Zika: Mosquito transmission and vector control

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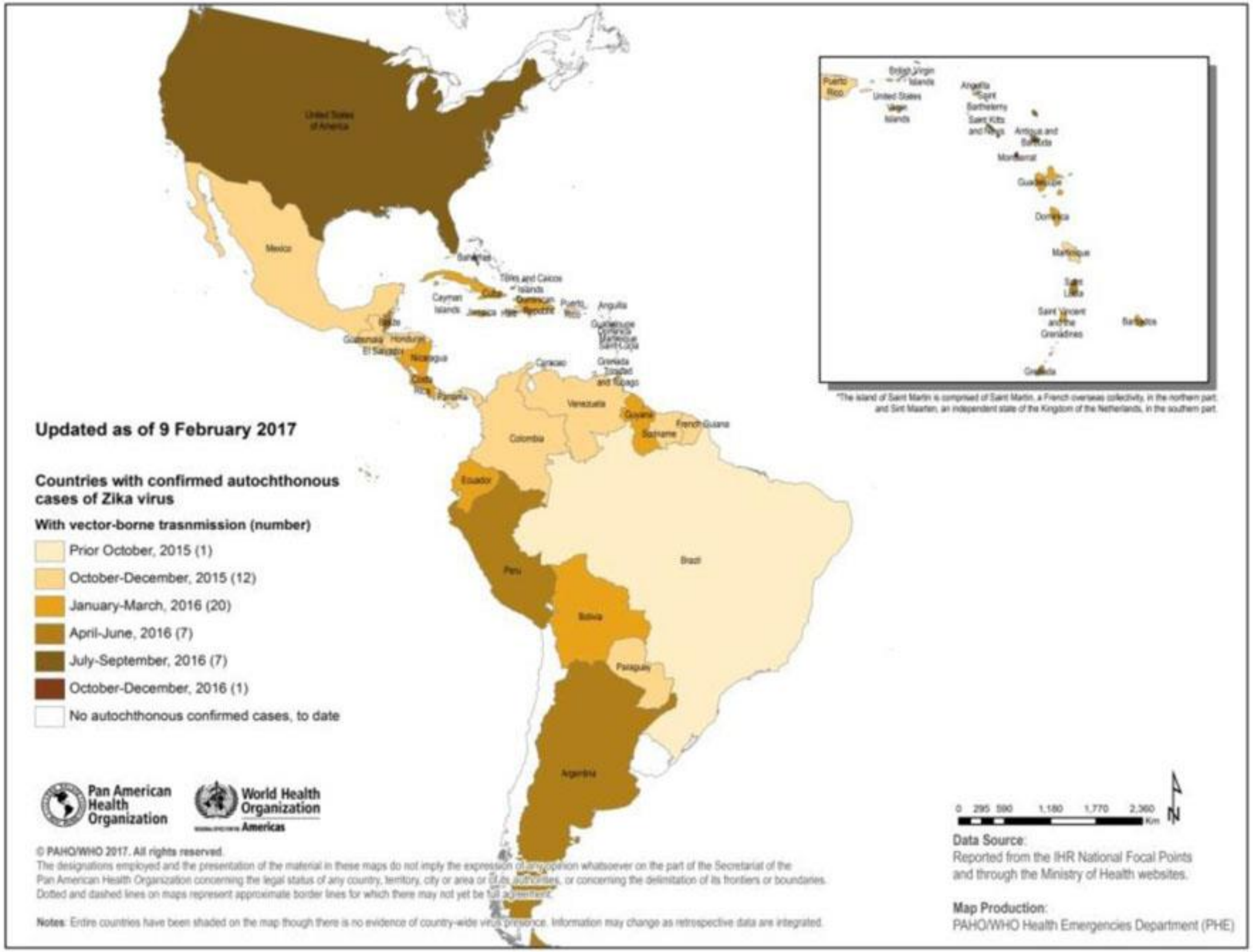
Scope of talk:

- Zika in the Americas and US.
- Mosquito biology relevant to transmission dynamics.
- Risks to Michigan residents.
- Vector control options.


Updated as of 9 February 2017
Countries with confirmed autochthonous cases of Zika virus
With vector-borne trasnmission (number)
Prior October, 2015 (1)
October-December, 2015 (12)
January-March, 2016 (20)
April-June, 2016 (7)
July-September, 2016 (7)
October-December, 2016 (1)
No autochthonous confirmed cases, to date
Mexico
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Argentina
Pan American Health Organization
World Health Organization
Americas
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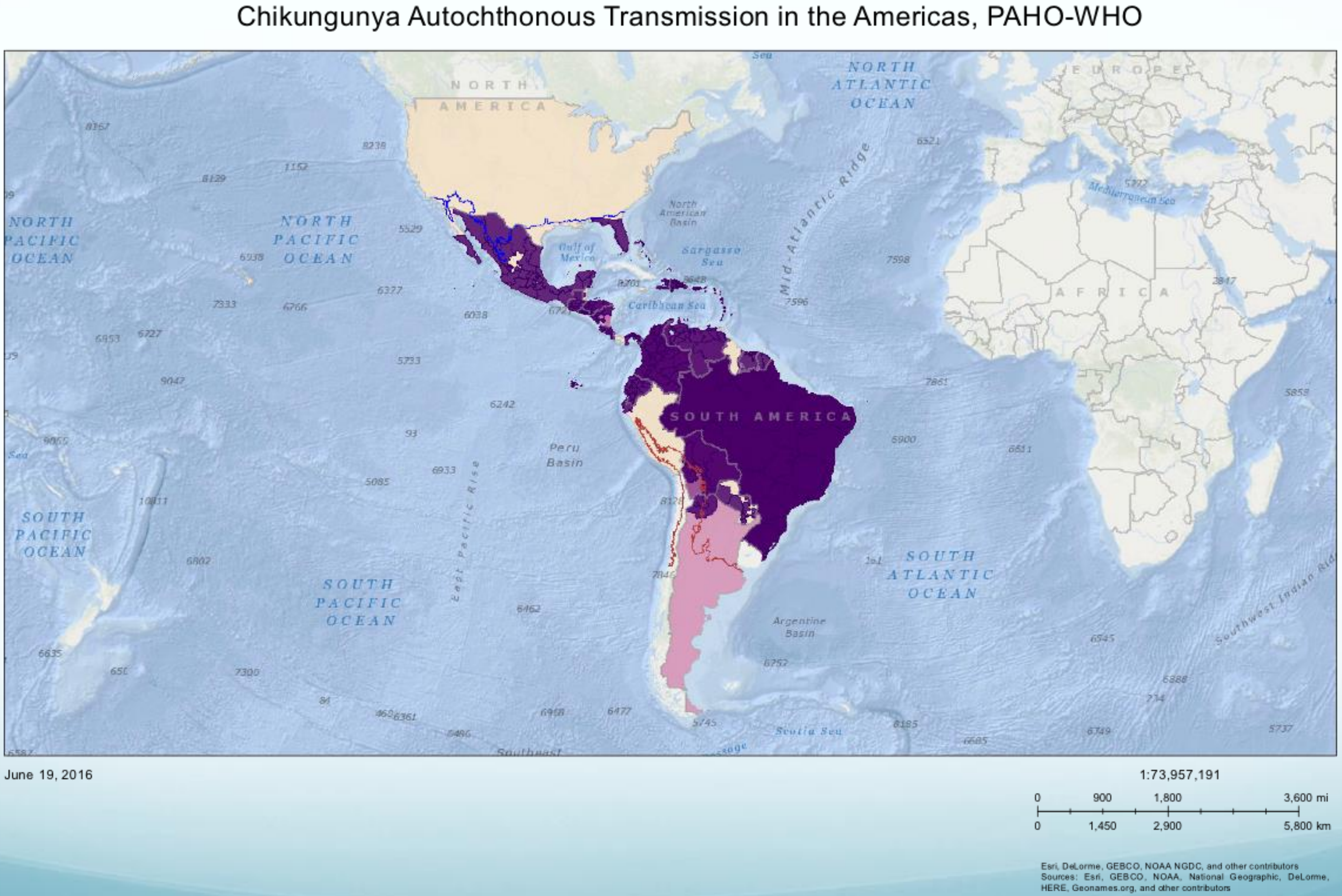
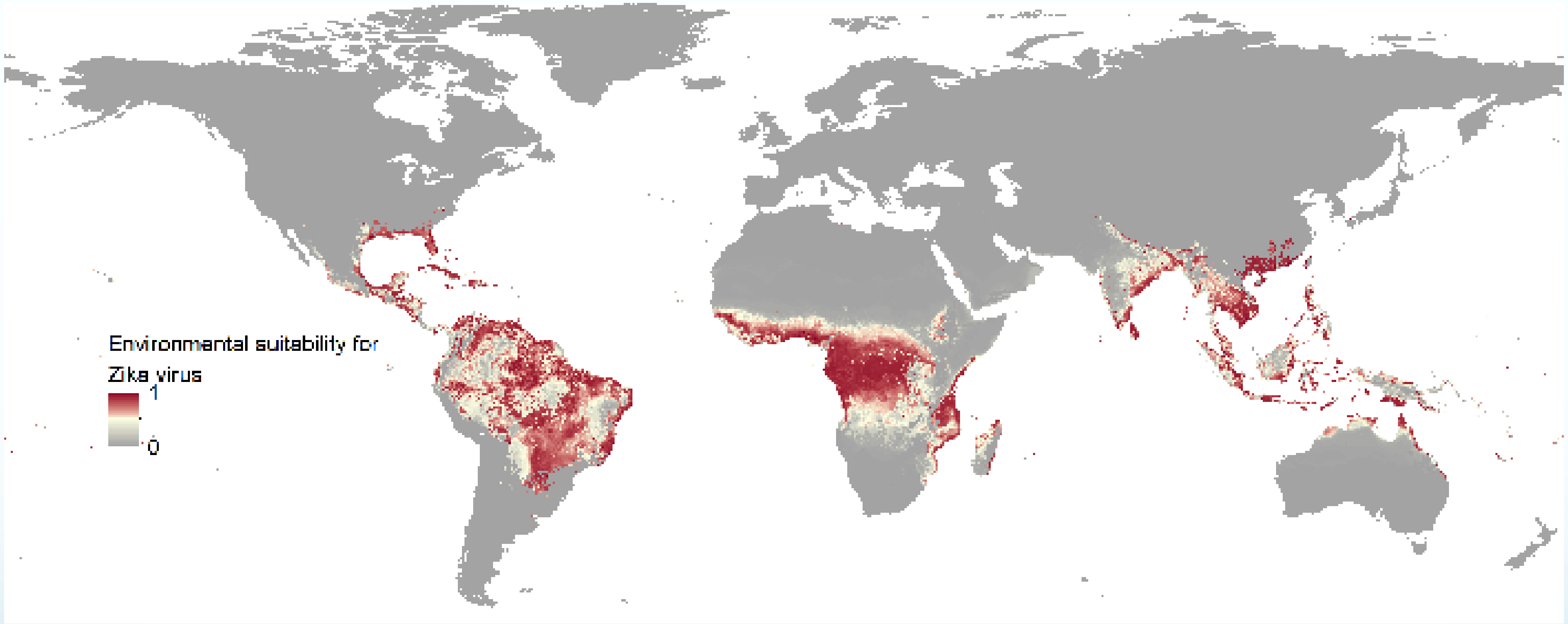
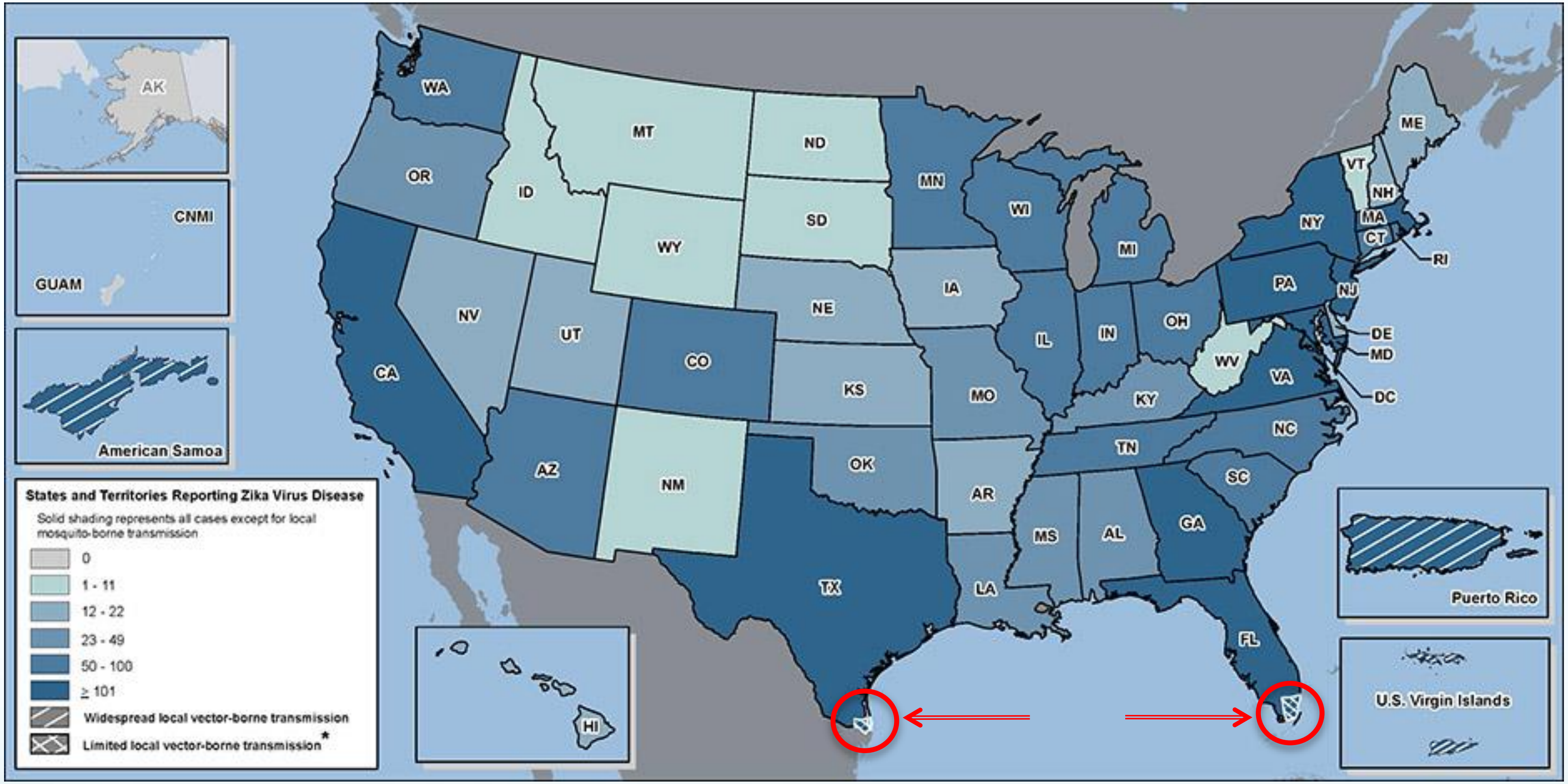
The designations employed and the presentation of the material in these maps do not imply the expression of any opinion whatsoever on the part of the Secretariat of the Pan American Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.
Notes: Entire countries have been shaded on the map though there is no evidence of country-wide virus presence. Information may change as retrospective data are integrated.
0 295 590 1,180 1,770 2,360 Km
N
Data Source:
Reported from the IHR National Focal Points and through the Ministry of Health websites.
Map Production:
PAHO/WHO Health Emergencies Department (PHE)

Chikungunya spread in the Americas (2013 – 2014) very similar to Zika



Zika risk based primarily on environmental suitability for main vector





CDC map, Feb 22, 2017

~ 5000 cases of Zika in US – almost all travel related

~ 250 cases of local mosquito transmission

A brief preface about transmission

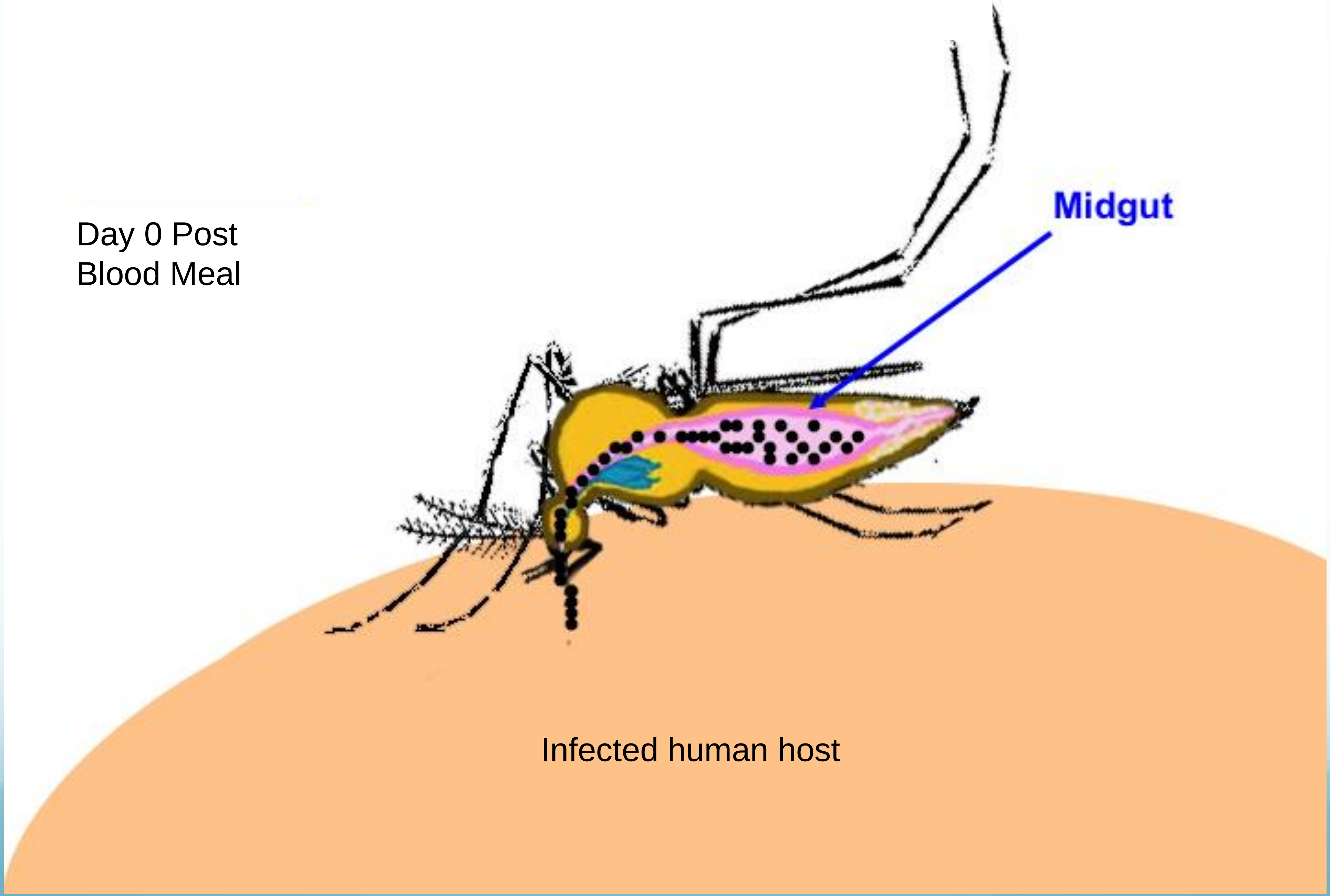
- Zika has spread quickly in a geographic sense because of human travel (and perhaps sexual transmission) – NOT via new or expanded mosquito populations.

- Mosquitoes must feed at least twice for transmission to occur, and there is an interval between feeding on one infected host and being able to infect another (extrinsic incubation period).

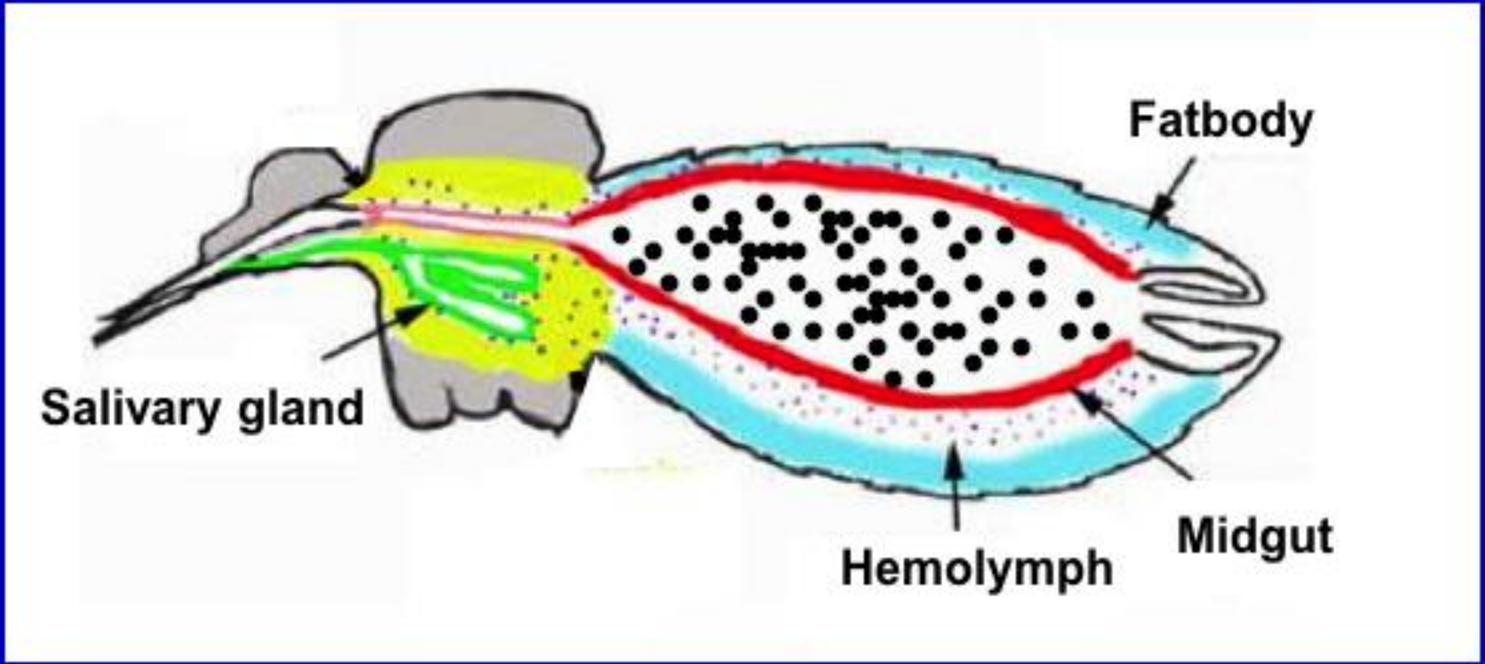
- Takes relatively few infected mosquitoes (e.g., <1%) to sustain disease transmission.

Virus propagation in mosquito

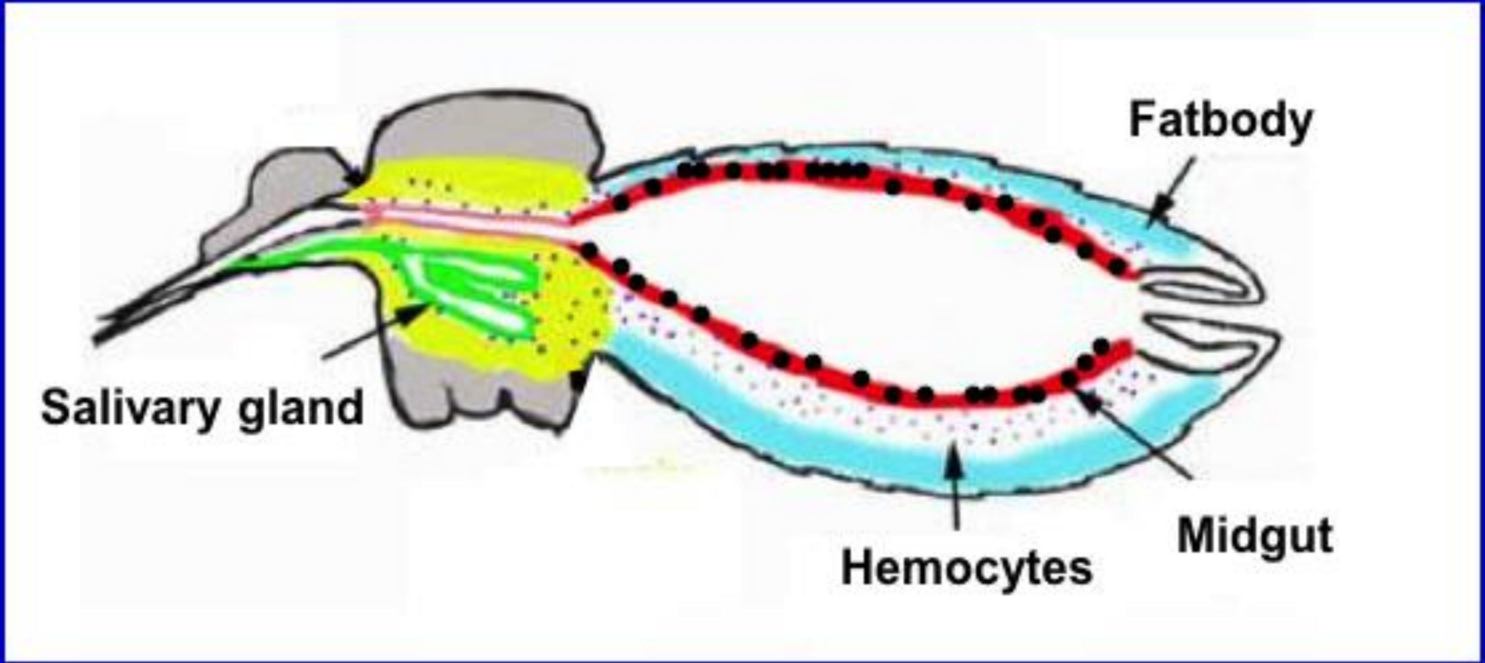
Day 0 Post
Blood Meal



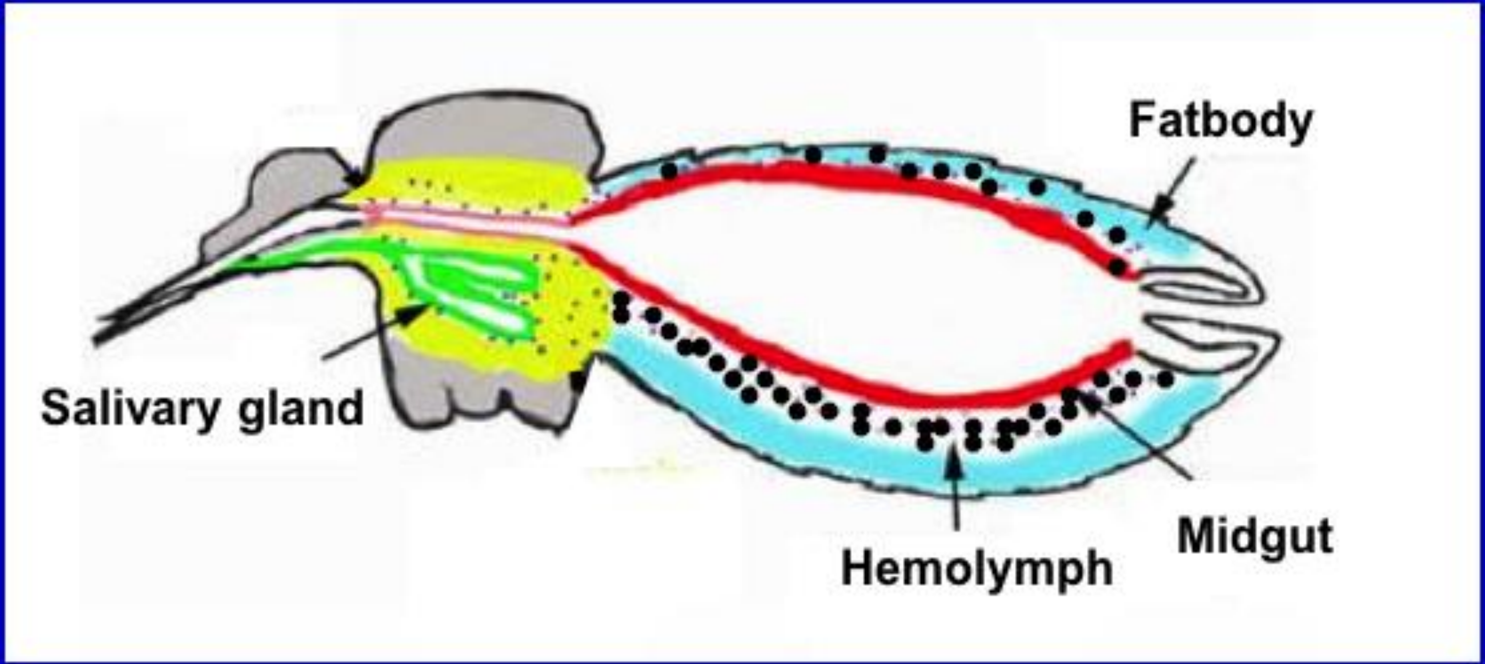
Virus particles in midgut lumen



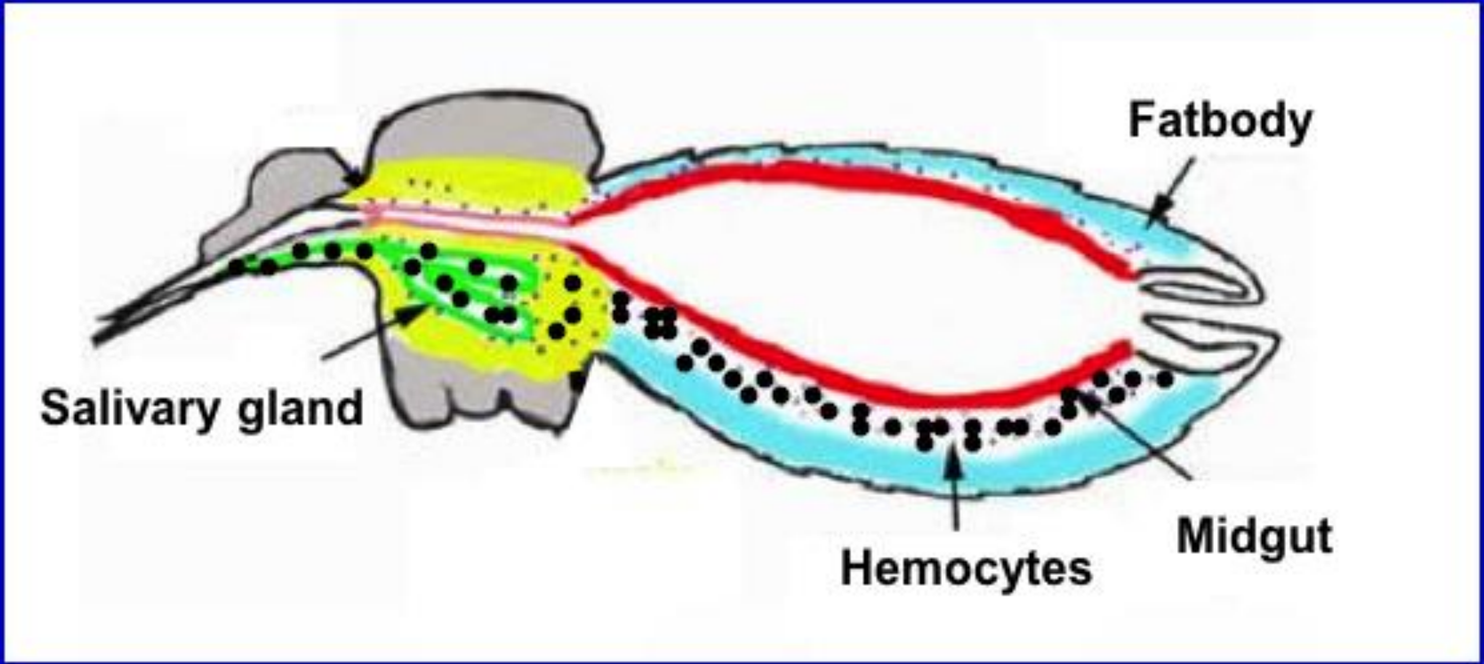
Virus particles replicate in midgut cells



Virus released into mosquito hemolymph (blood analog) and replication occurs in fat body (liver analog), other organs and hematocytes

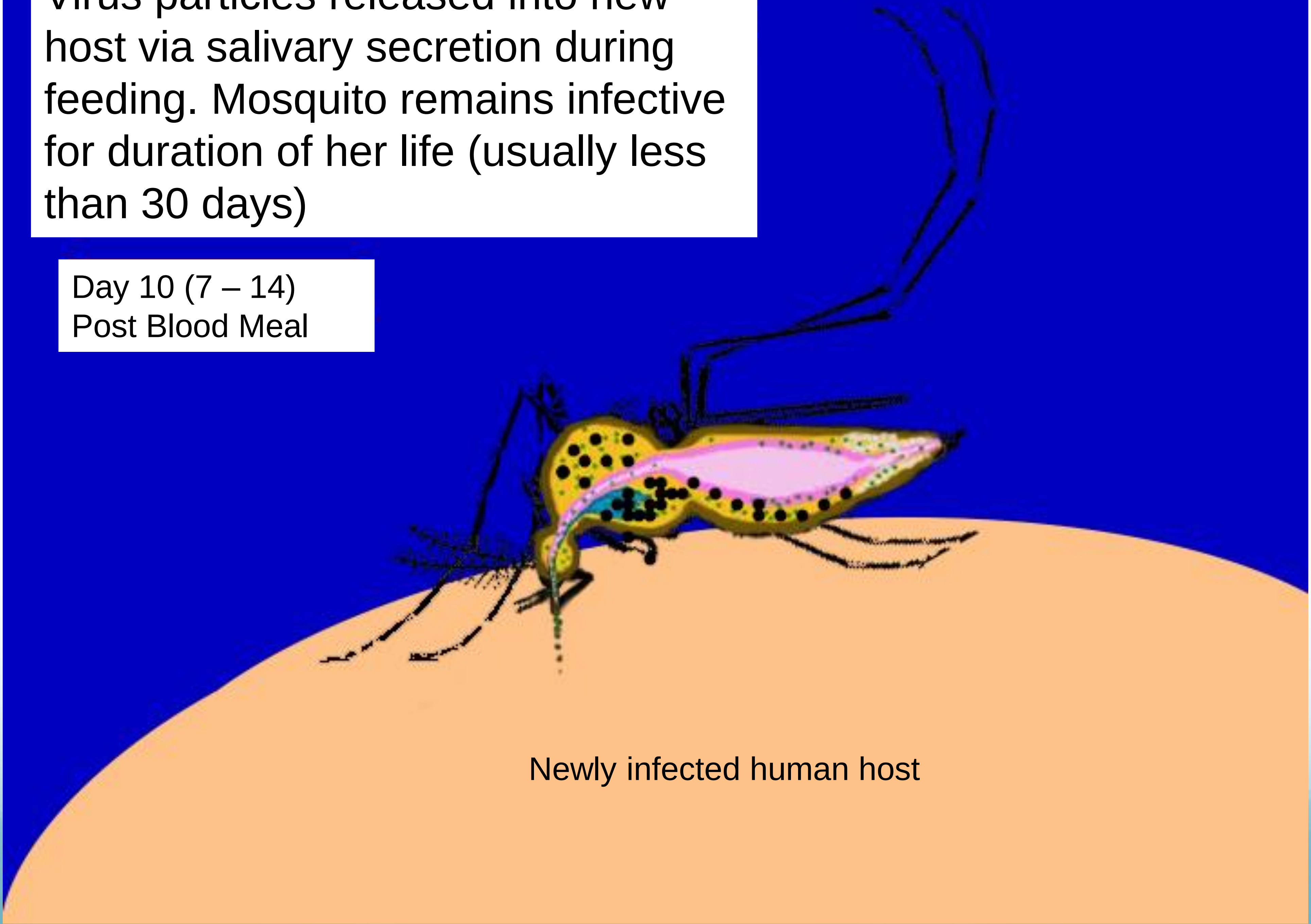


Virus replicates in salivary gland cells

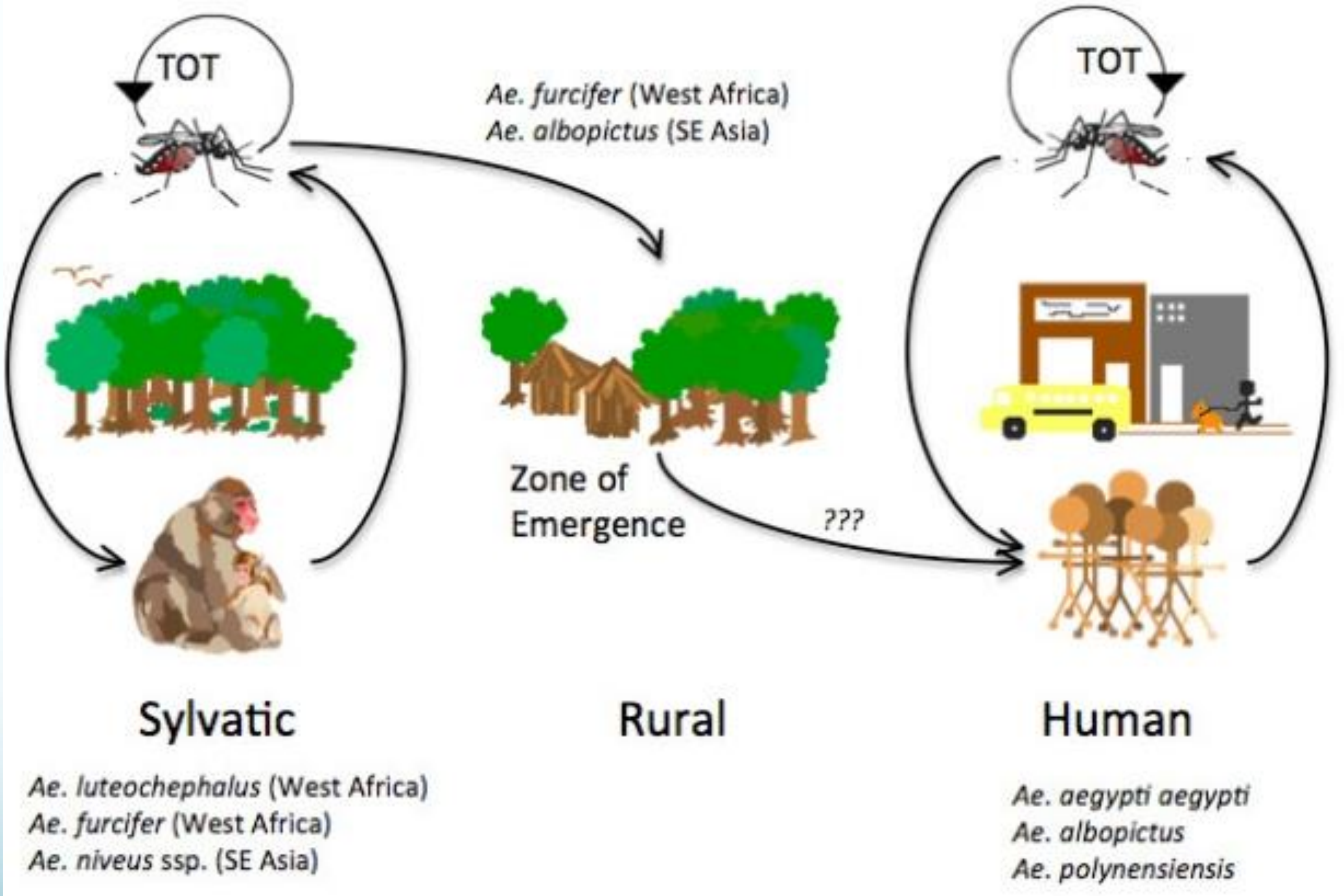


Virus particles released into new host via salivary secretion during feeding. Mosquito remains infective for duration of her life (usually less than 30 days)

Day 10 (7 – 14)
Post Blood Meal



Similar to dengue and chikungunya, Zika has an enzootic sylvatic cycle, but epidemics occur in urban/human cycles that can be self-sustaining



Dengue transmission cycles

Urban cycle arboviruses driven by *Aedes aegypti* and *Aedes albopictus*

Table 4 Epidemiological and clinical features of dengue, Zika, and chikungunya virus infections.[59,61,105–114]

	Dengue virus	Zika virus	Chikungunya virus
Virology			
Family	*Flaviviridae*	*Flaviviridae*	*Togaviridae*
Nucleic acid	Single-strand, positive sense, RNA.	Single-strand, positive sense, RNA.	Single-strand, positive sense, RNA.
Main divisions	4 serotypes (1 to 4)	2 lineages (African and Asian)	4 major lineages (West African, East/Central/South African [ECSA], Indian Ocean, Asian)
Epidemiology			
Natural reservoir	Primates (sylvatic cycle).	Primates (sylvatic cycle).	Primates (sylvatic cycle).
Key vectors for natural transmission	*Aedes* mosquitoes. Sylvatic cycle: *Ae. furcifer, Ae. luteocephalus, Ae. vittatus, Ae. taylori, Ae. niveus.* Urban cycle: *Ae. aegypti* and *Ae. albopictus*, other locally predominant species implicated (e.g. *Ae. polynesiensis, Ae. pseudoscutellaris, Ae. malayensis, Ae. cooki*).	*Aedes* mosquitoes. Sylvatic cycle: *Ae. africanus, Ae. furcifer, Ae. luteocephalus, Ae. vittatus, Ae. unilineatus, Ae. opok.* Urban cycle: *Ae. aegypti, Ae. albopictus*; other locally predominant species implicated (e.g. *Ae. hensilli, Ae. polynesiensis*).	*Aedes* mosquitoes. Sylvatic cycle: *Ae. africanus, Ae. furcifer, Ae. luteocephalus, Ae. neoafricanus, Ae. taylori, Ae. dalzieli, Ae. vigilax, Ae. camptorhynchites, Ae. fulgens.* Possibly *Mansonia* spp. as well. Urban cycle: *Ae. aegypti, Ae. albopictus.*

Primary (only?) vectors are *Aedes aegypti* and *Ae. albopictus*

Comparison of *A. aegypti* and *A. albopictus*:

A. aegypti	***A. albopictus***
bites primarily humans (*anthropophilic*)	bites primarily wild and domestic animals (*zoophilic*) but also humans
tends to bite indoors	tends to bite outdoors
feeds multiple times per cycle of egg production	feeds once per cycle of egg production
adapts well to human urban settlements	inhabits rural and urban areas

Ae. aegypti = yellow fever mosquito

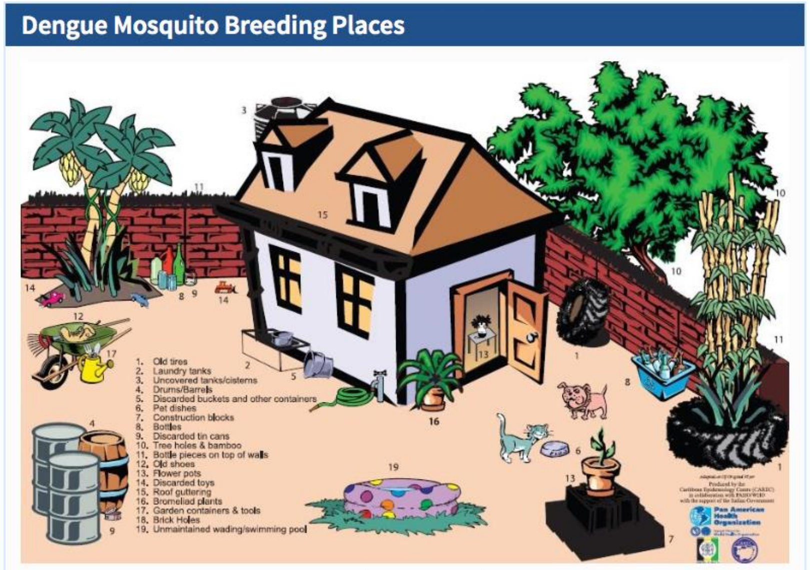
Ae. albopictus= Asian tiger mosquito

Important biological features of *Ae. albopictus* and *Ae. aegypti*

•**Container breeders and peridomestic habit (especially *Ae. aegypti*)**

•**Daytime biters and readily feed on humans**

•**Don't travel far from breeding sites**



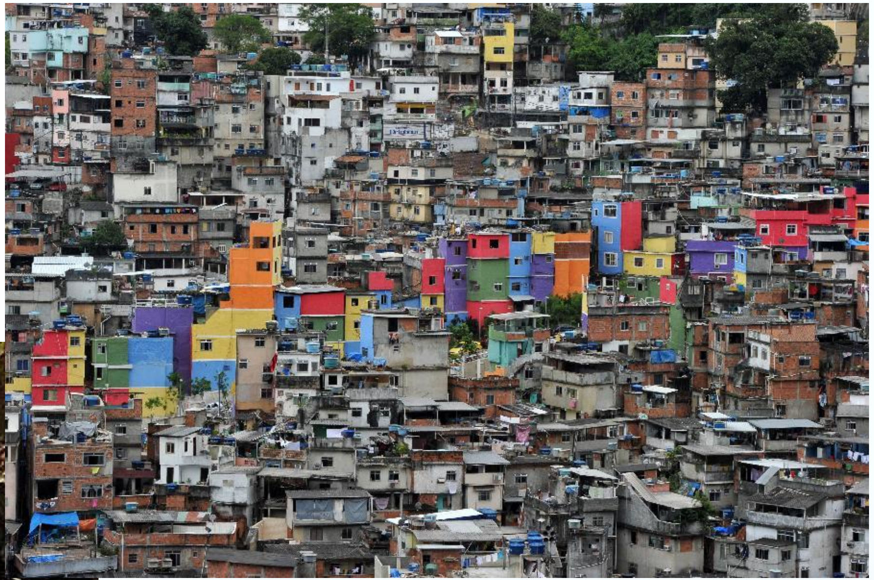
•***Ae. aegypti*** **tends to be a better vector of human disease because it feeds almost exclusively on people.** ***Ae. albopictus*** **is less selective**

•**Interestingly, when the 2 species co-occur,** ***Ae. albopictus*** **often displaces** ***Ae. aegpyti***

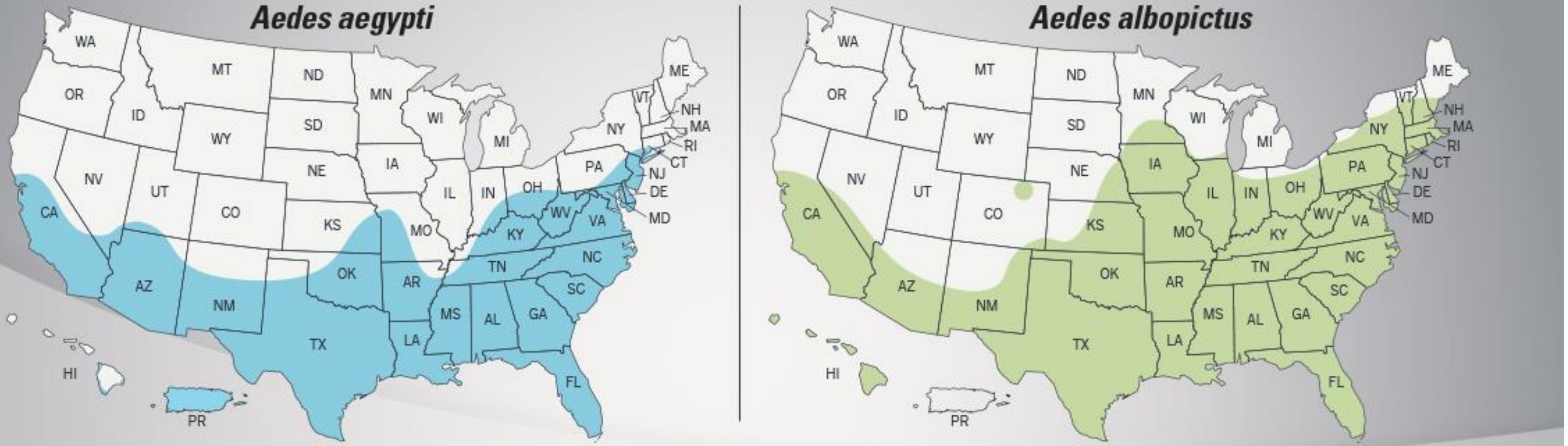
•**Neither species does well in harsh winter conditions or higher elevations, but** ***Ae. albopictus*** **is much more cold tolerant**

Examples of container habitats


L.E. Munstermann photo ©
KEEP OUT
NO Dumping



Estimated range of *Aedes aegypti* and *Aedes albopictus* in the United States, 2016*

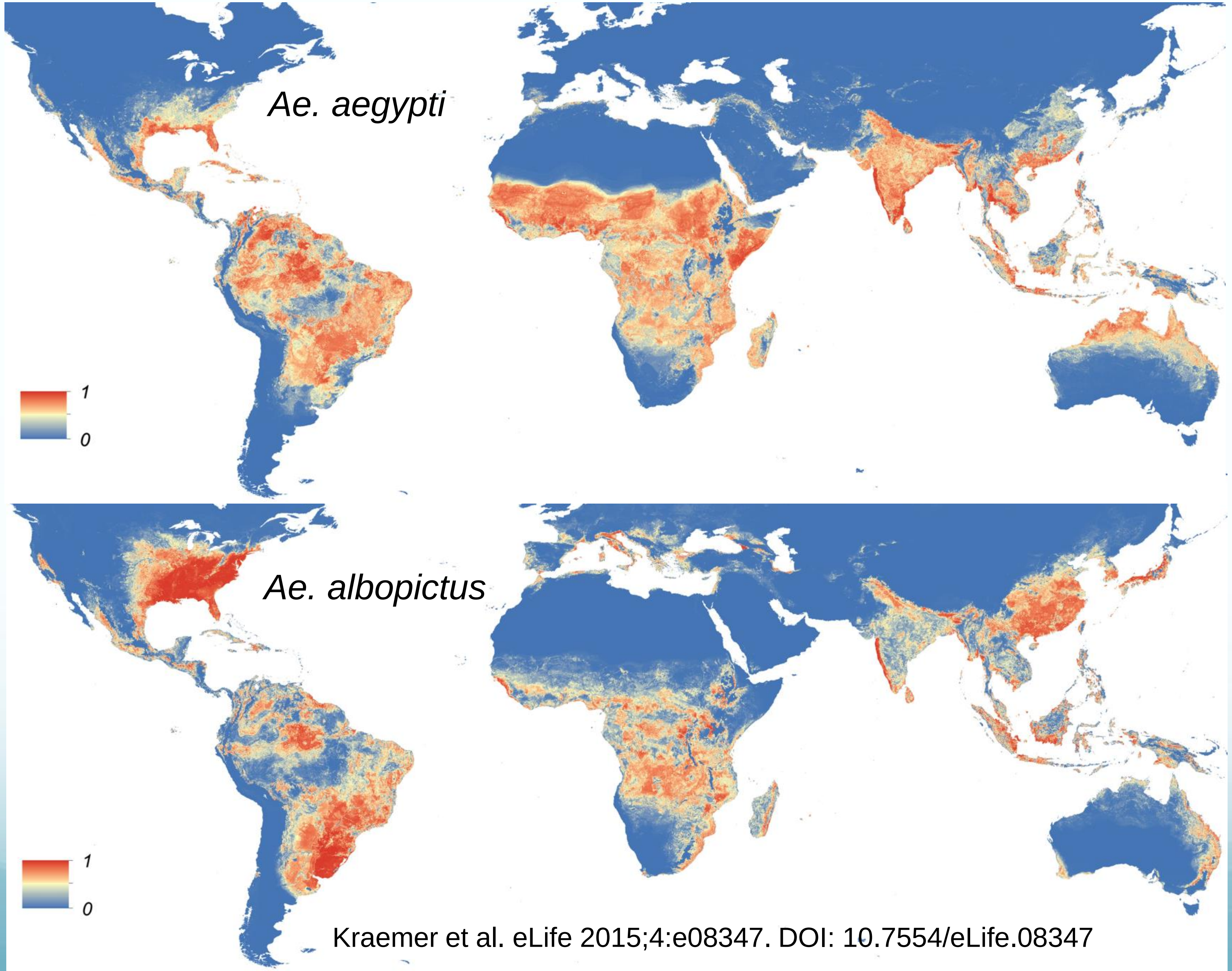


Aedes aegypti mosquitoes are more likely to spread viruses like Zika, dengue, chikungunya than other types of mosquitoes such as _Aedes albopictus_ mosquitoes.

- These maps show CDC's best estimate of the potential range of *Aedes aegypti* and *Aedes albopictus* in the United States.
- These maps include areas where mosquitoes are or have been previously found.
- Shaded areas on the maps do not necessarily mean that there are infected mosquitoes in that area.

**Maps have been updated from a variety of sources. These maps represent CDC's best estimate of the potential range of Aedes aegypti and Aedes albopictus in the United States. Maps are not meant to represent risk for spread of disease.*

SOURCE: Zika: Vector Surveillance and Control. www.cdc.gov/zika/vector/index.html



Kraemer et al. eLife 2015;4:e08347. DOI: 10.7554/eLife.08347

What about other vectors?

Many other species of *Aedes* in US and Michigan

Couldn’t one or more of them transmit the Zika?

Few have been tested, but…

Species (native range)	Transmit virus in lab?
Aedes triseriatus (N. America)	No
Aedes taeniorhynchus (N. America)	No
Aedes notoscriptus (Australia)	No
Aedes vigilax (Australia)	No
Aedes polynesiensis (French Polynesia)	No
Culex annulirostris (Australia)	No
Culex sitiens (Australia)	No
Culex pipiens/quinquefasciatus (global)	No (some exceptions)

No good evidence that mosquitoes other than *Aedes aegypti* or *Aedes albopictus* are involved in human to human transmission.

Competent vector ≠ Important vector
(vector competence vs vectorial capacity – ability to transmit the pathogen doesn't predict importance in actual disease transmission)

Laboratory transmission of West Nile virus by N. American mosquito species

ETR = Estimated Transmission Rate. Numbers are proportion (0 – 1) of new hosts infected by mosquitoes that had previously fed on an infectious host.

Species	N	DR	DTR	ETR
Ae. sollicitans	50	0.16	0.67	0.11
Cx pipiens	95	0.23	0.88	0.20
Ae. taen.	75	0.03	0.93	0.03
Ae. albopictus	61	0.85	0.86	0.73
Ae. japonicus	36	0.64	1.0	0.64
Ae. vexans	13	0.08	1.0	0.08
Ae. atropalpus	12	0.92	1.0	0.92

Ae. aegypti is a good Zika vector because:

It has some level of competency (not necessarily high) for virus transmission (virus replicates in the mosquito and makes it to salivary glands)

It lives almost exclusively near humans

It feeds almost exclusively on humans (High probability that first and subsequent blood meals come from humans). It's also known as a "sipper" – takes many small blood meals or multiple full blood meals between egg laying.

Why mosquito-transmitted Zika in Michigan is extremely unlikely

- **We don’t have the known vectors**

- **Our existing vectors aren’t primarily linked to humans as hosts**

- **Our mosquito breeding season is truncated compared to southern areas and there is no potential sylvatic cycle**

- **Similar viral diseases have not been locally transmitted outside of subtropical regions in the US (Ok, one exception).**

What if *Aedes albopictus* becomes established in Michigan (or some other mosquito-borne disease emerges)?

The forearm of a public health technician, covered with sterile female Aedes aegypti mosquitoes in Guatemala City, on January 26, 2016.

1. Source reduction

Remove standing water and potential breeding sites

2. Larvicides

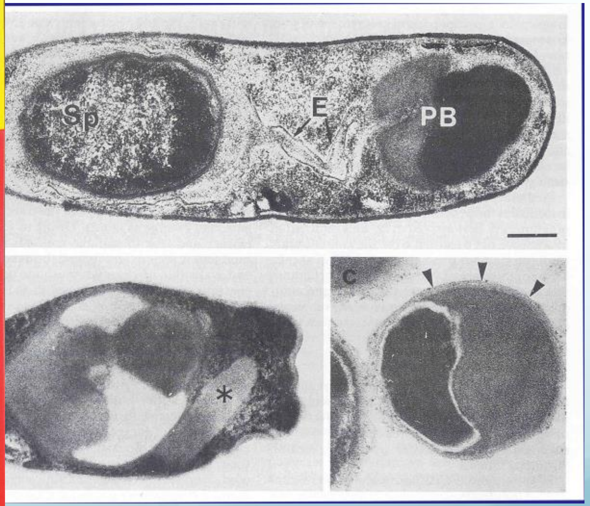
Bacterial larvicides are safe (approved for use in livestock watering containers), can be very effective and are specific for mosquitoes and some other Diptera (fly) larvae. Were applied via aerial spraying in Florida during Zika outbreak. Other larval controls include growth regulators (stop development) that are very safe and effective.

Bacillus thuringiensis var. israelensis

(Vectobac, Teknar)

B. sphaericus

(Vectolex)



3. Adulticides

Sometimes the only option. ULV (ultra low volume) is best, but ephemeral. All are broad-spectrum insecticides that will be harmful to other insects, but generally safe for vertebrates (fish and amphibians slightly more susceptible)

Department of Health drives fumigating a neighborhood to prevent the spread of Zika virus in San Juan, Puerto Rico, on January 27, 2016.

Many innovative new methods in use, in field trials, or in development that target *Ae. aegypti* and *Ae. albopictus*

e.g., **Autocidal Gravid Ovitraps (AGOs)** – attract female mosquitoes looking for places to lay eggs. Current version uses no insecticides, just sticky trap paper. Shown to reduce the number of infected Aedes aegypti AND number of human dengue/chikungunya cases in Puerto Rico

Course screen

Resting chamber

Sticky trap paper

Fine screen

Hay infusion/water (attractant)

Next Generation of Mosquito Control: Several new population or disease transmission reduction methods are currently being field and/or lab tested. These involve the release of modified (genetically or with symbiotic bacteria) mosquitoes.