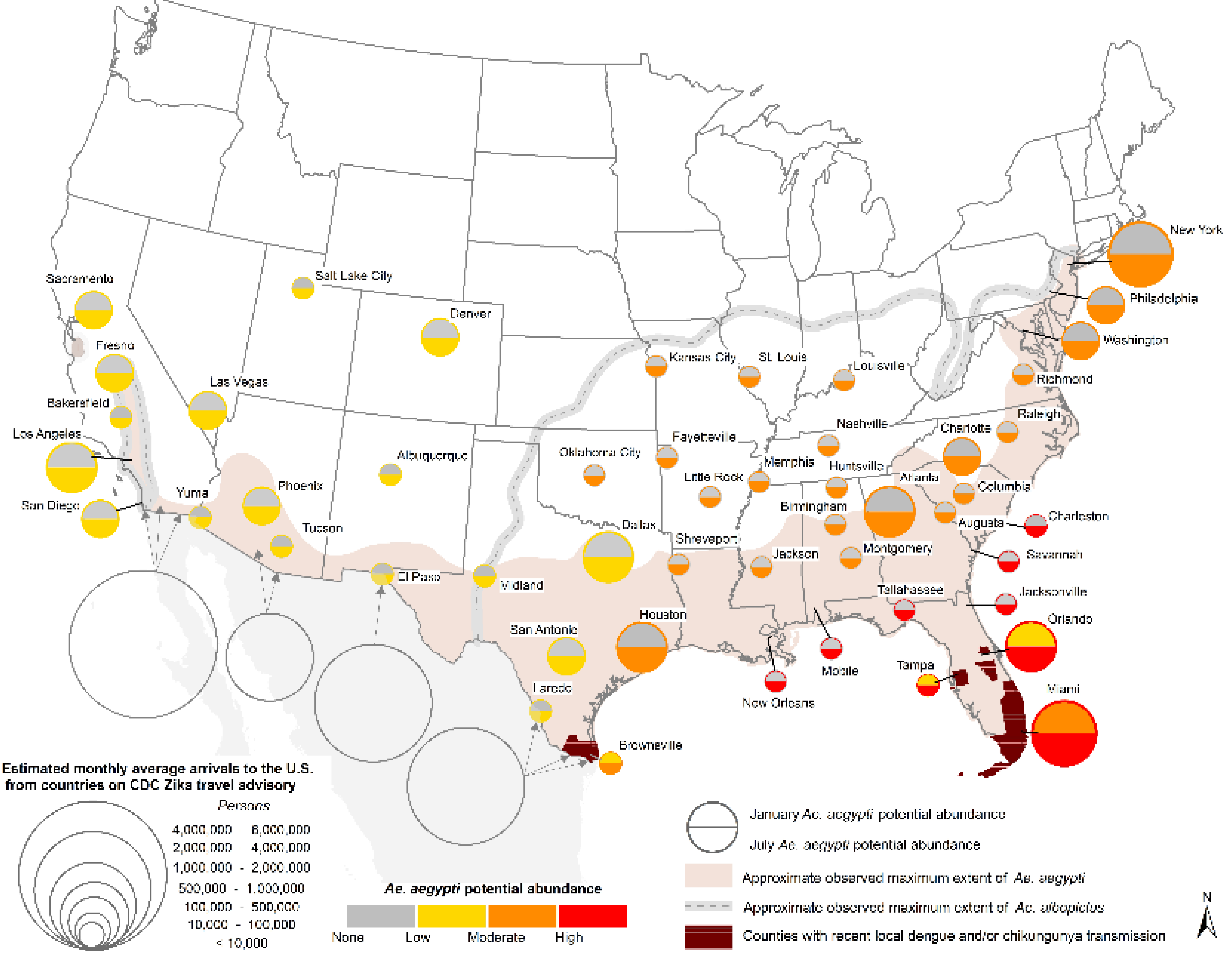
Least frequently reported

Public Health Activity	Federal	Tribal	State/Territorial	City/County	University / Academia	Other
Developing policies and plans such as municipal heat-wave preparedness plans that support individual and community health efforts.	75%	26%	35%	62%	20%	38%
Linking people to needed health services and ensuring the provision of health care following disasters.	25%	42%	48%	57%	15%	31%
Forming public health partnerships with industry, other professional groups, faith communities or others, to craft and implement solutions.	0%	37%	35%	62%	40%	62%
Conducting program assessments of preparedness efforts such as heat-wave plans.	25%	26%	30%	53%	20%	15%
Training health care providers on health impacts of climate change.	0%	5%	22%	21%	35%	15%
Informing the public about the health impacts of climate change.	75%	53%	65%	47%	55%	62%
Informing policymakers about the health impacts of climate change.	50%	53%	48%	36%	50%	62%
Investigating the relationships among weather and water, food, or vector-borne outbreaks.	25%	26%	35%	40%	35%	15%
Tracking of diseases and trends related to long-term climatic changes.	25%	5%	52%	49%	40%	0%
Working with partners to develop or use early warning systems for climate sensitive diseases.	50%	11%	4%	34%	10%	15%
Researching health effects of climate change, including innovative techniques such as modeling, and research on optimal adaptation strategies.	75%	32%	57%	28%	55%	0%
None of the above.	0%	5%	4%	4%	10%	8%

Arora, M. 2019

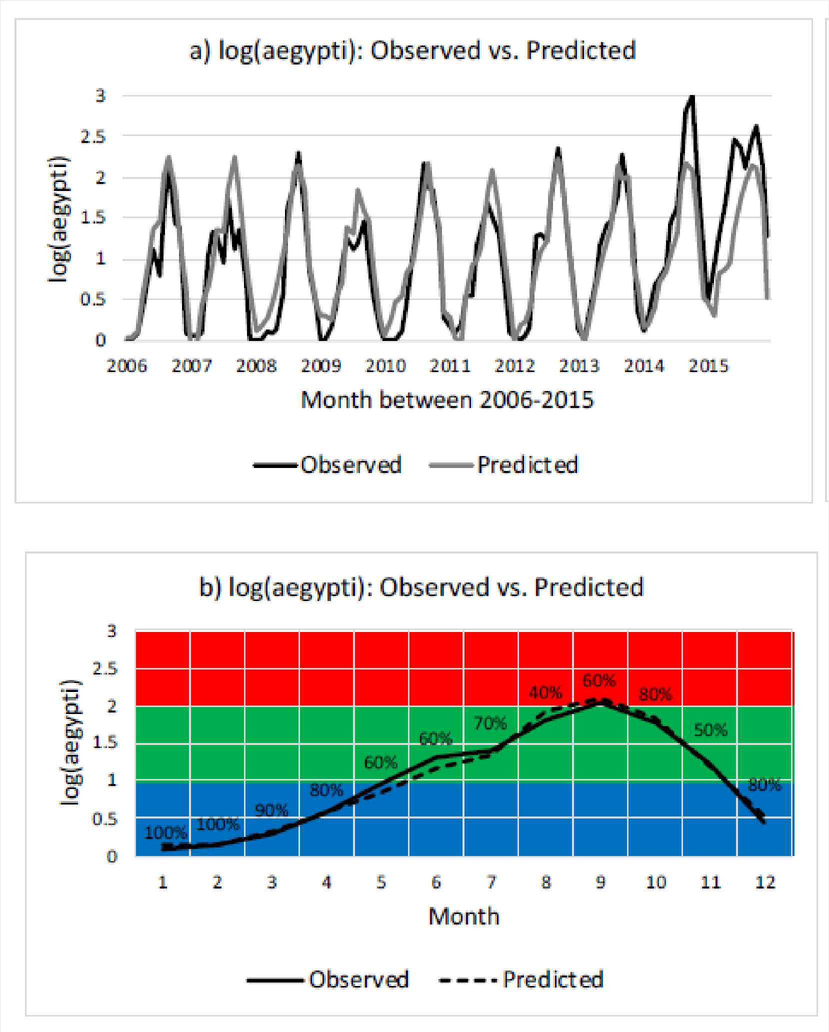
Zika Risk in CONUS

- Climate-driven mosquito models with
  - travel,
  - socioeconomic conditions
  - virus history
- Rapid analysis
- Designed for widespread dissemination to stakeholders and the public.
- One time assessment



Monaghan AJ, Morin CW,....Ernst K. PLOS Currents (March 2016)

Adaptation strategies: Early Warning and Public Engagement

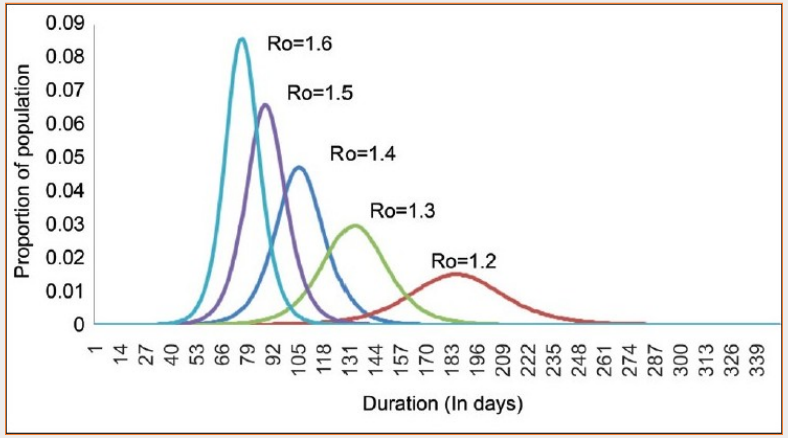


Monaghan et. al. 2019

Theoretical framework of Kidenga surveillance functionality

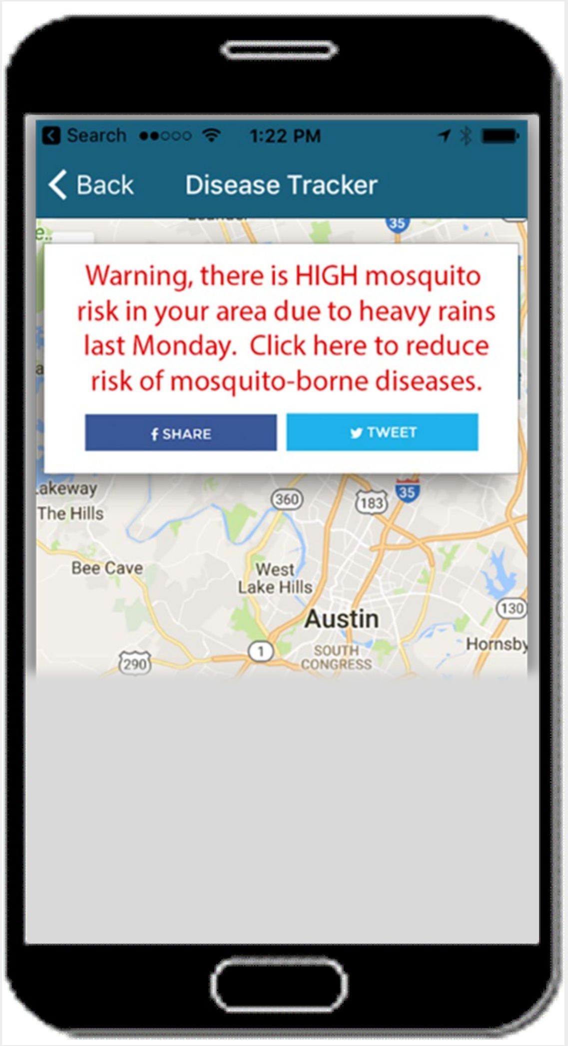
Community more informed about risk during high risk time periods

Early detection of people with symptoms. Public health can take early action.



Reduce vector contact and transmission.

Kidenga 2.0: Iterate with alerts and cues to action



Discussion points

- Enormously complex systems determine infectious potential
- Developing methodologies to predict and prepare for complex interactions
- Capitalize on benefits of anthropocene
  - Global networks
  - Rapid information sharing
  - Technological breakthroughs
  - Capacity building

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