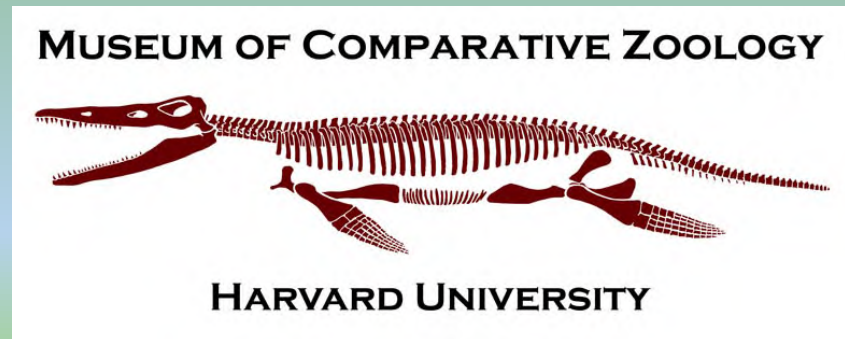
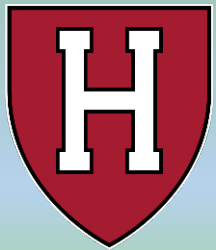


# Invasive Freshwater Mosquitoes as Emerging Disease Vectors Along a Caribbean Basin—Appalachian Plateau Transect

David Bruce Conn<sup>1,2</sup> and Denise Andriot Conn<sup>2</sup>

<sup>1</sup>Harvard University Museum of Comparative Zoology, USA

<sup>2</sup>Berry College One Health Center, USA



# Mosquitoes are fundamentally aquatic species.

- Adults feed in terrestrial environments, but all egg-laying, embryonic development, larval feeding, growth, pupation, and metamorphosis, occur in aquatic environments.
- Some inhabit brackish waters, but the vast majority inhabit diverse freshwater habitats.



*Aedes aegypti*



*Aedes salinarius*



*Culex coronator*



*Anopheles punctipennis*

# Many Diseases Are Transmitted by Exotic Invasive Mosquito Vectors

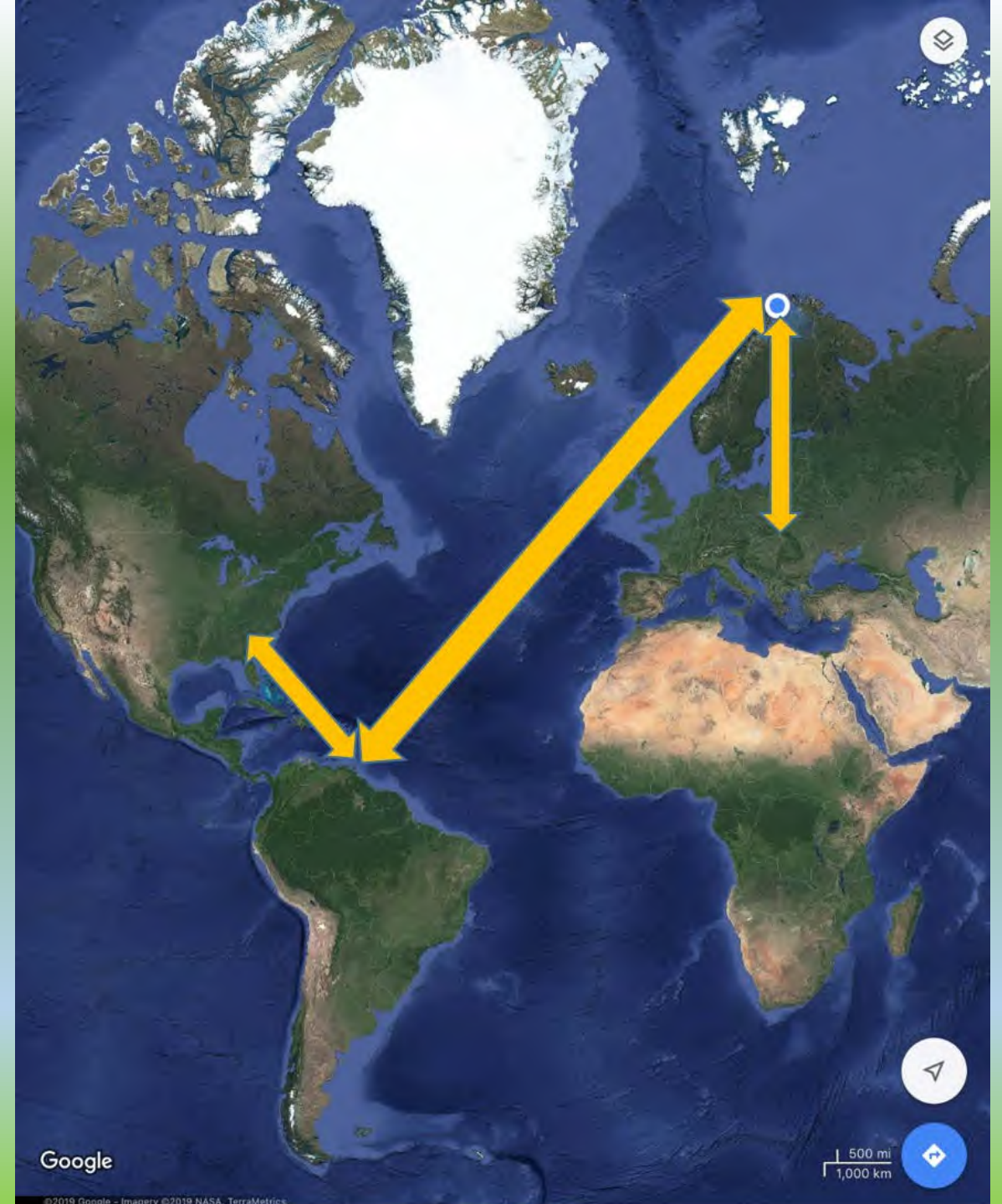
- Yellow Fever
- Zika virus
- Dengue Virus
- Chikungunya Virus
- LaCrosse Virus
- West Nile Virus
- Dirofilariosis (heartworm)
- Lymphatic Filariosis (Elephantiasis)
  - .....and more.....



# From the Arctic to the Equator

Spanning the Northern  
Hemisphere

The Caribbean –  
Appalachian Transect is  
part of this larger global  
initiative.



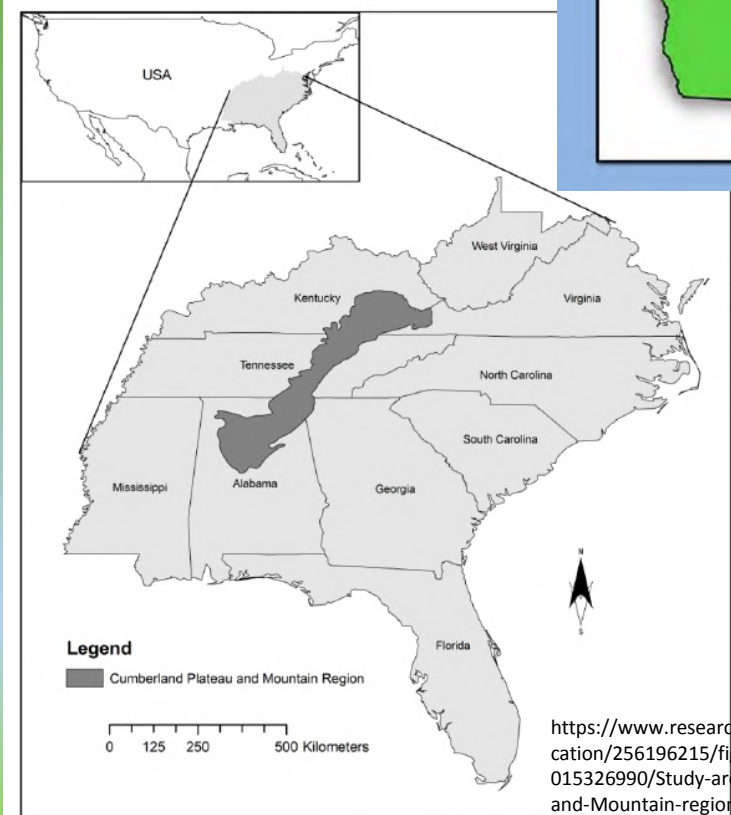
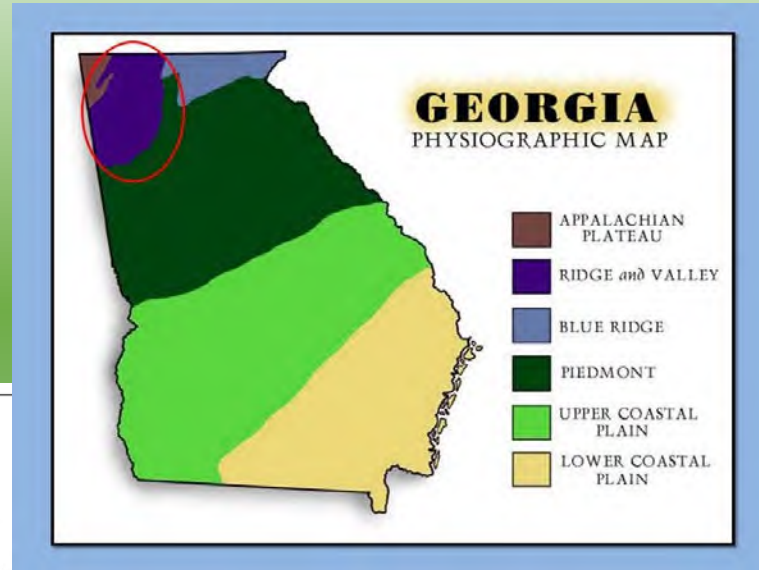
# The Caribbean-Appalachian Transect and Corridor

- In 2013-2014, mosquito-borne Chikungunya virus, crossed the Atlantic Ocean from Africa and moved into the Americas through the Caribbean Corridor and then on to both South America and North America.
- In 2013-2015, mosquito-borne Zika virus, originally from Africa, crossed the Pacific Ocean from Asia into the Americas through South America and then through the Caribbean Corridor to North America.





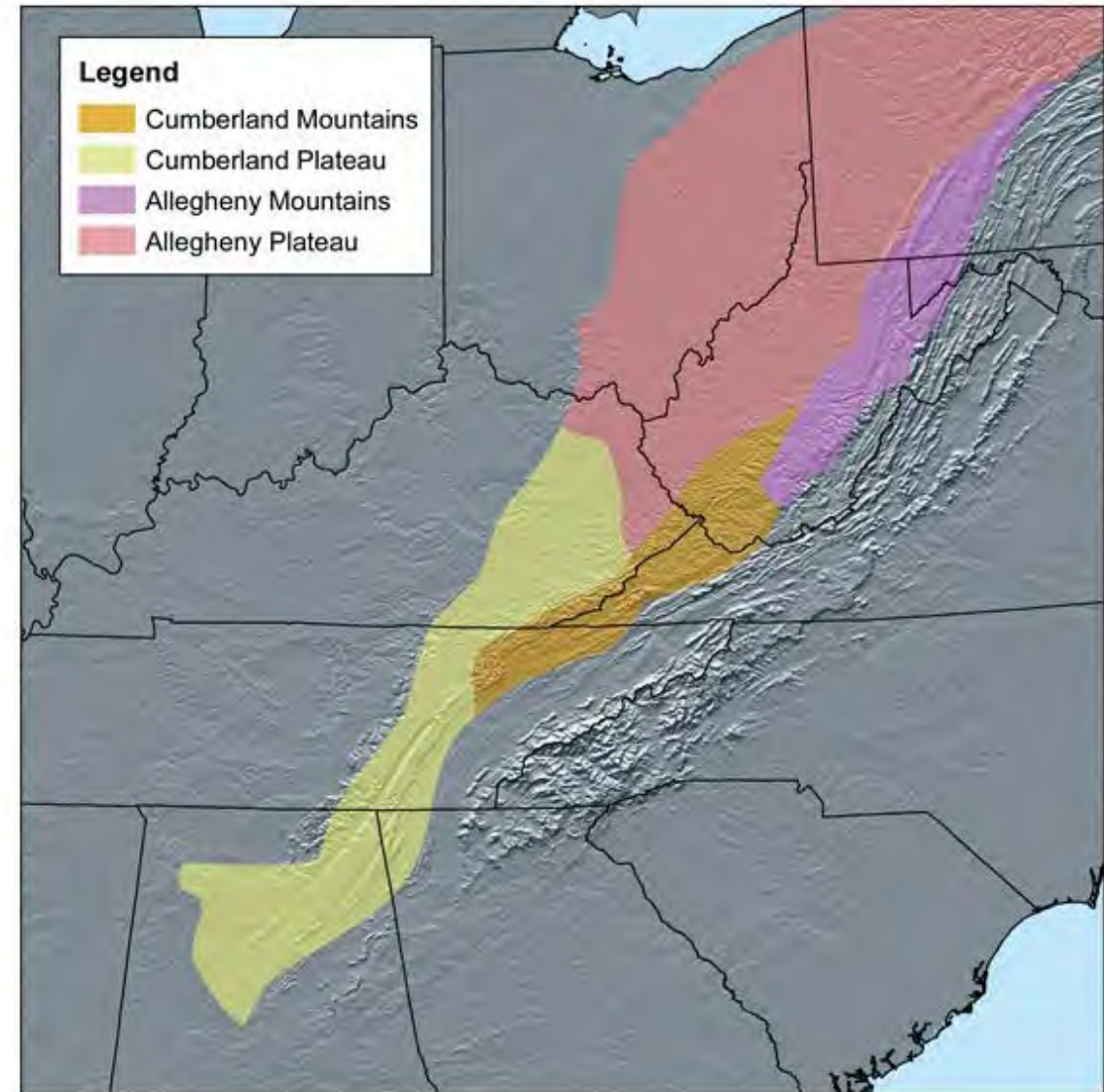
# Across Coastal Plain & Piedmont to High Plateau



<https://quizizz.com/admin/quiz/584aa533eb9a80964ba3cb1a/five-regions-of-georgia>

**The Cumberland Plateau has long been known as the first abrupt rise in elevation from the southern coastal areas, thus affecting animal migration into the interior.**

[https://www.researchgate.net/profile/Dawn\\_Lemke/publication/256196215/figure/fig1/AS:297812018384903@1448015326990/Study-area-location-map-Cumberland-Plateau-and-Mountain-region-in-the-southeastern\\_W640.jpg](https://www.researchgate.net/profile/Dawn_Lemke/publication/256196215/figure/fig1/AS:297812018384903@1448015326990/Study-area-location-map-Cumberland-Plateau-and-Mountain-region-in-the-southeastern_W640.jpg)



[https://en.wikipedia.org/wiki/Cumberland\\_Plateau](https://en.wikipedia.org/wiki/Cumberland_Plateau)

# Caribbean Basin – Appalachian Plateau Transect

- Southern Middle Tennessee (altitude 640 m)
- Northeast Alabama (altitude 300-500 m)
- Northwest Georgia (altitude 180-500 m)
- Southwest Florida (Everglades and Naples) \*
- Haiti \*
- Puerto Rico \*
- St. Thomas, U.S. Virgin Islands \*
- St. Maarten \*
- St. Kitts \*
- Aruba \*
- Bonaire \*
- Curaçao \*
- All Florida and Caribbean sites near sea level  
(altitude 0-20 m)

All Caribbean sites are urban.





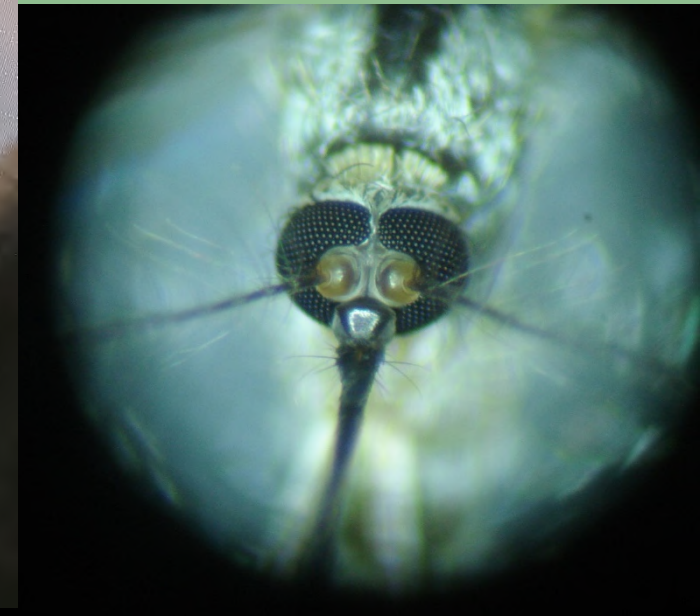
# Caribbean Basin – Appalachian Plateau Transect

- Tennessee, USA – long-term comprehensive; multiple years
  - Alabama, USA – preliminary larva sampling, dip; one year
  - Georgia, USA – long-term comprehensive; multiple years
  - Florida, USA – short-term, dip and HLC; multiple years
    - Everglades (rural/sylvan); Naples (urban)
  - Central Caribbean – 1-day field sampling, dip and HLC; multiple years
    - Puerto Rico; Haiti; St. Maarten; St. Kitts; St. Thomas USVI
  - Southern Caribbean – 1-day field sampling, dip and HLC; multiple years
    - Aruba; Curaçao; Bonaire
- Dip includes siphoning with valved basting bulb
  - HLC = Human Landing Catch



# Mobile Mosquiter Equipment

- LED magnifying lens
- 10-30x LED hand microscope
- 30-90x LED hand microscope
- Glass screwtop vials
- Nalgene water tube
- Valved basting bulb
- Zip-seal baggies
- Watchmaker forceps







Highly invasive exotic *Aedes albopictus*

The Human Landing Catch (HLC) technique.



# Zero mosquitoes observed at these Caribbean Locations

- Labadee, Haiti
- Charlotte Amalie, St. Thomas, USVI
- Philipsburg, St. Maarten (Dutch)
- Marigot, St. Maarten (French)
- Kralendijk, Bonaire
- Oranjestad, Aruba
- Willemstad, Curaçao





# Basseterre, St. Kitts

August 2018

Dense populations of exotic invasive *Aedes aegypti* in urban areas with dense human populations.



Flower Pots



Storm Sewer Grates



*Aedes aegypti*  
Larvae and adults



# San Juan, Puerto Rico

August 2018, March 2019, August 2019



**Invasive**  
***Aedes aegypti***  
Larvae & adults

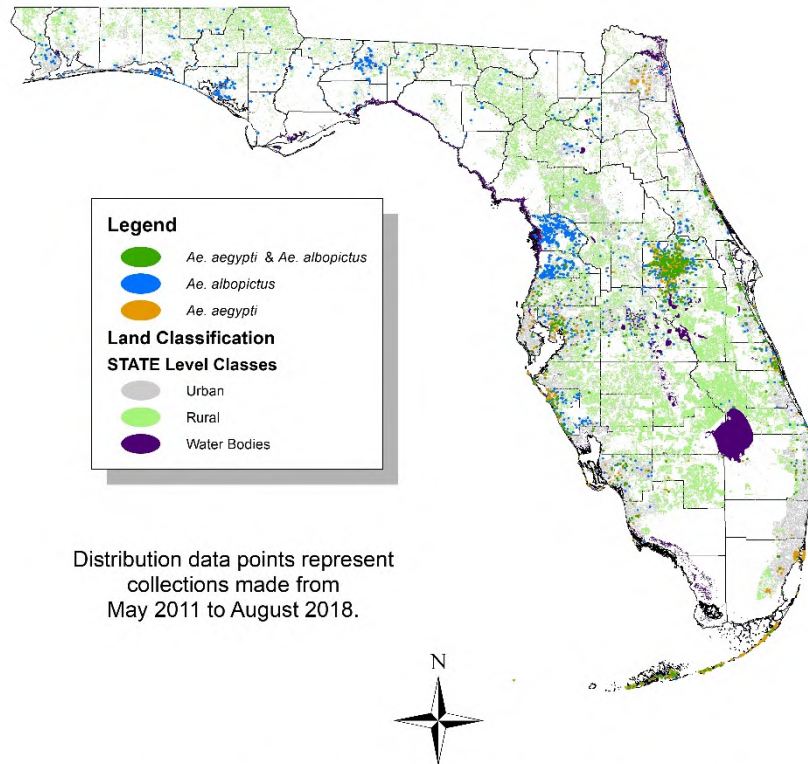
Dense populations of exotic invasive  
***Aedes aegypti*** in urban areas with  
dense human populations.

**Water Meter Wells**



# Florida: Subtropical Paradise in the “1<sup>st</sup> World”

Collections of *Aedes aegypti* and  
*Aedes albopictus* in Florida

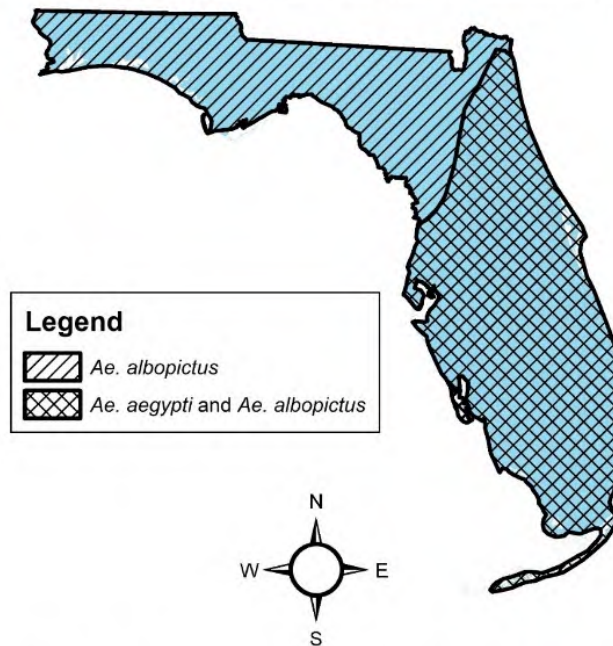


Credit: C. Parker, Florida Medical Entomology Laboratory, University of Florida, IFAS  
C.R. Connolly, Centers for Disease Control and Prevention, Fort Collins, CO  
FDOH Contract CODNW  
Updated August 2018

## Florida's Mosquito Control Districts 56 Districts and 61 Programs

Estimated Distribution of  
*Ae. aegypti* and *Ae. albopictus*  
in Florida\*

\*Distribution is based on presence data for *Ae. aegypti* and *Ae. albopictus* from 2011 - 2018



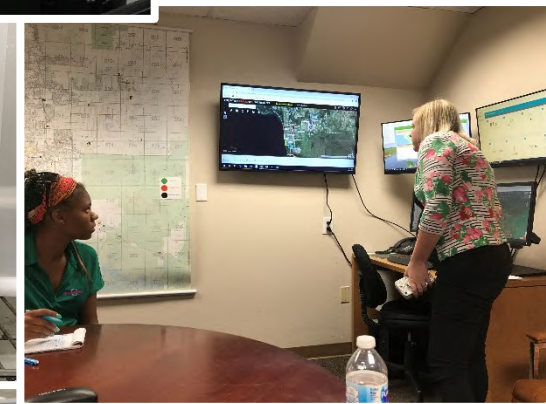
Credit: C. Parker, Florida Medical Entomology Laboratory, University of Florida, IFAS  
C.R. Connolly, Centers for Disease Control and Prevention, Fort Collins, CO  
FDOH Contract CODNW  
Updated August 2018





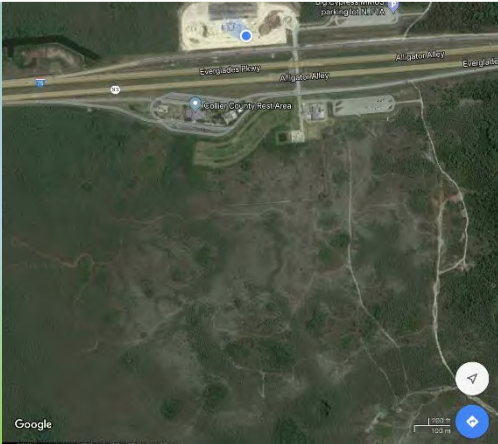
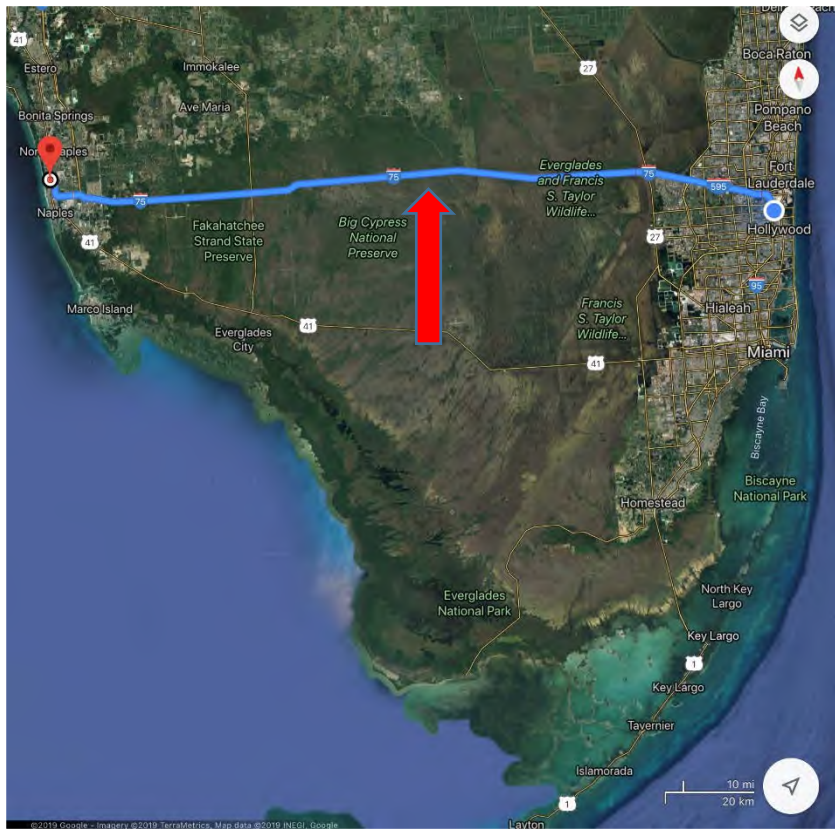
# Collier Mosquito Control District

- Airplanes
- Helicopters
- Drones
- Laboratories
- Rearing
- Fish predators
- Situation Room
- Control Center





# Florida: Collier County: The Everglades (sylvan) May-June 2019



*Psorophora ciliata*



*Psorophora columbiae*

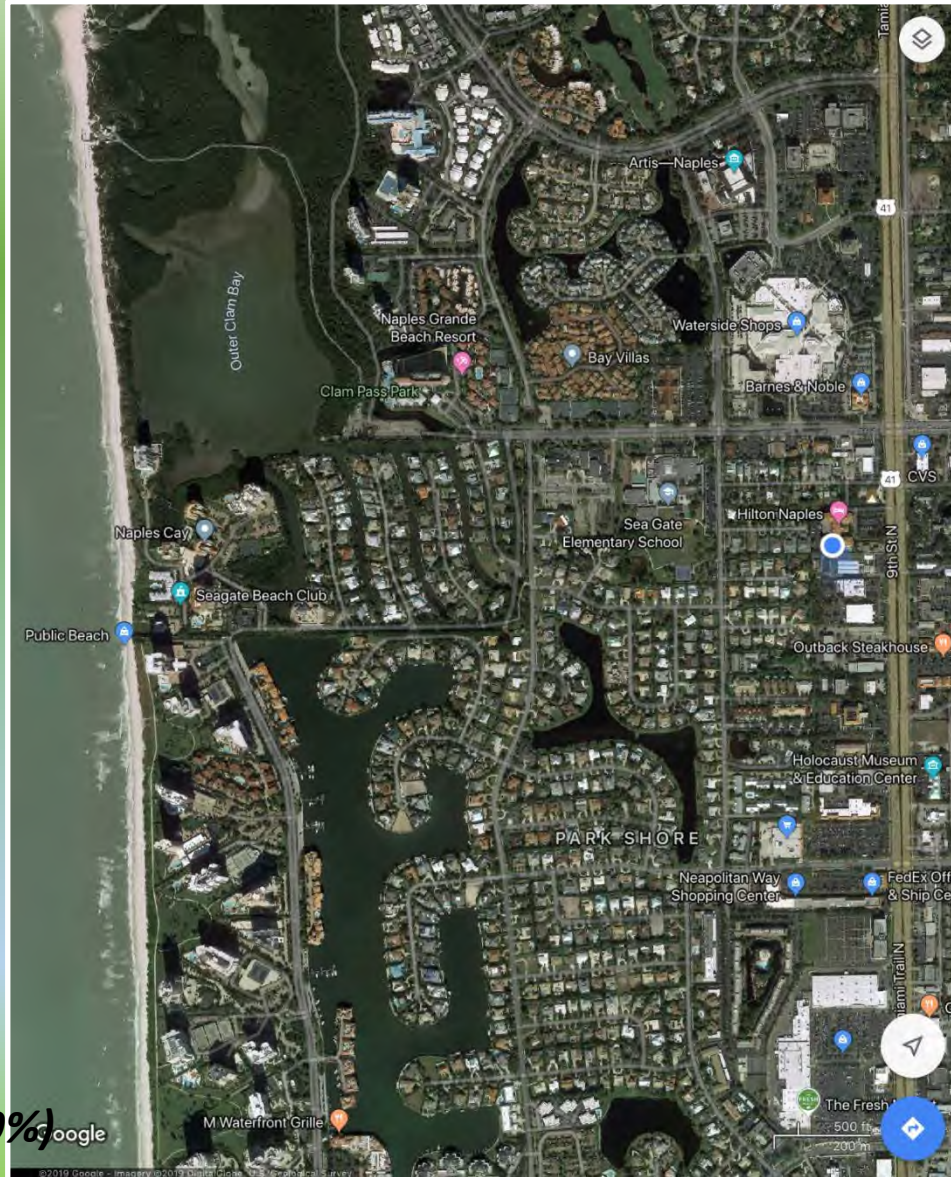
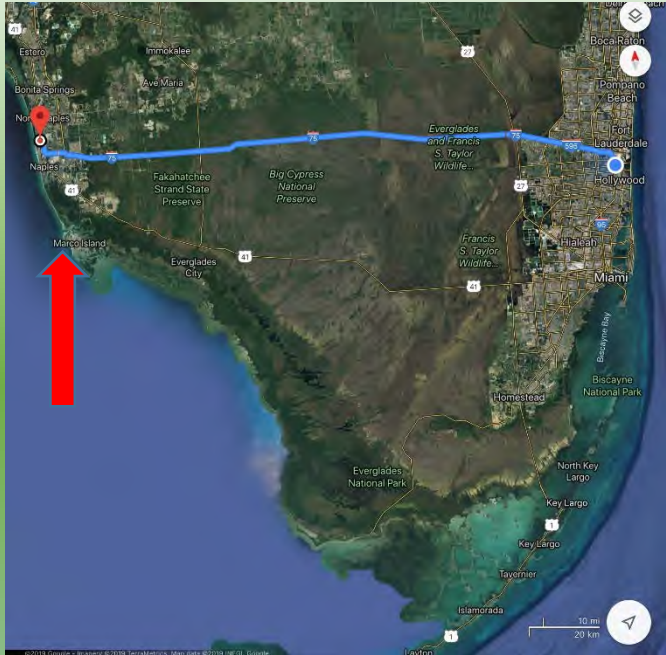


**No invasives**





# Florida: Collier County: Naples (urban) May-June 2019 — dominated by exotic invasives



## Exotic invasive

*Aedes aegypti*  
adults

*Aedes aegypti* (80%)

*Aedes albopictus* (1%)

*Aedes taeniorhynchus* – native (19%)

*Aedes aegypti* habitat  
Flower pots  
Air condition drips  
Storm sewers

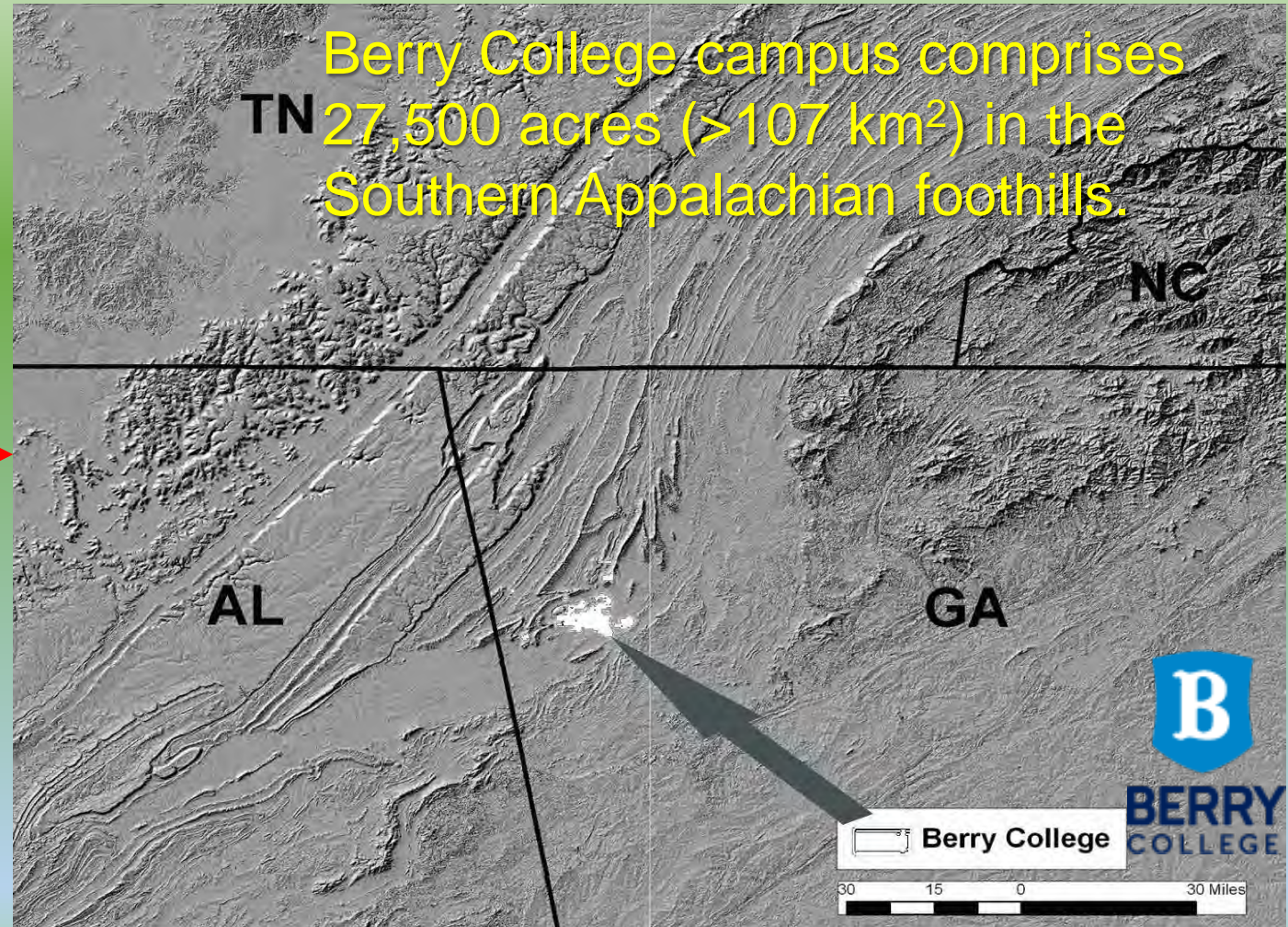


# Berry College One Health Center



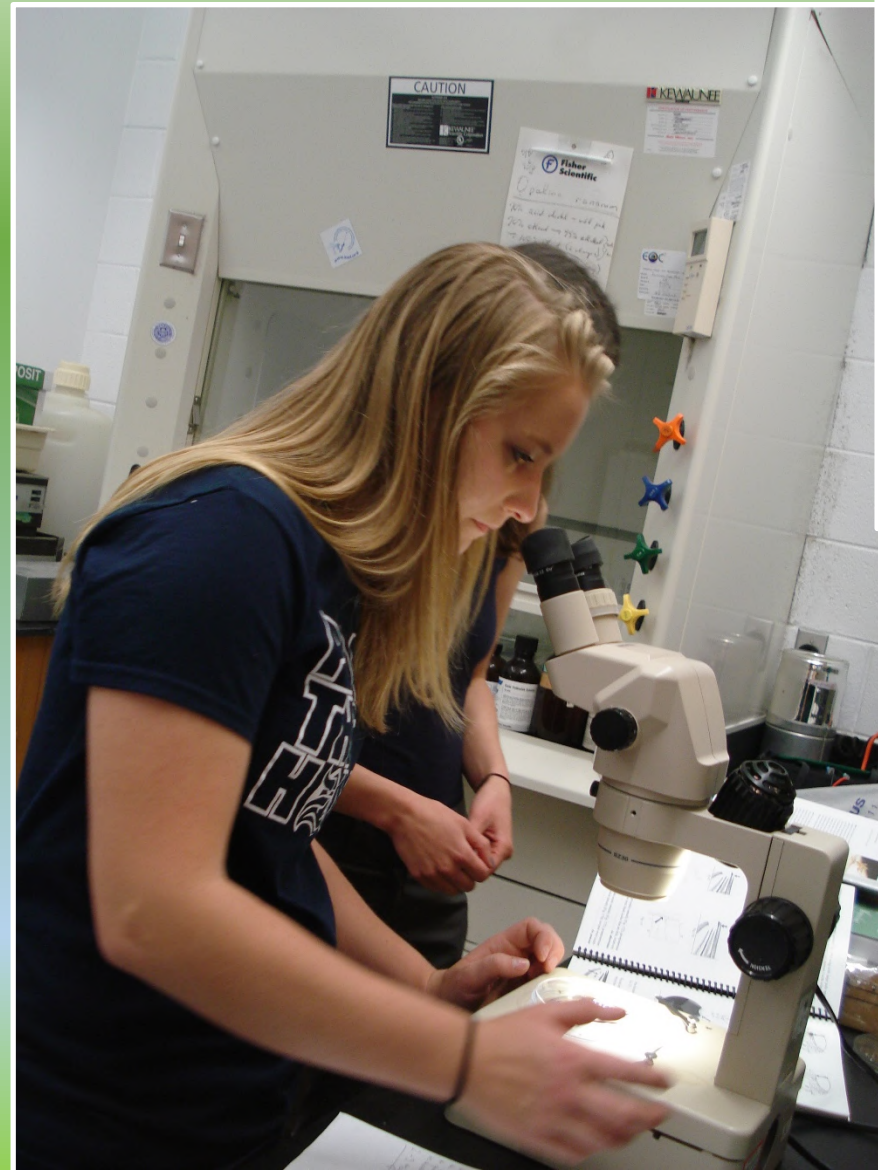
<http://cdoovision.com/map-of-us-geographic-regions/map-of-us-geographic-regions-united-states-geography/>

Largest university campus in the USA; actively managed as a field site for research and education in the natural sciences.





# Trapping and lab work for Georgia program.





## Exotic Invasive

Mosquitoes Collected in  
2017 at Berry College,  
Georgia.

308 specimens  
belonging to 23 species.

<i>Aedes albopictus</i>	251	4
<i>Aedes canadensis</i>	1	1
<i>Aedes cinereus</i>	1	1
<i>Aedes sticticus</i>	6	3
<i>Aedes triseriatus</i>	1	1
<i>Aedes vexans</i>	43	5
<i>Anopheles crucians</i>	1	1
<i>Anopheles punctipennis</i>	8	3
<i>Anopheles quadrimaculatus</i>	6	4
<i>Culex coronator</i>	4	4
<i>Culex erraticus</i>	21	7
<i>Culex nigripalpus</i>	7	2
<i>Culex peccator</i>	1	1
<i>Culex pipiens (group)</i>	5	3
<i>Culex quinquefasciatus</i>	1	1
<i>Culex salinarius</i>	4	2
<i>Culex tarsalis</i>	1	1
<i>Culex territans</i>	1	1
<i>Psorophora ciliata</i>	1	1
<i>Psorophora columbiae</i>	1	1
<i>Psorophora ferox</i>	2	1
<i>Psorophora howardii</i>	1	1
<i>Uranotaenia sapphirina</i>	12	3

Left: Number of  
each mosquito  
species collected  
in all traps.

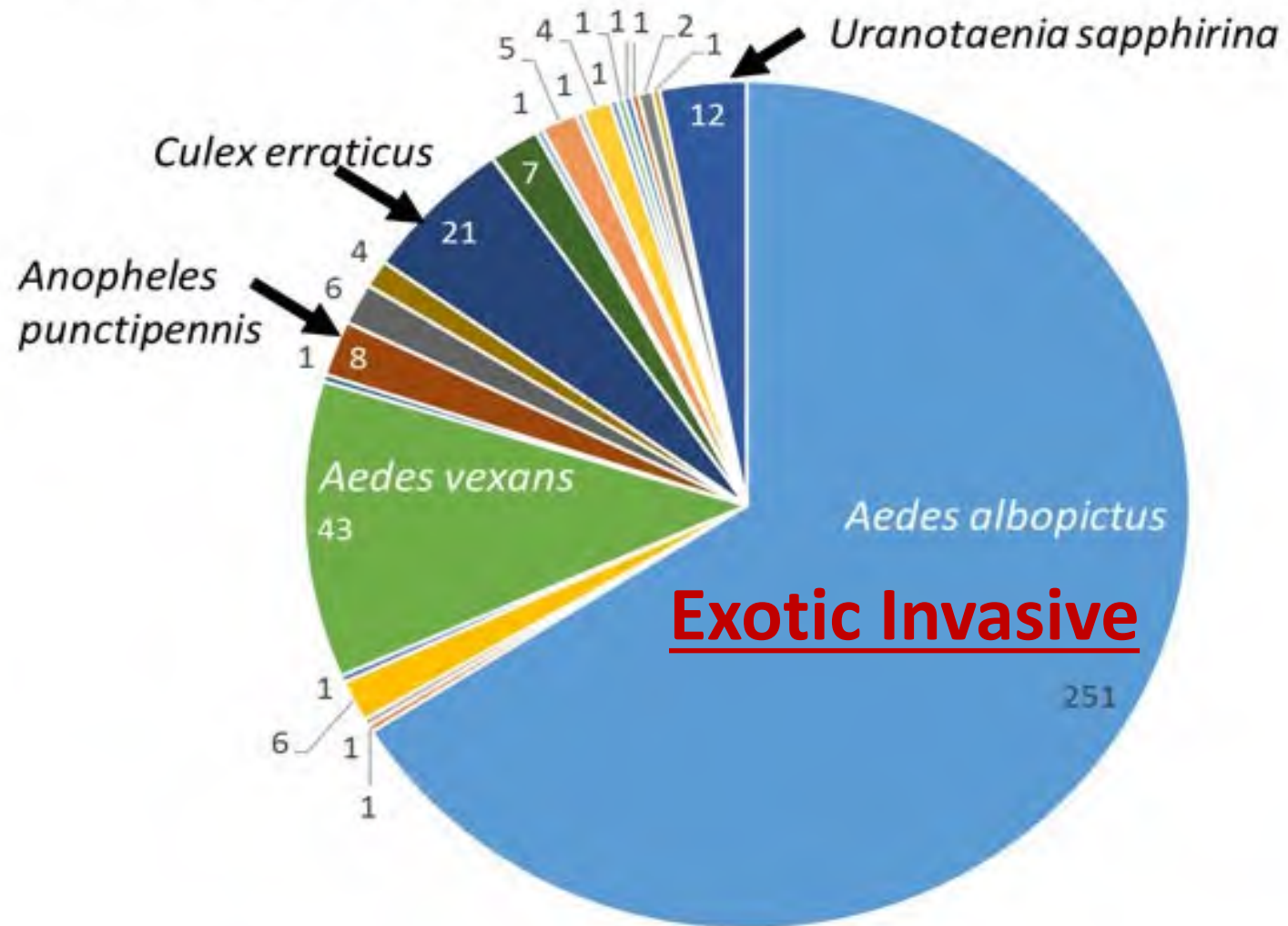
Right: Number of  
sites from which  
mosquitoes were  
collected (n=9).

Three most  
widespread  
species.



# 2017 data on mosquitoes at Berry College

### Relative Numbers of Mosquitoes Collected at All Berry College Sites (5 most common named)





## Exotic Invasives

## Mosquito Data for Berry College Through September 2019

More than 1000  
specimens belonging to  
total of 35 species.

Mosquito Species Collected at Berry College, 2017-2019	
<i>Aedes albopictus</i>	<i>Culex coronator</i>
<i>Aedes atlanticus</i>	<i>Culex erraticus</i>
<i>Aedes canadensis</i>	<i>Culex nigripalpus</i>
<i>Aedes cinereus</i>	<i>Culex peccator</i>
<i>Aedes dupreei</i>	<i>Culex pipiens (group)</i>
<i>Aedes grossbecki</i>	<i>Culex quinquefasciatus</i>
<i>Aedes hendersoni</i>	<i>Culex salinarius</i>
<i>Aedes japonicus</i>	<i>Culex tarsalis</i>
<i>Aedes sticticus</i>	<i>Culex territans</i>
<i>Aedes tormentor</i>	<i>Culiseta melanura</i>
<i>Aedes triseriatus</i>	<i>Orthopodomyia alba</i>
<i>Aedes trivittatus</i>	<i>Psorophora ciliata</i>
<i>Aedes vexans</i>	<i>Psorophora columbiae</i>
<i>Anopheles crucians</i>	<i>Psorophora cyanescens</i>
<i>Anopheles punctipennis</i>	<i>Psorophora ferox</i>
<i>Anopheles quadrimaculatus</i>	<i>Psorophora howardii</i>
<i>Coquillettidia perturbans</i>	<i>Psorophora mathesoni</i>
	<i>Uranotaenia sapphirina</i>



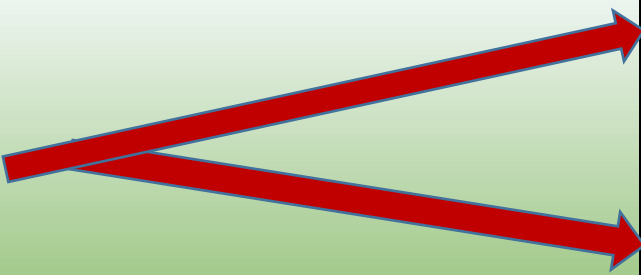
# Trapping and lab work for Tennessee program





## Exotic Invasives

Mosquito species (25 total)  
collected atop Cumberland  
Plateau at study site in  
Monteagle, Tennessee.  
2017-2018



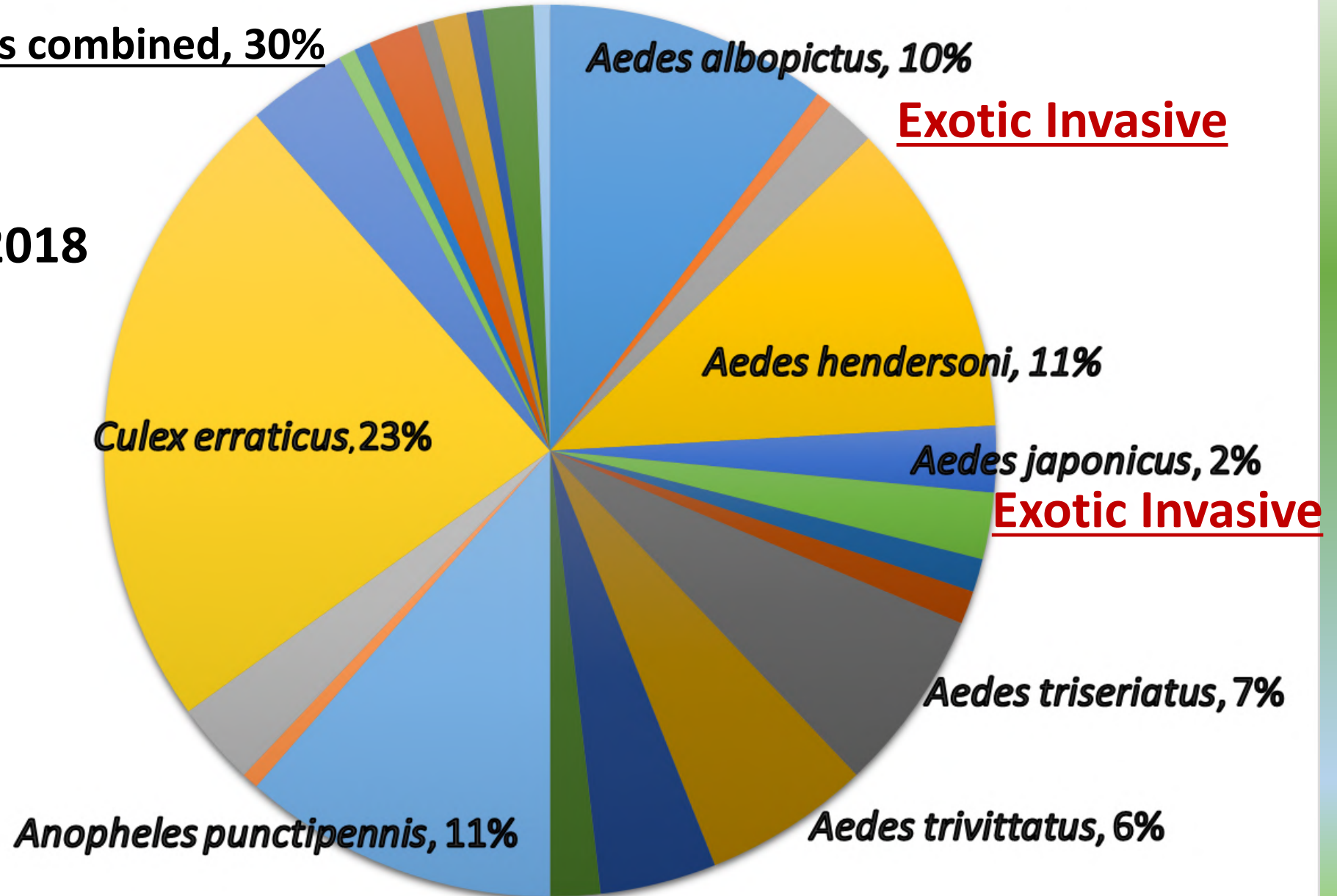
Species	No. Collected	No. Sites
<i>Aedes albopictus</i>	17	1
<i>Aedes atlanticus</i>	1	1
<i>Aedes c. canadensis</i>	3	1
<i>Aedes hendersoni</i>	19	2
<i>Aedes japonicus</i>	4	3
<i>Aedes sticticus</i>	4	1
<i>Aedes thibaulti</i>	2	1
<i>Aedes tormentor</i>	2	2
<i>Aedes triseriatus</i>	11	1
<i>Aedes trivittatus</i>	10	4
<i>Aedes vexans</i>	7	3
<i>Anopheles crucians</i> complex	3	1
<i>Anopheles punctipennis</i>	19	2
<i>Anopheles quadrimaculatus</i> s.l.	1	1
<i>Coquillettidia perturbans</i>	5	3
<i>Culex erraticus</i>	39	2
<i>Culex nigripalpus</i>	6	2
<i>Culex peccator</i>	1	1
<i>Culex pipiens/quinqnesfasciatus</i>	1	1
<i>Culex restuans</i>	3	1
<i>Culex territans</i>	1	1
<i>Psorophora ferox</i>	2	2
<i>Psorophora horrida</i>	1	1
<i>Toxorhynchites rutilus</i>	3	1
<i>Uranotaenia sapphirina</i>	1	1
<b>TOTAL</b>	<b>166</b>	<b>8</b>



Noteworthy Mosquito Species on Cumberland Plateau, Monteagle, Tennessee

All others combined, 30%

2017-2018





## Exotic Invasives

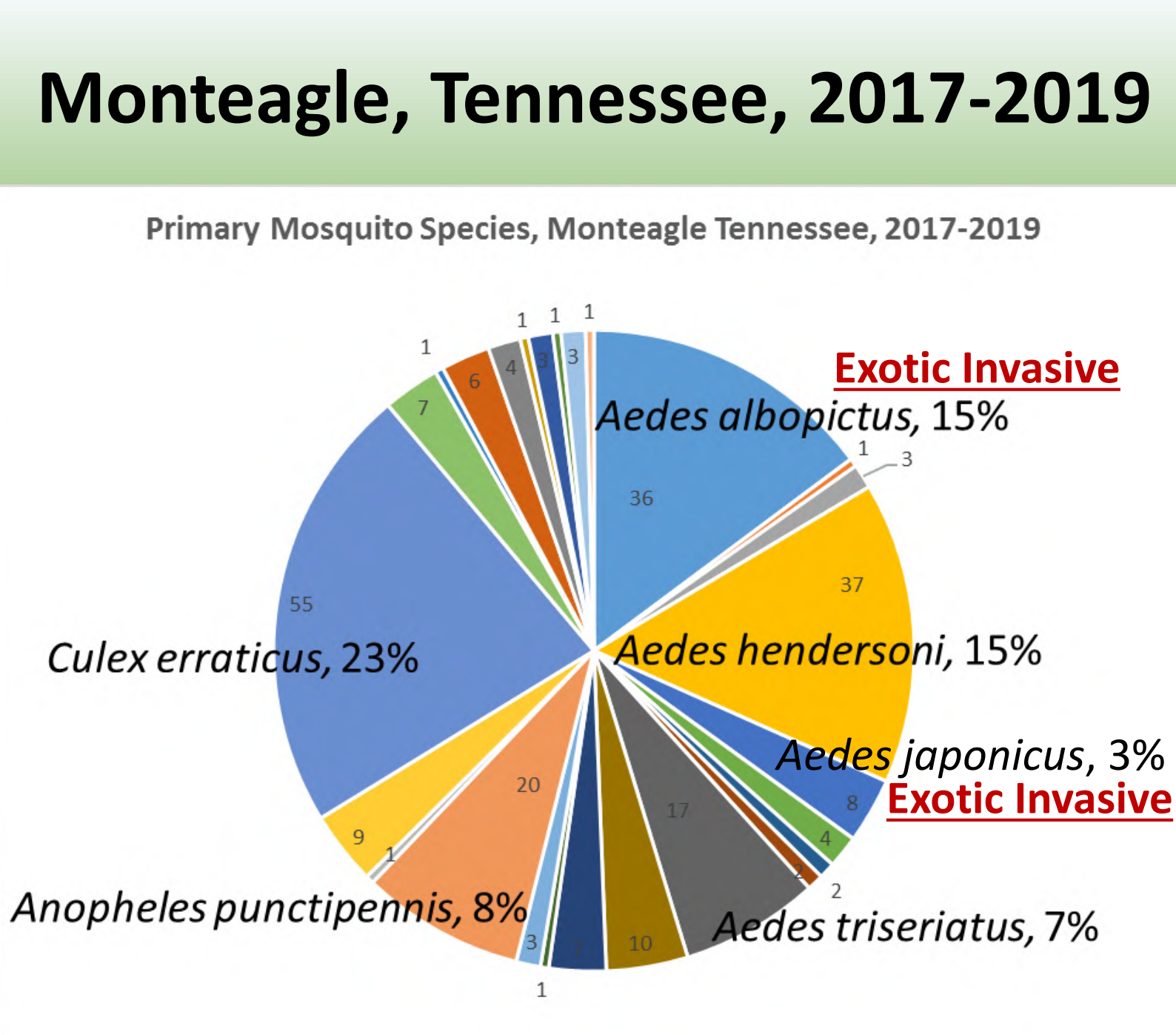


Mosquito species (26 total)  
collected atop Cumberland  
Plateau at study site in  
Monteagle, Tennessee.  
2017-2019

Mosquito Species	No. Collected	No. Sites
<i>Aedes albopictus</i>	36	2
<i>Aedes atlanticus</i>	1	1
<i>Aedes c. canadensis</i>	3	1
<i>Aedes hendersoni</i>	37	2
<i>Aedes japonicus</i>	8	3
<i>Aedes sticticus</i>	4	1
<i>Aedes thibaulti</i>	2	1
<i>Aedes tormentor</i>	2	2
<i>Aedes triseriatus</i>	17	1
<i>Aedes trivittatus</i>	10	4
<i>Aedes vexans</i>	7	3
<i>Anopheles barberi</i>	1	1
<i>Anopheles crucians</i> complex	3	1
<i>Anopheles punctipennis</i>	20	2
<i>Anopheles quadrimaculatus</i> s.l.	1	1
<i>Coquillettidia perturbans</i>	9	3
<i>Culex erraticus</i>	55	2
<i>Culex nigripalpus</i>	7	2
<i>Culex peccator</i>	1	1
<i>Culex pipiens/quinquesfasciatus</i>	6	1
<i>Culex restuans</i>	4	1
<i>Culex territans</i>	1	1
<i>Psorophora ferox</i>	3	2
<i>Psorophora horrida</i>	1	1
<i>Toxorhynchites rutilus</i>	3	1
<i>Uranotaenia sapphirina</i>	1	1
TOTAL	243	9



Mosquito Species	No. Collected	No. Sites
<i>Aedes albopictus</i>	36	2
<i>Aedes atlanticus</i>	1	1
<i>Aedes c. canadensis</i>	3	1
<i>Aedes hendersoni</i>	37	2
<i>Aedes japonicus</i>	8	3
<i>Aedes sticticus</i>	4	1
<i>Aedes thibaulti</i>	2	1
<i>Aedes tormentor</i>	2	2
<i>Aedes triseriatus</i>	17	1
<i>Aedes trivittatus</i>	10	4
<i>Aedes vexans</i>	7	3
<i>Anopheles barberi</i>	1	1
<i>Anopheles crucians</i> complex	3	1
<i>Anopheles punctipennis</i>	20	2
<i>Anopheles quadrimaculatus s.l.</i>	1	1
<i>Coquilleltidia perturbans</i>	9	3
<i>Culex erraticus</i>	55	2
<i>Culex nigripalpus</i>	7	2
<i>Culex peccator</i>	1	1
<i>Culex pipiens/quinqnesfasciatus</i>	6	1
<i>Culex restuans</i>	4	1
<i>Culex territans</i>	1	1
<i>Psorophora ferox</i>	3	2
<i>Psorophora horrida</i>	1	1
<i>Toxorhynchites rutilus</i>	3	1
<i>Uranotaenia sappphirina</i>	1	1
TOTAL	243	9





# Conclusions

- The invasive mosquito, *Aedes aegypti*, colonizing from Africa several centuries ago, is still well established across the Caribbean and southern Florida, with potential to expand northward.
- The invasive mosquito, *Aedes albopictus*, colonizing from Asia over the last few decades, continues to expand explosively from Florida to the top of the Cumberland Plateau and beyond.
- The invasive mosquito, *Aedes japonicus*, colonizing from Asia only within the last few years, has gained a solid foothold and continues to expand northward from Georgia into the southern Appalachian highlands including the Cumberland Plateau and beyond.

**All three mosquito species are competent vectors of diverse disease pathogens, so all must be carefully monitored and controlled!**



# Thank you! Merci!

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Author email addresses: [dconn@lsdiv.harvard.edu](mailto:dconn@lsdiv.harvard.edu); [bconn@berry.edu](mailto:bconn@berry.edu)