Centralized Intern Training

DHHS Six Forks Campus

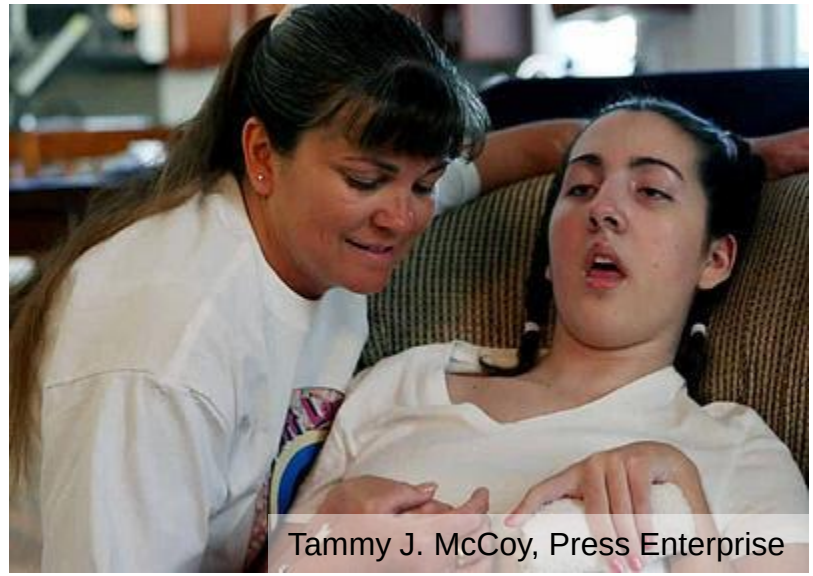
Michael S. Doyle, MS Entomology
State Public Health Entomologist

December 8, 2021

Why are we concerned about mosquitoes?

Biting activity…

- is annoying and can interfere with our daily activities.
- can potentially transmit pathogens that cause illness in people, pets and domestic animals.



Tammy J. McCoy, Press Enterprise

1955 Salt Marsh Mosquito Study Commission

1. **Now that our principal concern with malaria is the prevention of reintroduction** rather than the application of control measures in areas of high endemicity, we have time and facilities to **devote to pest mosquitoes**

2. **The duty of this Commission is to make a study of salt-marsh mosquito problems** in eastern North Carolina, investigate the capacity of each county, town and city to provide funds for control operations, and make a report of its findings, along with recommendations, to the Governor

3. With no legislative appropriation for the coming season, operations will again be dependent upon funds given us from the Contingency and Emergency Fund

4. It is hoped, however, that the 1957 General Assembly will appropriate a sizeable sum and enact legislation that will provide for the formation of mosquito control districts similar to those in other states

-- Mosquito News Vol. 16, No. 2, June 1956

North Carolina General Statutes: Mosquito and Vector Control

- 130A-352. **Creation and purpose of mosquito control districts.**

- For the purpose of protecting and **promoting the public health and welfare by providing for the control of mosquitoes** and other arthropods of public health significance, mosquito control districts may be created in accordance with the provisions of this Part. **A mosquito control district may be comprised of one or more contiguous counties or contiguous parts of one or more counties.**

- 130A-353. Nature of district; procedure for forming districts

- 130A-354. Governing bodies for mosquito control districts

- 130A-355. Corporate powers

- 130A-356. Adoption of plan of operation

Past versus Present

~1955 to 2011
Mosquito and Vector Control Program

Department of
Environment and Natural Resources (DENR)

⇩

Division of Environmental Health

⇩

Public Health Pest Management Section

⇩

Enabling statutes for State Vector Control program repealed by Session Laws 2011-145, s. 13.3(j)

2016 – Present
Vector-borne Disease Surveillance and Response

Department of
Health and Human Services (DHHS)

⇩

Division of Public Health

⇩

Epidemiology Section

⇩

Communicable Disease Branch

⇩

Medical Consultation Unit

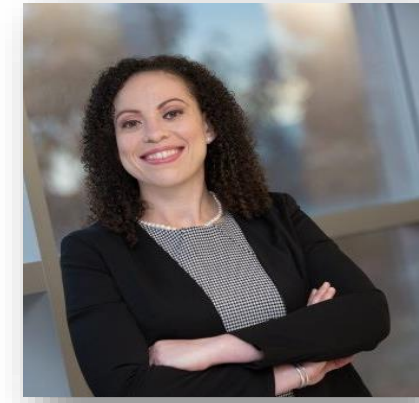
⇩

Vector-Borne Disease Program

NC DHHS Vector-borne Staff

Michael Doyle, MS
State PH Entomologist

Carl Williams, DVM
State Public Health Veterinarian



Alexis M. Barbarin, PhD
State PH Entomologist

Erica Berl, DVM
Public Health Veterinarian

Teresa Fisher, RN, BSN
Vector-borne Nurse Consultant

Roles of the DHHS Vector-borne Disease Program

1. Human Disease Surveillance

- Mosquito and tickborne disease **human case investigation and reporting**
- **Veterinary arboviral case reporting** in collaboration with NCDA&CS
- **Targeted tick surveillance** to identify areas of pathogen emergence or disease risk areas

2. Education/Subject Matter Expertise

- **Assist Local Health Departments** and public with Vector-borne disease concerns

3. Support development of Integrated Mosquito Management (IMM) at local level

- **AA 908 funding** and oversight
- **Mosquito population data** oversight (e.g., MosquitoNet)
- **Insecticide Resistance testing** in collaboration with local and university partners

NC Statewide Mosquito Abatement Contract (MAC)

- Active as of August 2021
- Issued by the NC Dept. of Public Safety, Emergency Mngt.
- Three-year contract (expires Aug 2024)
- Awarded to Clarke Environmental
- Services include aerial ULV, truck ULV, barrier spraying, truck-mounted larviciding, granular larviciding, backpack larviciding, dump & toss, mosquito trapping, plus more.
- Designed to range from a small single-county disease outbreak to 20+ county post-hurricane aerial spray event

Hot off the presses!

- **Statewide – can be activated by individual local gov’ts, multiple local gov’ts, and/or the state.**
- **NOT intended for private businesses or for-profit agricultural or livestock operations**
- **Undeclared emergencies: The local government may use the contract, but must pay for all services without reimbursement**
- **Declared Emergencies:**
  - State of NC and FEMA reimbursements are available
  - NC declaration requires that a local government’s storm costs **must exceed 1% of its general operating budget or $10,000, whichever is higher**.
  - NC reimburses 75% of the costs; local government pays 25%
  - FEMA typically reimburses >= 75% of costs above normal mosquito control costs for that time period

➢ Who will manage the contract?

- ❑ Undeclared events: The local government
- ❑ Declared events: Still in discussion

➢ What will be *typically* required from local programs for reimbursement?

1. Three years of typical mosquito spending
2. Three years of historical mosquito data for that time period
3. Post-landfall and post-spray mosquito data
   - ❑ Mosquito traps, BG Counter, and/or landing rate counts
   - ❑ Counts from several locations in the county (to determine spray areas)
   - ❑ Larval dip data (optional – to determine timing of adult emergence)

➢ https://www.ncdps.gov/mosquito-abatement-contract

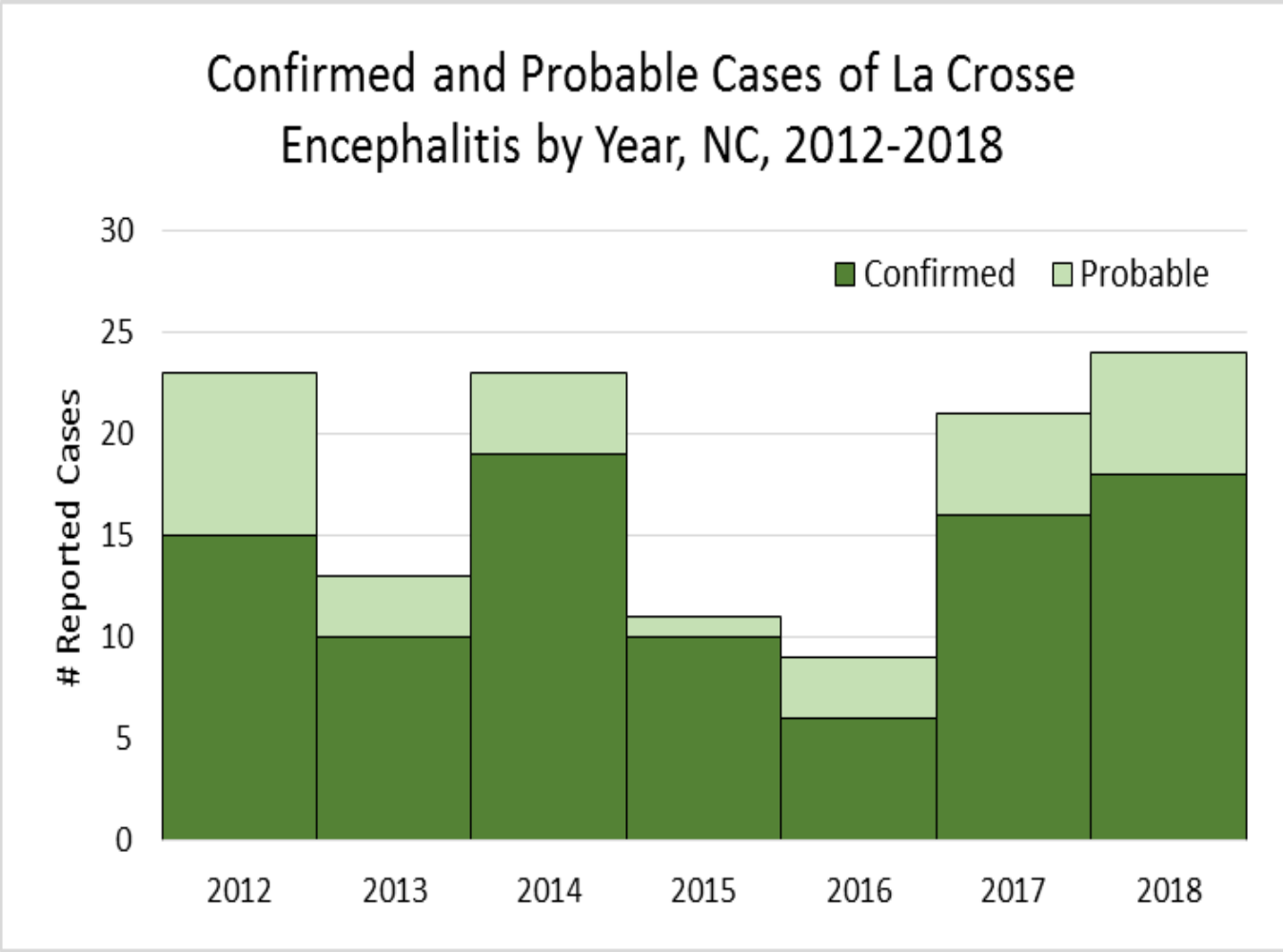
Roles of the State Laboratory of Public Health

1. Human Disease Testing
   - Endemic Arboviral Diseases
     - La Crosse Encephalitis
     - West Nile Virus
     - Eastern Equine Encephalitis
   - Travel-Associated Arboviral Diseases
     - Dengue
     - Chikungunya
     - Zika
   - Endemic Tickborne diseases
     - Rocky Mountain Spotted Fever
     - Ehrlichiosis
     - Anaplasmosis
2. Mosquito Pool and Tick Testing
     - Endemic Arboviral Diseases

Disease	Total Confirmed cases by year of report 2018*	Total Probable cases by year of report 2018*	Total Events Reviewed and closed by NC DPH 1/1/18 - 12/31/2018
La Crosse Enceph.	18	6	36
East. Equine Enceph.	0	0	3
West Nile Virus (neuro.)	3 (2 fatalities)	7	72
Chikungunya**	0	3	14
Dengue**	11	3	27
Zika**	2	5	39
Malaria**	62	0	69

**** 2018 data are preliminary **Imported***

NC EDSS Event Data – Cases Submitted to CDC

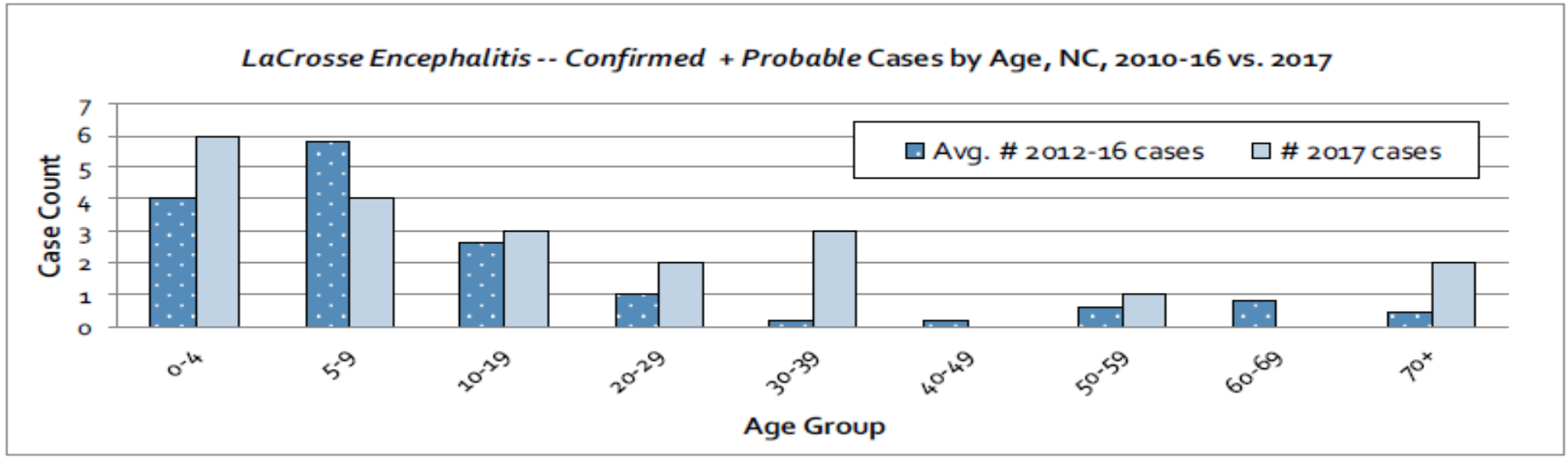


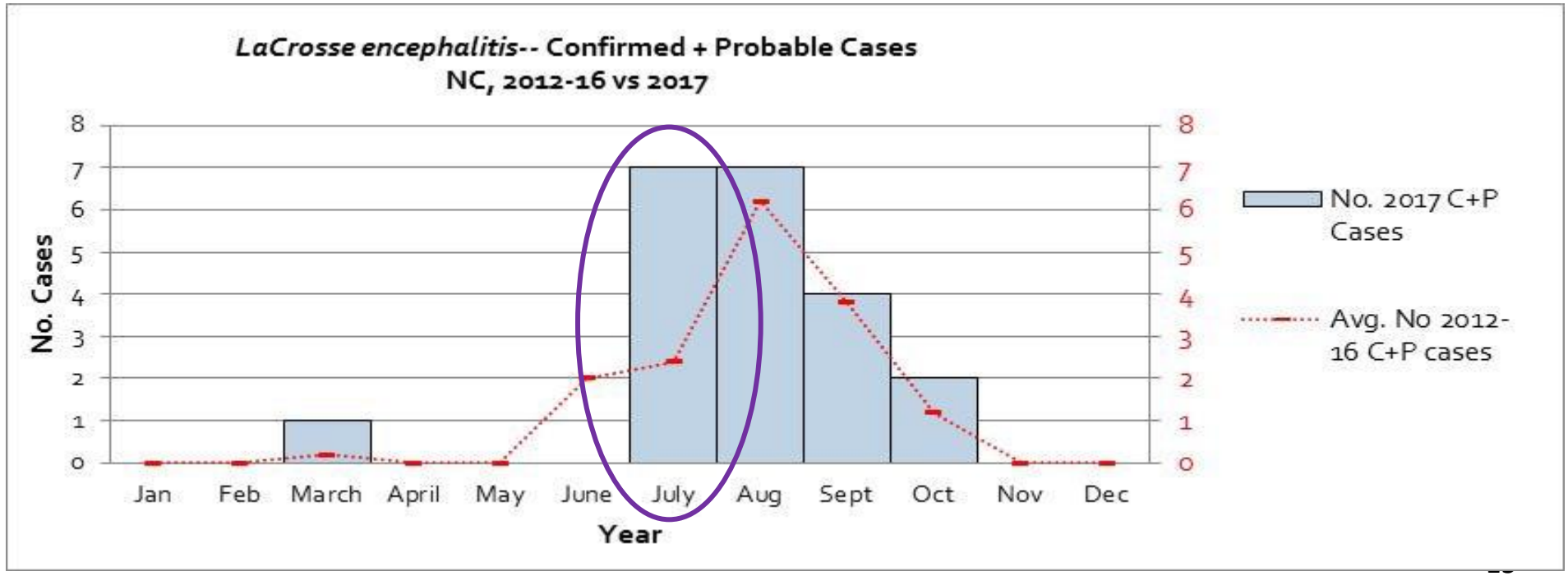
Historical La Crosse Encephalitis

LAC Encephalitis Incidence by County, Jan. 1, 2018 - Dec. 31, 2018

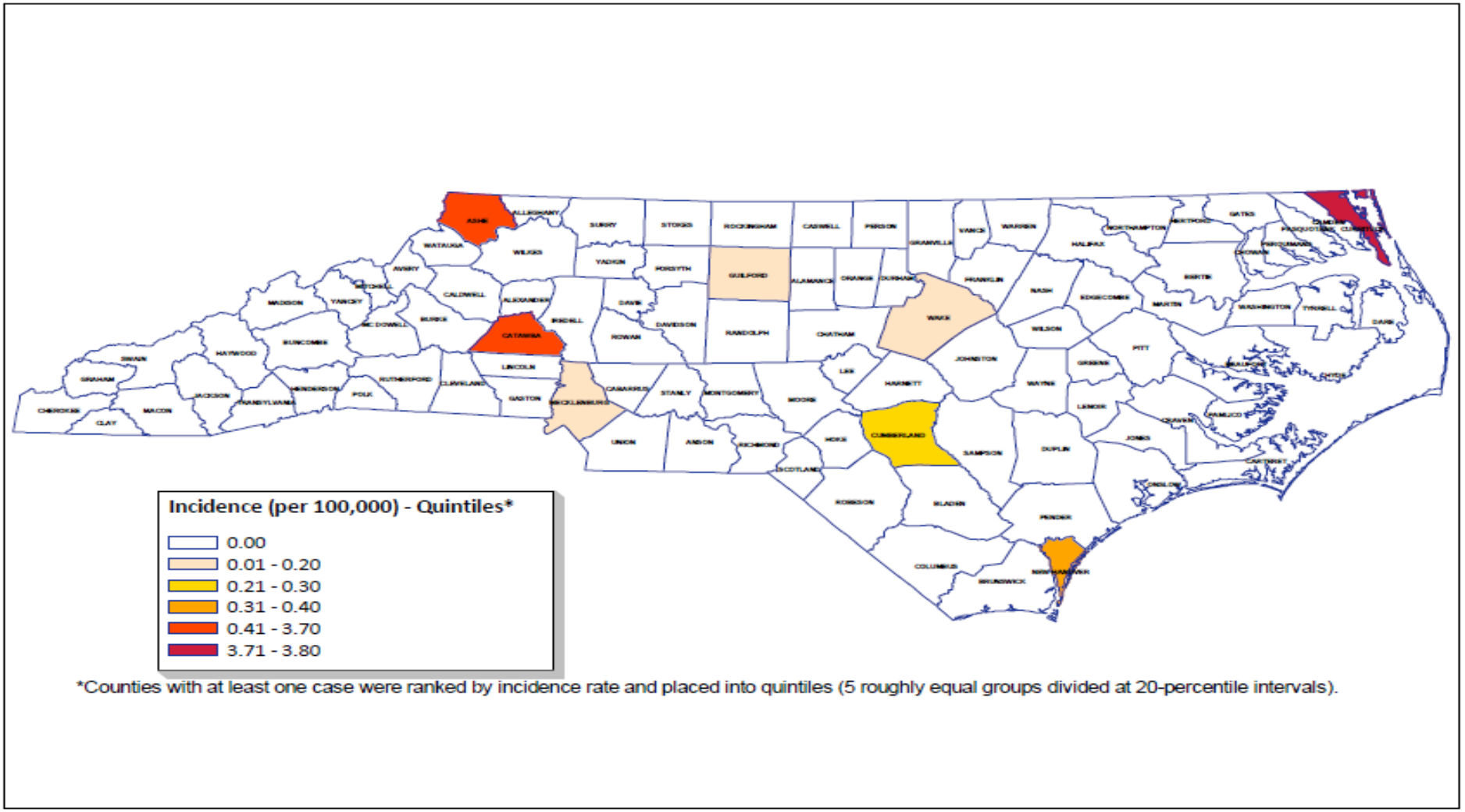
*Counties with at least one case were ranked by incidence rate and placed into quintiles (5 roughly equal groups divided at 20-percentile intervals).

2018 La Crosse Encephalitis


LaCrosse Encephalitis -- Confirmed + Probable Cases by Age, NC, 2010-16 vs. 2017
Case Count
0
1
2
3
4
5
6
7
Avg. # 2012-16 cases
2017 cases
0-4
5-9
10-19
20-29
30-39
40-49
50-59
60-69
70+
Age Group

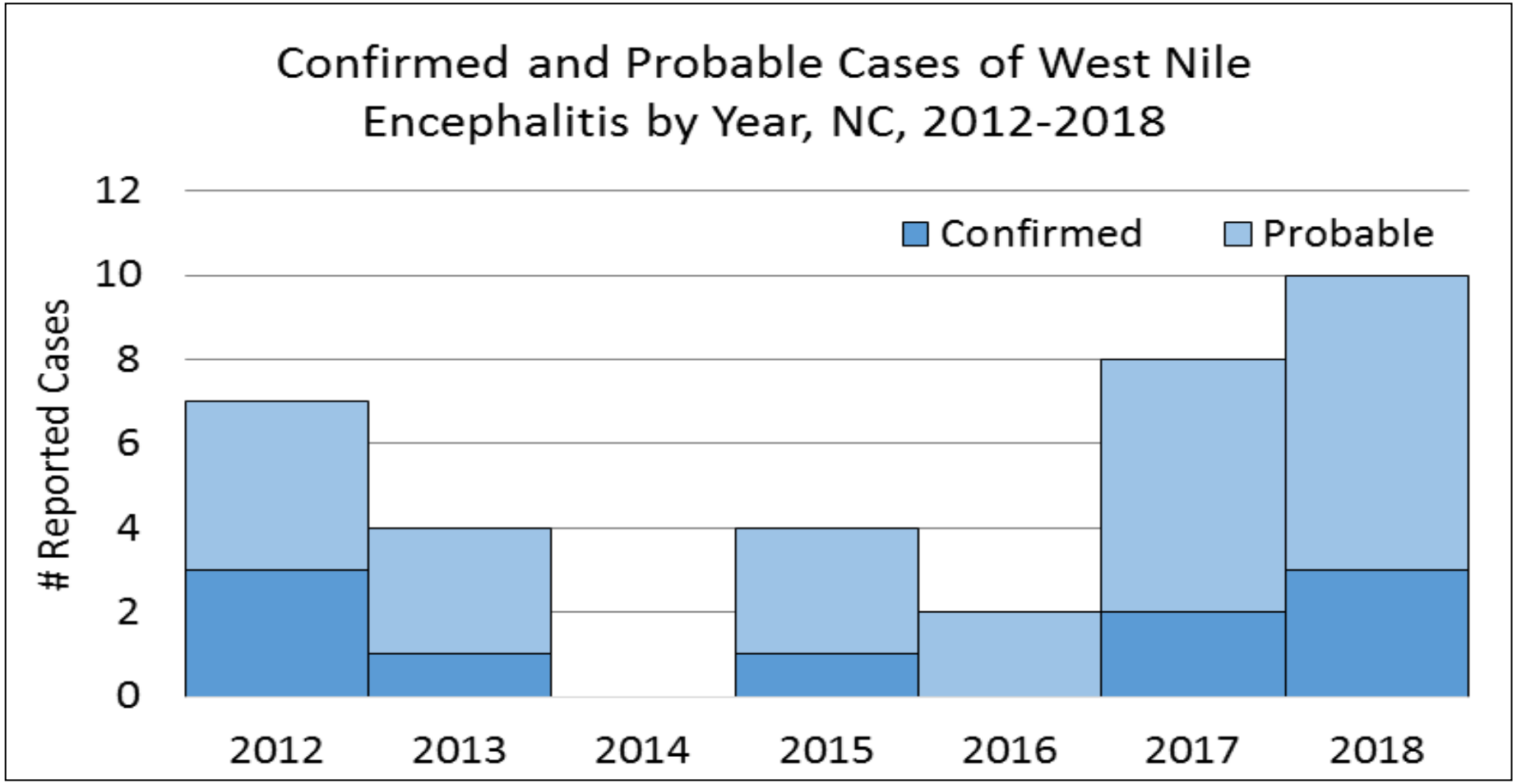

LaCrosse encephalitis-- Confirmed + Probable Cases
NC, 2012-16 vs 2017
No. Cases
0
1
2
3
4
5
6
7
8
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec
Year
No. 2017 C+P Cases
Avg. No 2012-16 C+P cases

WNV Encephalitis Incidence by County, Jan. 1, 2018 - Dec. 31, 2018

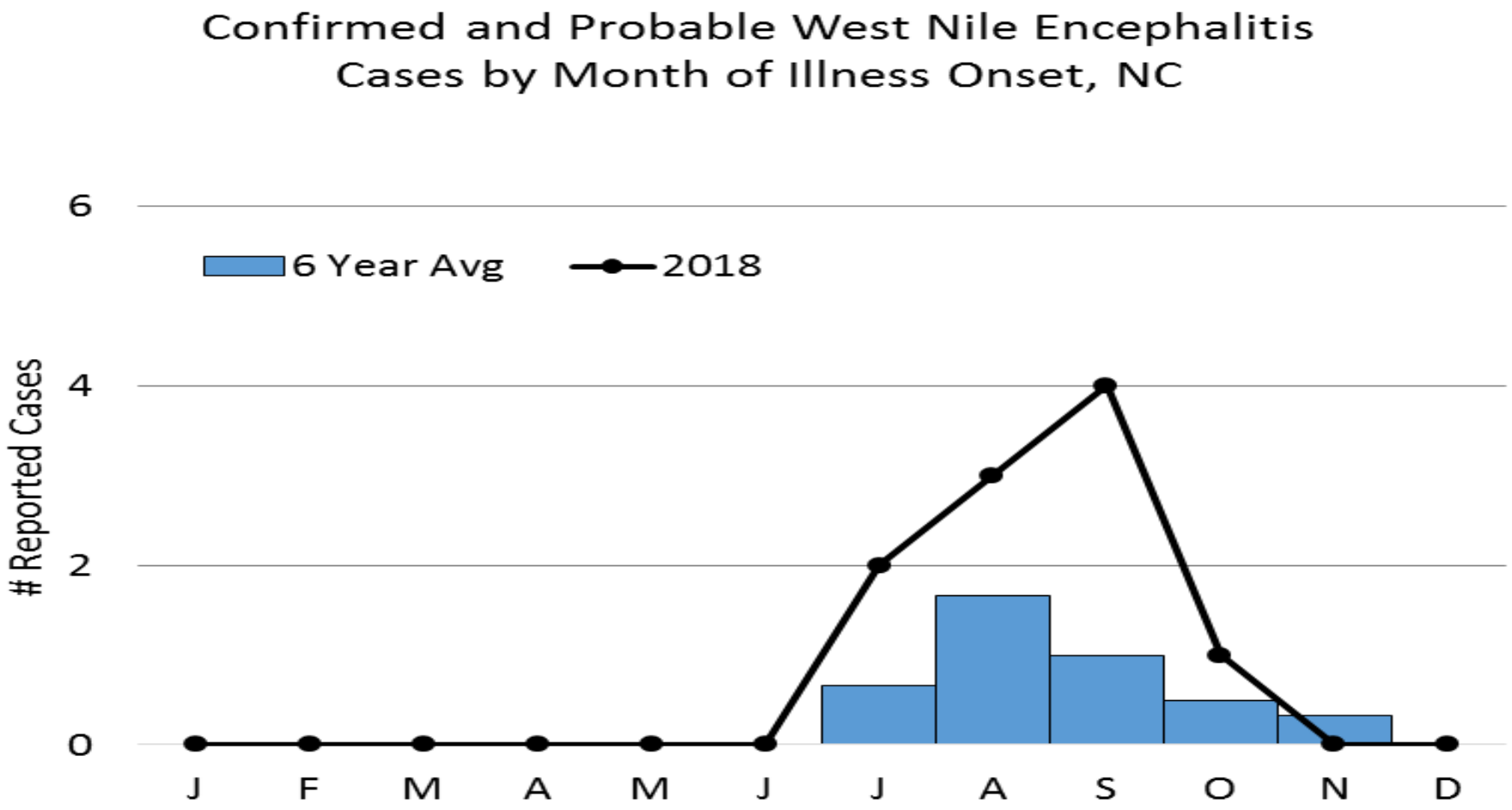


*Counties with at least one case were ranked by incidence rate and placed into quintiles (5 roughly equal groups divided at 20-percentile intervals).

2018 West Nile Encephalitis (Neuroinvasive)



Historical West Nile Encephalitis



Historical West Nile Encephalitis

MOSQUITO						
Pathogen	Positive Mosquito Pools in 2018	Total Pools Tested as 2018	% pools positive	Counties	Date of Trap Setting	Species Tested
East. Equine Enceph.	7	170	4.1%	Brunswick	7/17	Cs. melanura*, Cx. erraticus, Cx. salinarius, Cq. perturbans
	0	103	0.0%	New Hanover	7/17	Cs. Melanura, Cx. erraticus, Ae. taeniorhynchus
	0	121	0.0%	Forsyth	7/12	Ae. albopictus, Ae. j. japonicus, Ae. triseriatus, Ae. vexans, Cx. erraticus, Cx. pipiens, Cx. salinarius, Cx. restuans
West Nile Virus	0	170	0.0%	Brunswick	n/a	See above
	0	104	0.0%	New Hanover	n/a	See above
	3	121	2.4%	Forsyth	8/30	Cx. pipiens*, + above

*positive

SLPH Data – Results Submitted to ArboNet

EQUINE			
Disease	Total Positive Horses in 2018	Counties	Dates of Disease Onset
East. Equine Enceph.	7	Onslow	6/28
		Richmond	7/2
		Onslow	7/12
		Duplin	7/21
		Craven	7/22
		Carteret	8/1
		Duplin	8/23
West Nile Virus	5	Pender	8/27
		Surry	9/8
		Yadkin	9/18
		Davie	10/15
		Johnston	10/29

NCDA & CS Data – Results Submitted to ArboNet

MOSQUITO BIOLOGY AND ITS EFFECT ON DISEASE TRANSMISSION

Mosquito Life Cycle

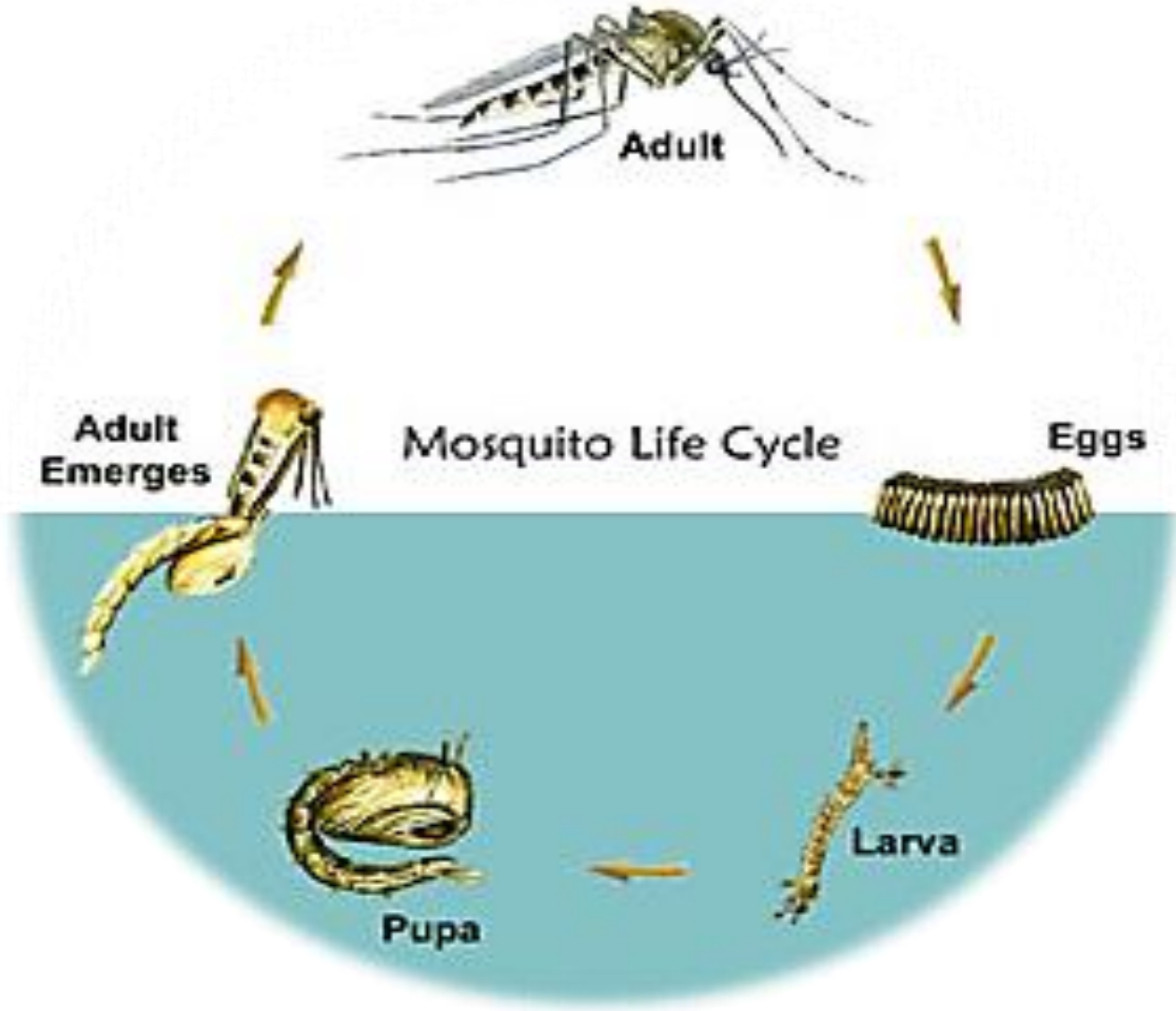


Photo courtesy of Woodstream Corp.

22

Mosquito Facts

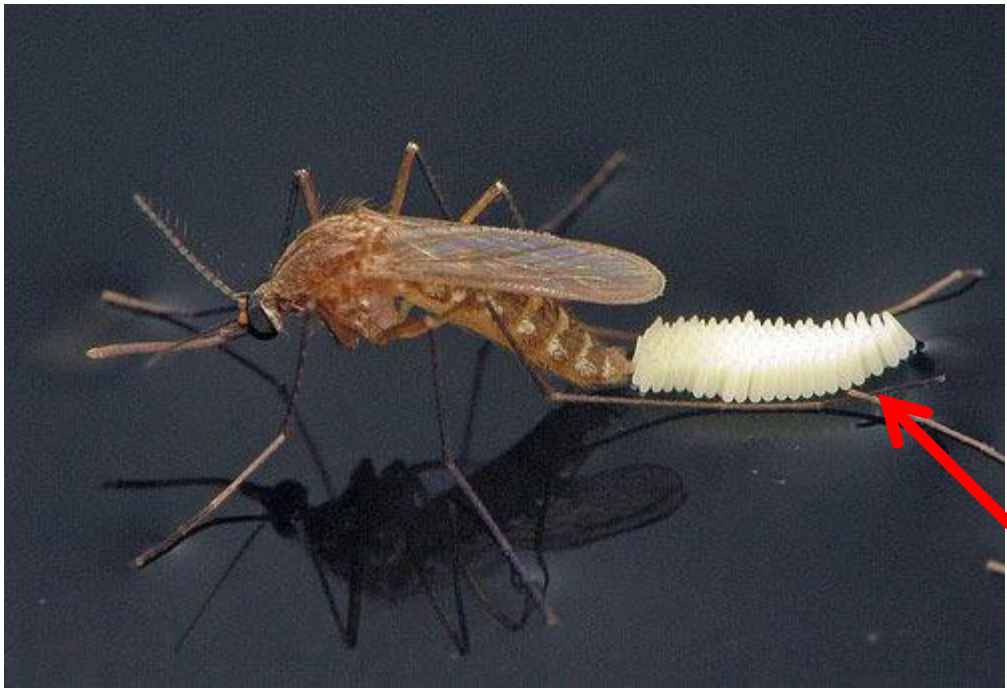
1. Mosquitoes **NEED** water to complete their life cycle.
2. All mosquitoes feed on plant nectar (sugar source).
3. <u>Female</u> mosquitoes bite animals because they need a blood meal as a protein source to produce eggs.
4. There are
   - ~3200 species of mosquitoes worldwide.
   - 176 species in the U.S.
   - 67 species in NC

   Not all mosquito species feed on people.

Like birds, all mosquito species are not the same

Mosquito Egg Laying

Some mosquitoes breed in permanent waters. They overwinter as adults and lay eggs singly or in rafts on the water surface



These eggs hatch in **24-36 hours**.

Mosquito Egg Laying

Other mosquitoes deposit eggs in/on objects or depressions (such as tree holes). These eggs are resistant to desiccation, and remain viable for months and even years. Eggs hatch after several flooding/drying events (rather than all at once).

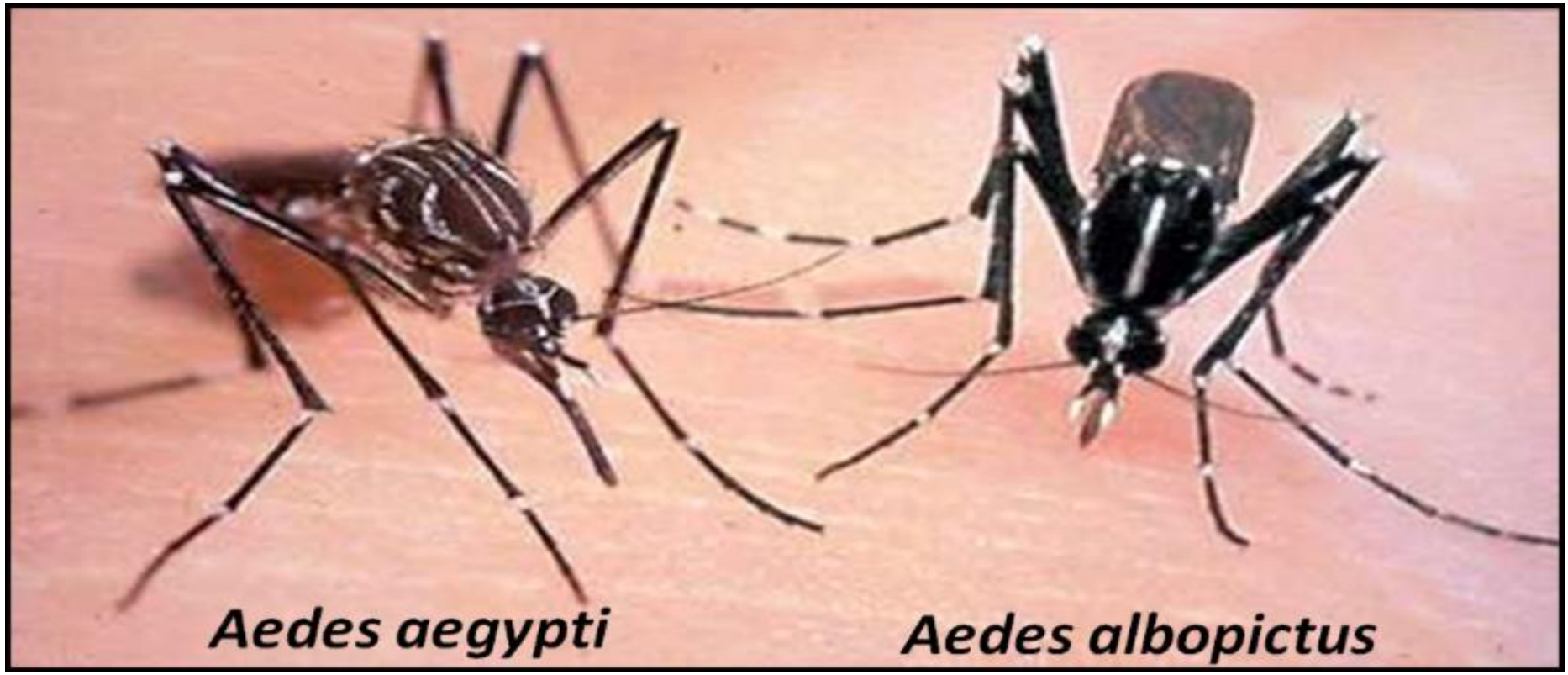
These mosquitoes overwinter in the egg stage.

Mosquito Larvae

- Eggs hatch into **larvae** called "wigglers" which feed on bacteria and other microorganisms in the water. Larvae must come to the surface of the water to breathe through their 'siphon'

- Larvae pass through 4 growth stages, called "instars". Depending on water temperature, larvae mature in **4-10 days.**

Physical/Morphological Differences



Zika Vectors

Aedes aegypti

- Very closely associated with people
- Does not depend greatly on vegetation
- Indoor/outdoor (resting, biting, oviposition)
- Urban/suburban/rural areas
- Greater resistance to desiccation
- Vector of Dengue, Chikungunya and Zika

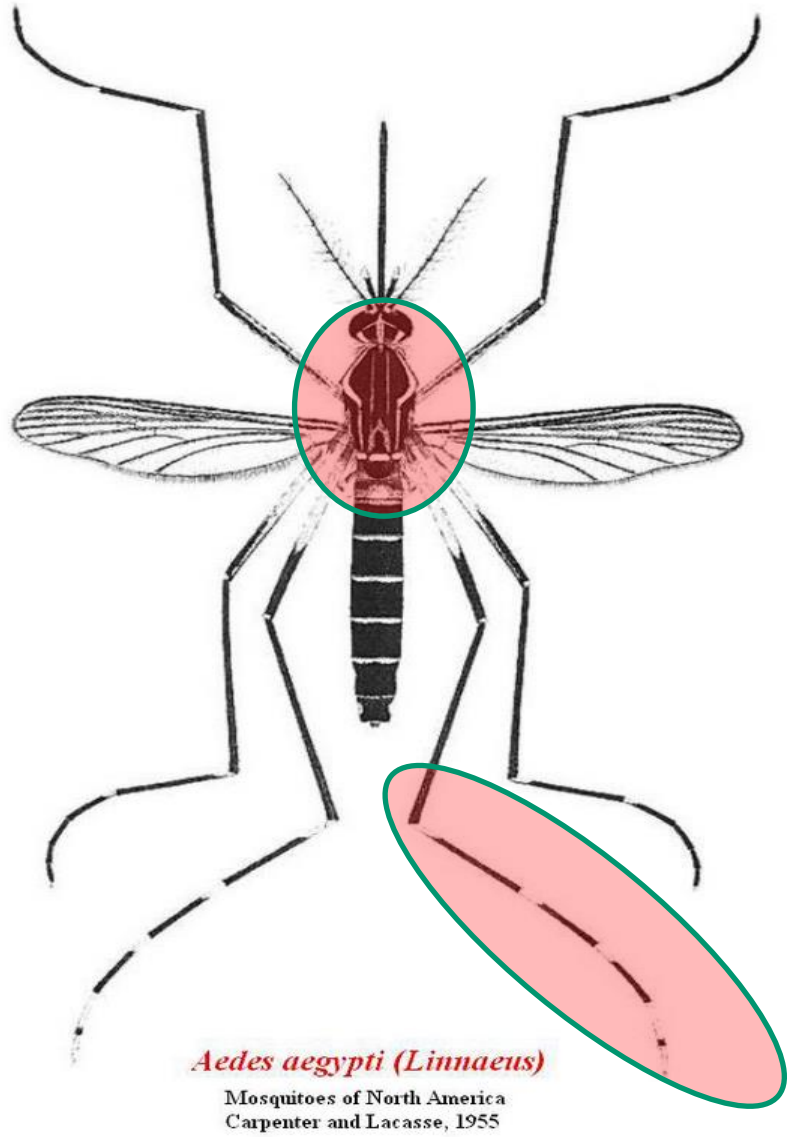
Aedes albopictus

- Less dependent on people
- Rests in/near vegetation
- Outdoor mosquito
- Suburban/rural areas
- Greater cold hardiness
- In some areas, may be main vector of Dengue
- Vector WNV and Zika

Both are container-inhabiting

Adapted from R. Barrera (DB/CDC)

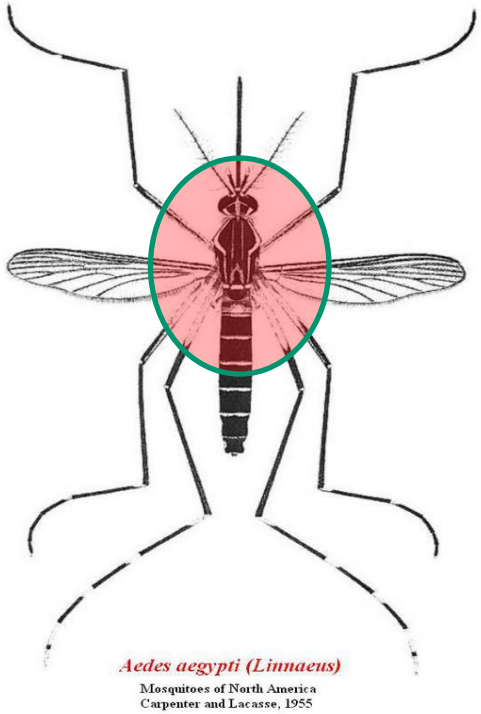
Physical Differences



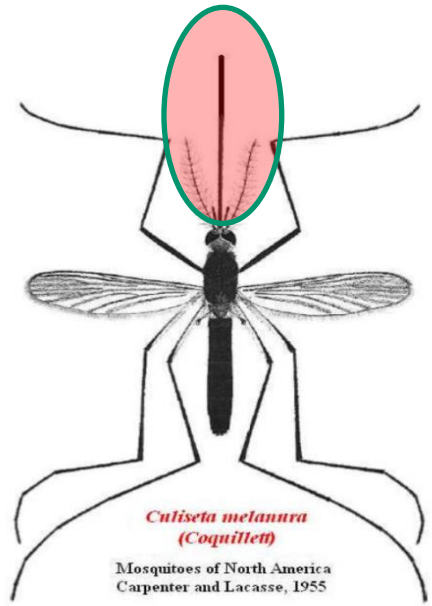
Aedes aegypti (Linnaeus)

Mosquitoes of North America
Carpenter and Lacasse, 1955

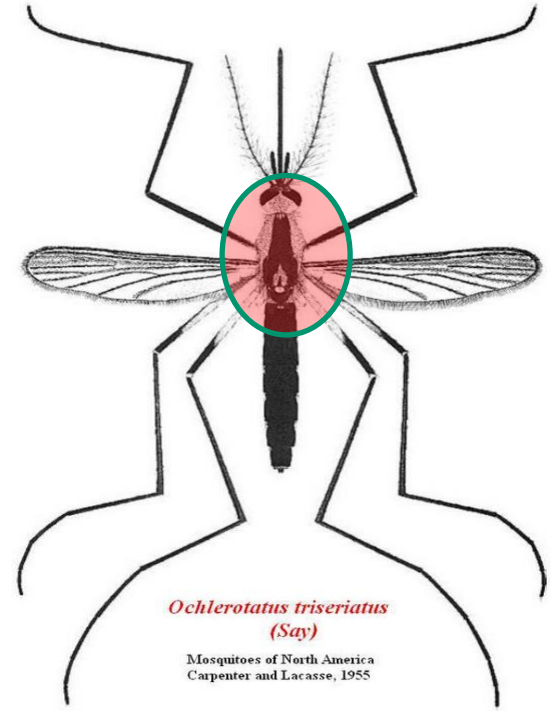
Physical Differences



Zika
Yellow Fever
Dengue

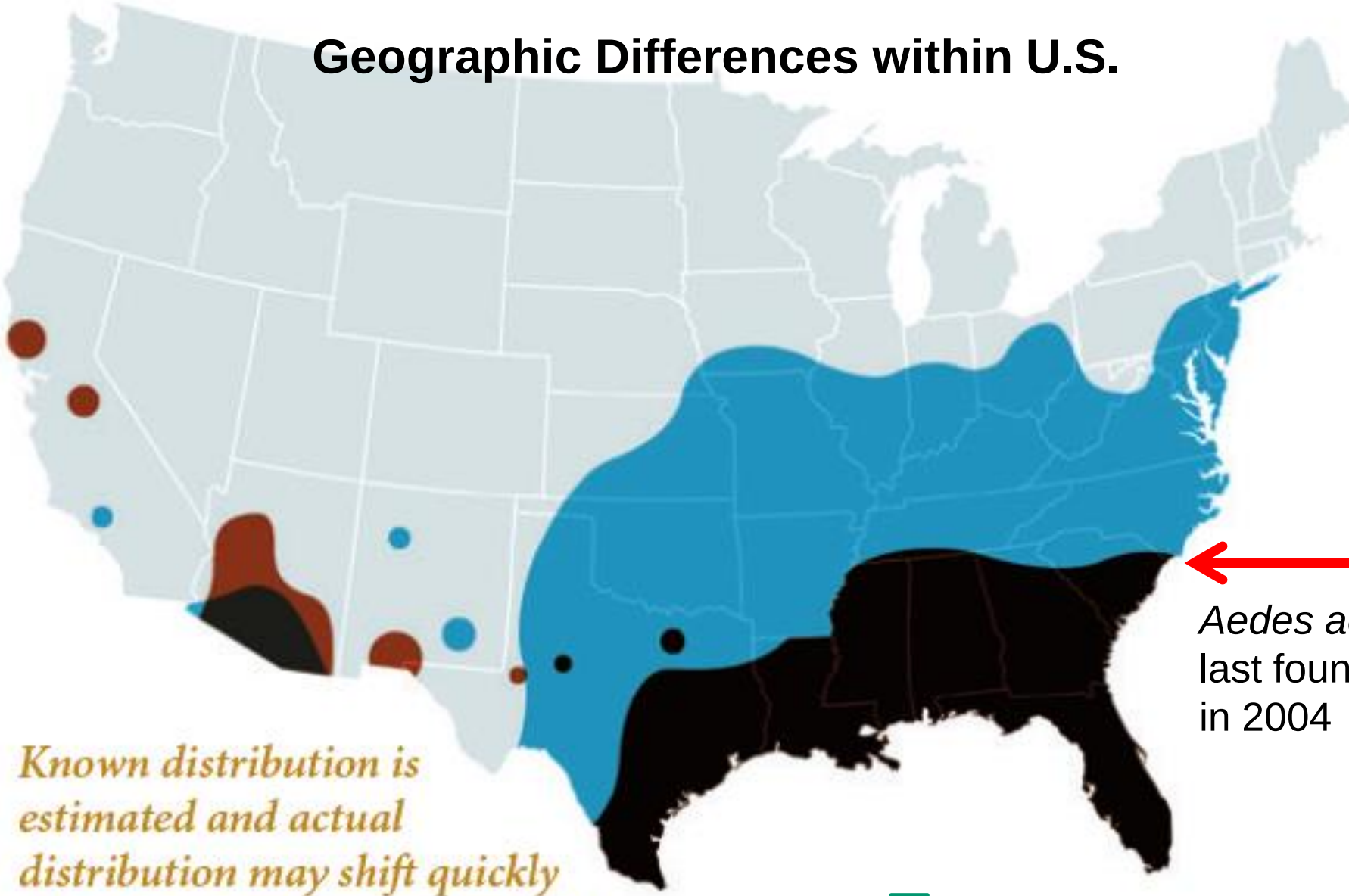


Eastern
Equine
Encephalitis



LaCrosse
Encephalitis

Geographic Differences within U.S.



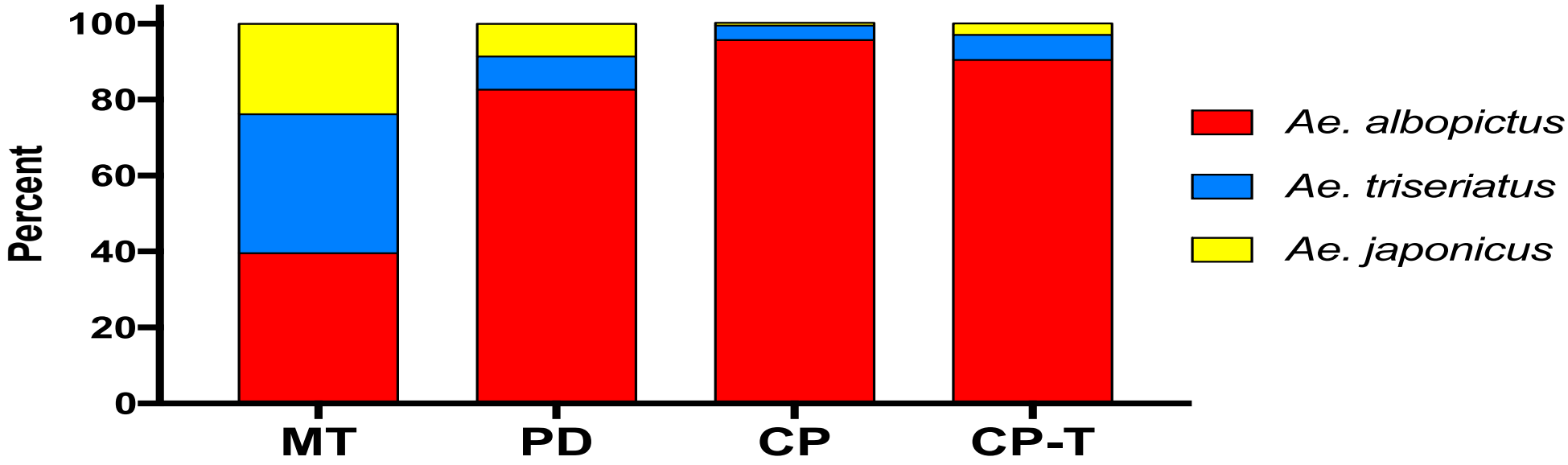
Aedes aegypti last found in NC in 2004

Known distribution is estimated and actual distribution may shift quickly due to mosquito movement and weather patterns.

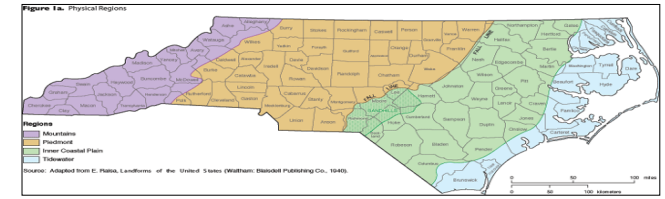
Aedes albopictus
Aedes aegypti

Geographic Differences within N. Carolina

Ovitrap Collections (2016)
Relative Proportions by Region



MT: Mountains
PD: Piedmont
CP: Coastal Plains
CP-T: Coastal Plains-Tidewater



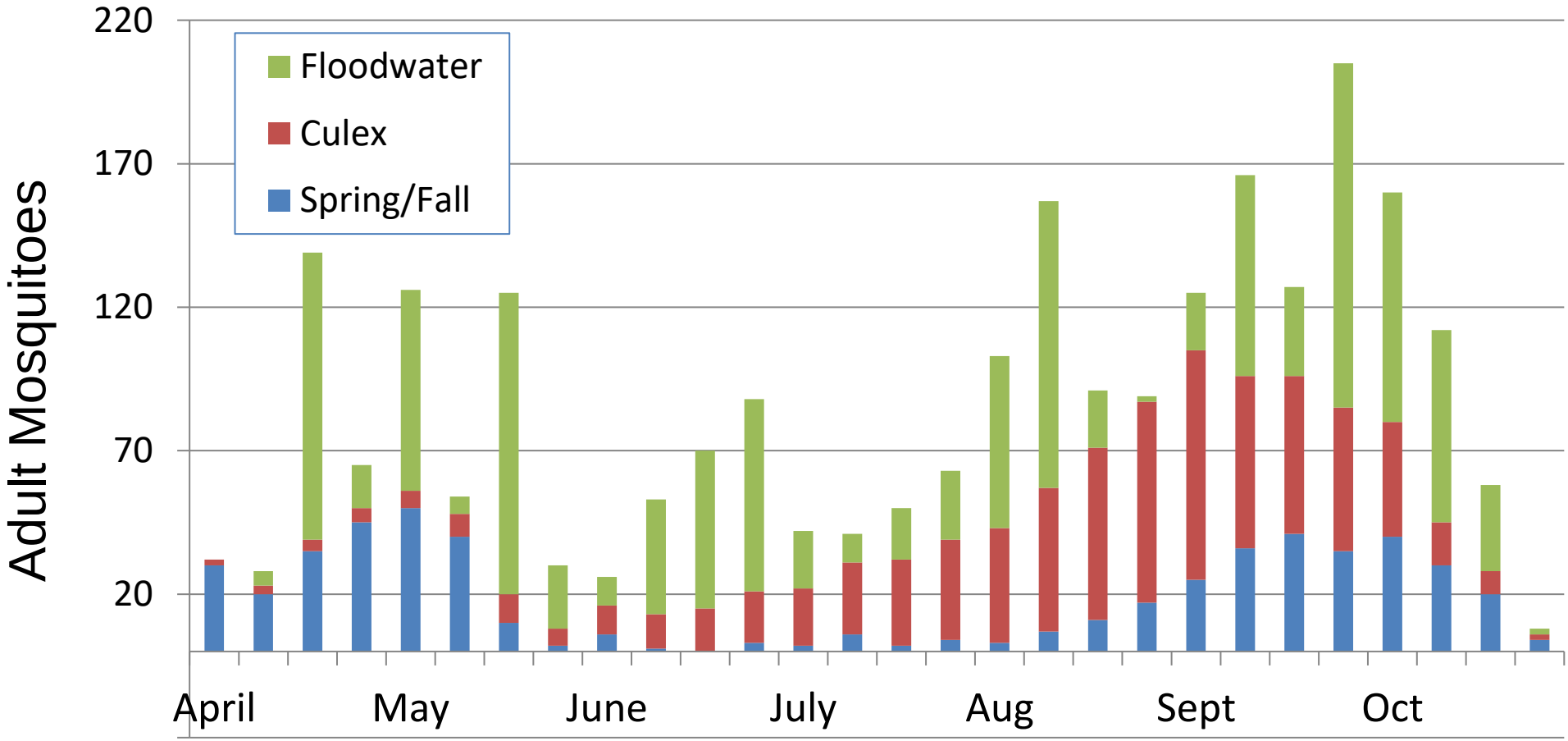
LAC Encephalitis Incidence by County, Jan. 1, 2017 - Dec. 31, 2017

*Counties with at least one case were ranked by incidence rate and placed into quintiles (5 roughly equal groups divided at 20-percentile intervals).

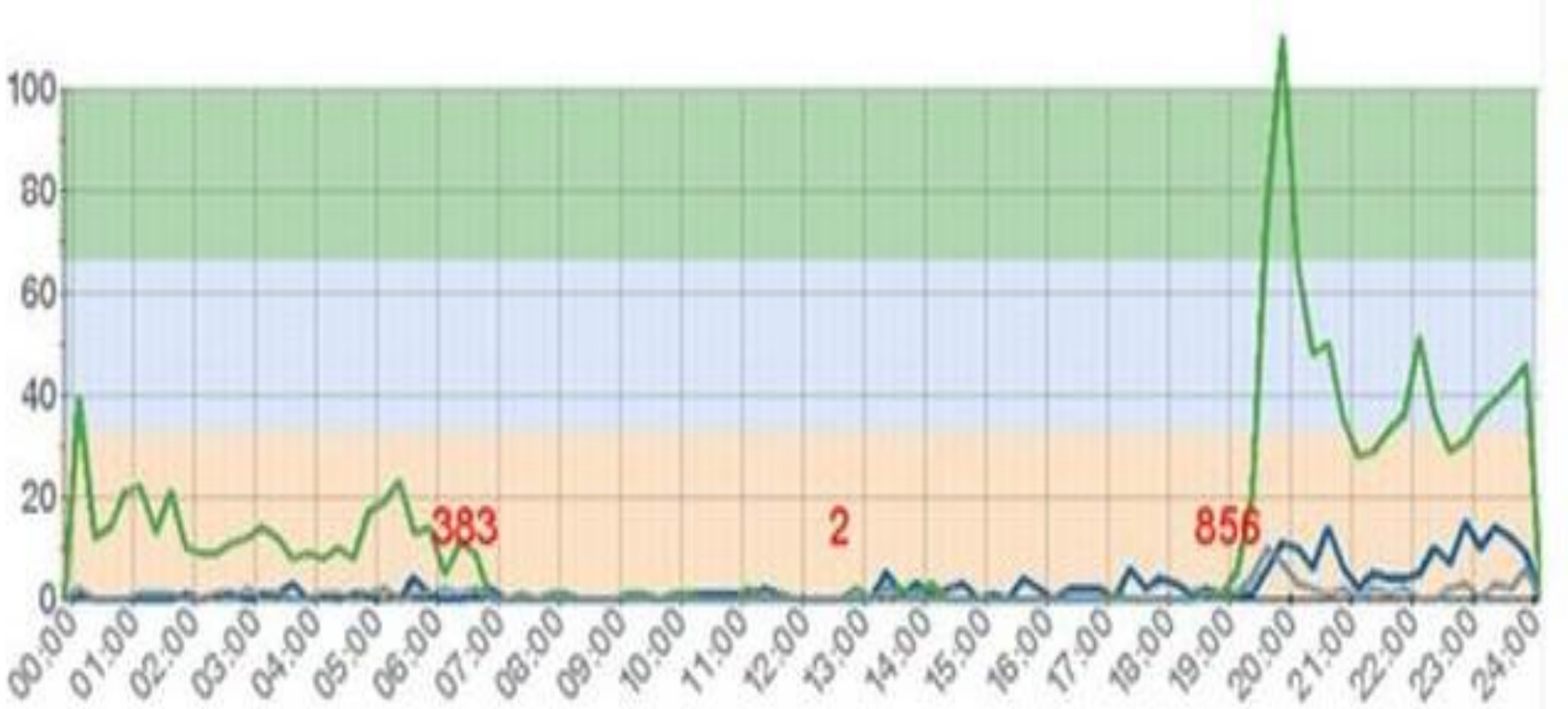
Flight Range Differences

Source: Google Earth

Seasonal Population Differences



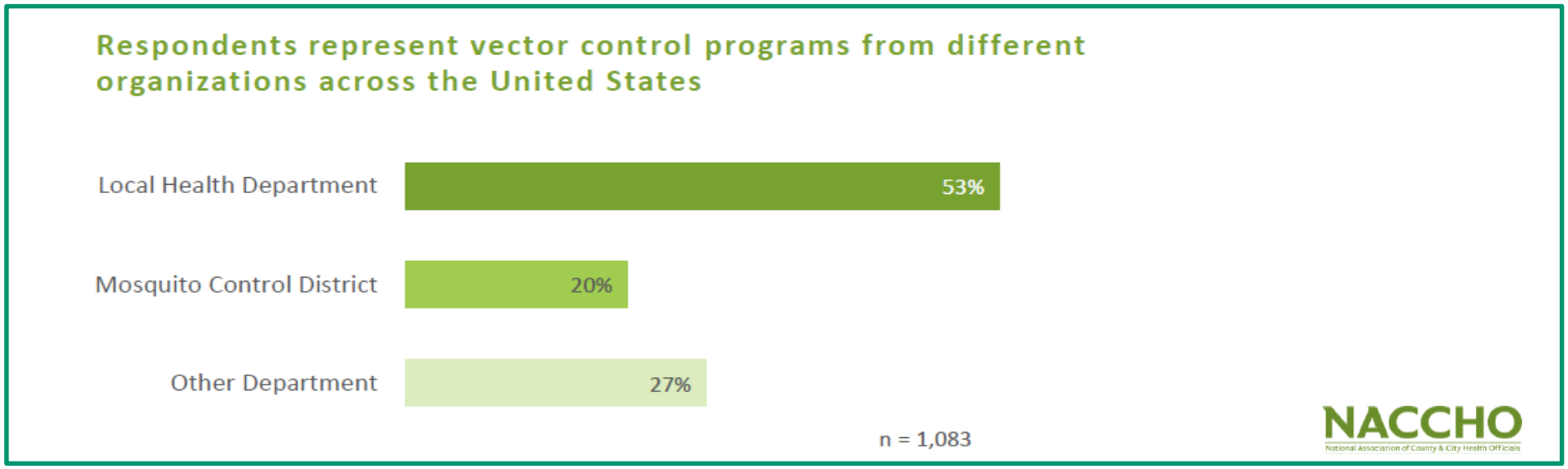
Human Host Seeking Time Differences

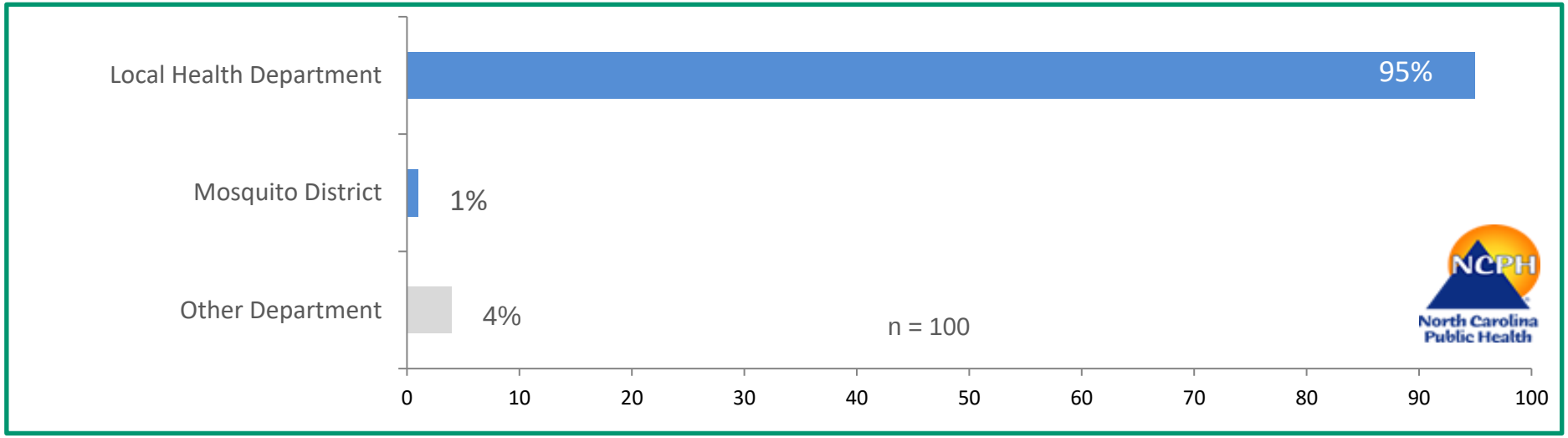


BG-Counter Results -- Trap O38
Marie Hemmen, New Hanover County, NC
(424 ml CO2/min)

North Carolina
Vector Control Capacity

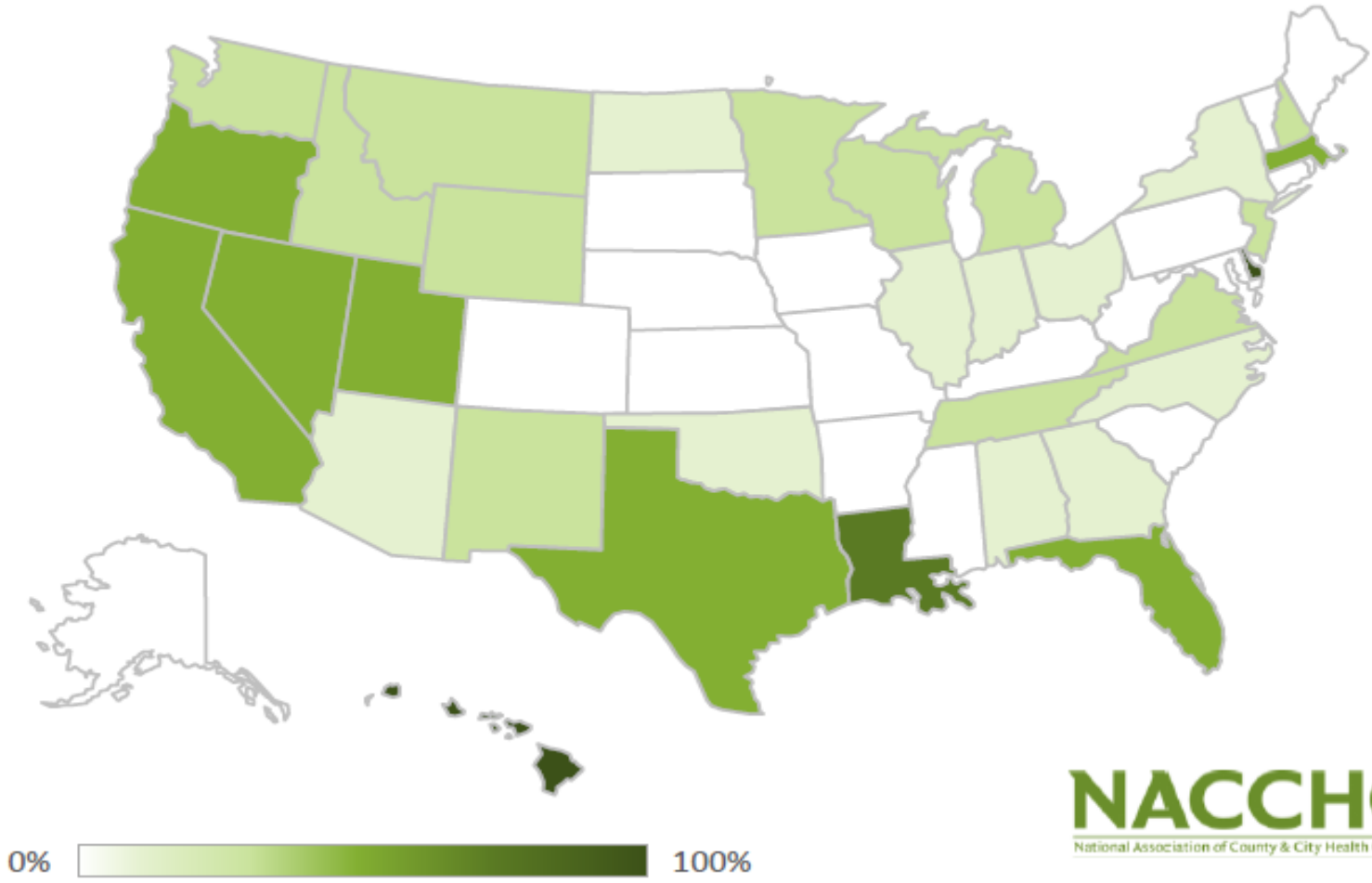
Structure of U.S. and NC Vector Control Programs





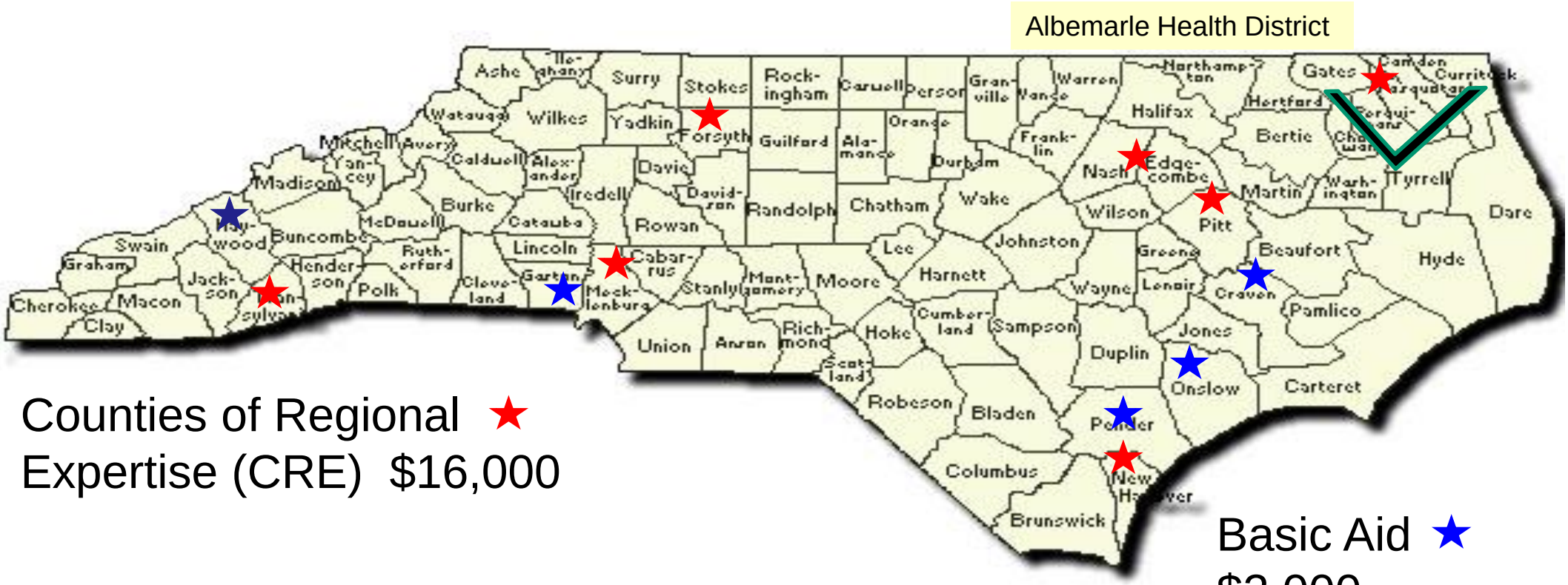
Geographic differences in Mosquito Programs

Percentage of vector control programs ranked as “fully capable” or “competent” by state



NACCHO
National Association of County & City Health Officials

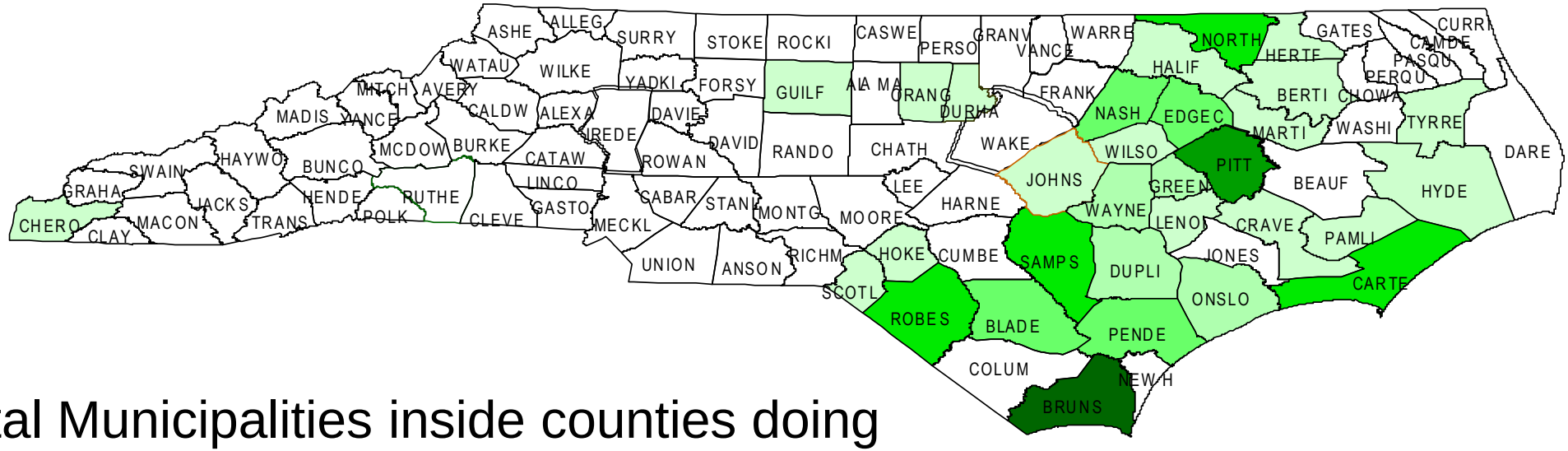
2021-22 Counties Receiving AA 908 “Aid to County” Funds for Mosquito/Tick Programs



Counties of Regional Expertise (CRE) $16,000

Basic Aid $2,000

Non-County Mosquito Programs



Total Municipalities inside counties doing some form of mosquito control (2017)

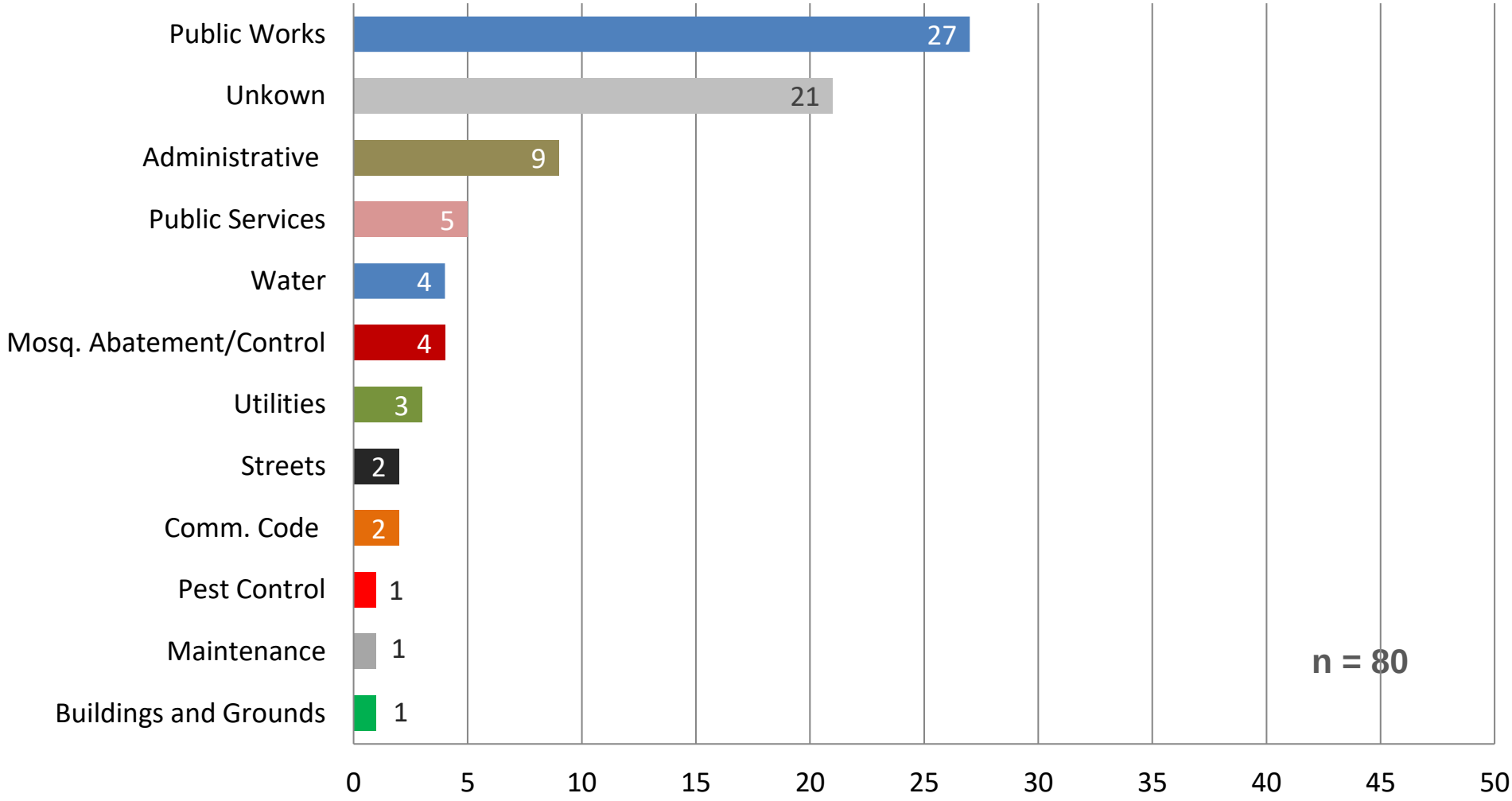
Brunswick	13
Pitt	9
Carteret	6
Robeson	6
Sampson	6
Northampton	5
Bladen	3
Edgecombe	2.2

Nash	2.2
Pender	3
Duplin	2
Greene	2
Onslow	2
Wayne	2
Bertie	1
Cherokee	1

Craven	1
Durham	0.5
Guilford	1
Halifax	1
Hertford	1
Hoke	1
Hyde	1
Johnston	1

Lenoir	1
Martin	1
Orange	0.5
Pamlico	1
Scotland	1
Tyrell	1
Wilson	0.33

NC Vector Programs – 80 CITIES/TOWNS/VILLAGES



Emergency Vector Control Services Contract – Continuing in 2018

1. To be activated upon local transmission of Zika (or other mosquito-borne disease)
2. Includes multiple levels of response, from simple surveillance to complex neighborhood-level control efforts
3. Large-scale mosquito control contractor would perform treatments
4. Partner with counties which have established mosquito surveillance/control programs, based on County resources
    1. Public Relations
    2. Mosquito Surveillance
    3. GIS assistance

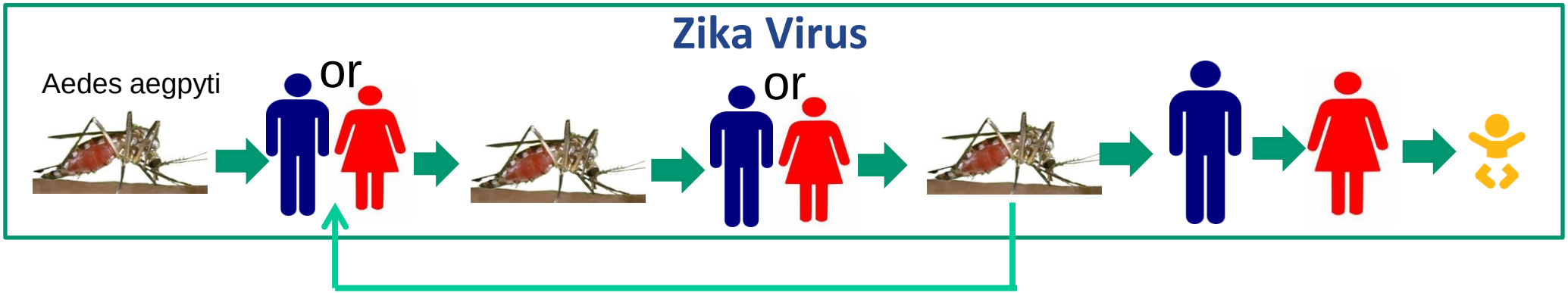
DISEASE TRANSMISSION CYCLES

Spread of Zika Virus

Reservoir Host

www.wikihow.com

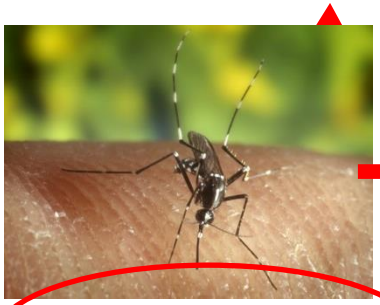
How Zika is transmitted…



Spread of West Nile Virus &EEEV

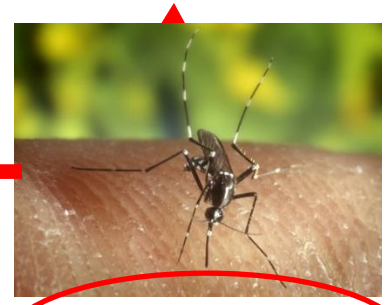
Dead-end Host

Dead-end Host



Bridge Vector

Reservoir &
Amplifying Hosts

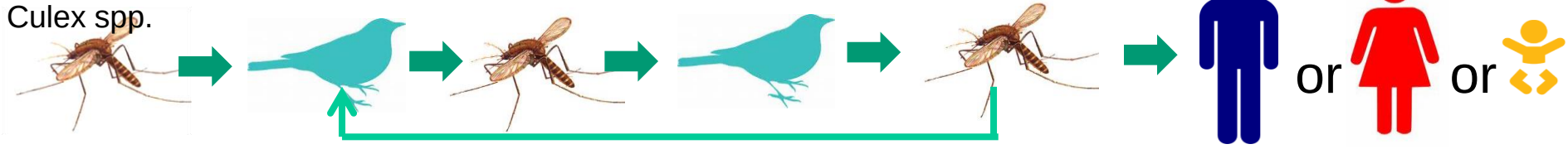


Bridge Vector

Diseases often have unique Mosquito Specie(s) which Transmit them…

West Nile Virus (WNV)

Culex spp.

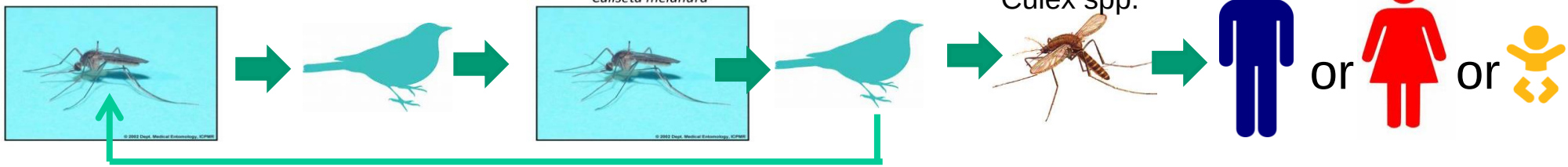


LaCrosse Encephalitus (LAC)

Aedes triseriatus

Eastern Equine Encephalitis (EEE)

Culiseta melanura



Integrated Mosquito Management

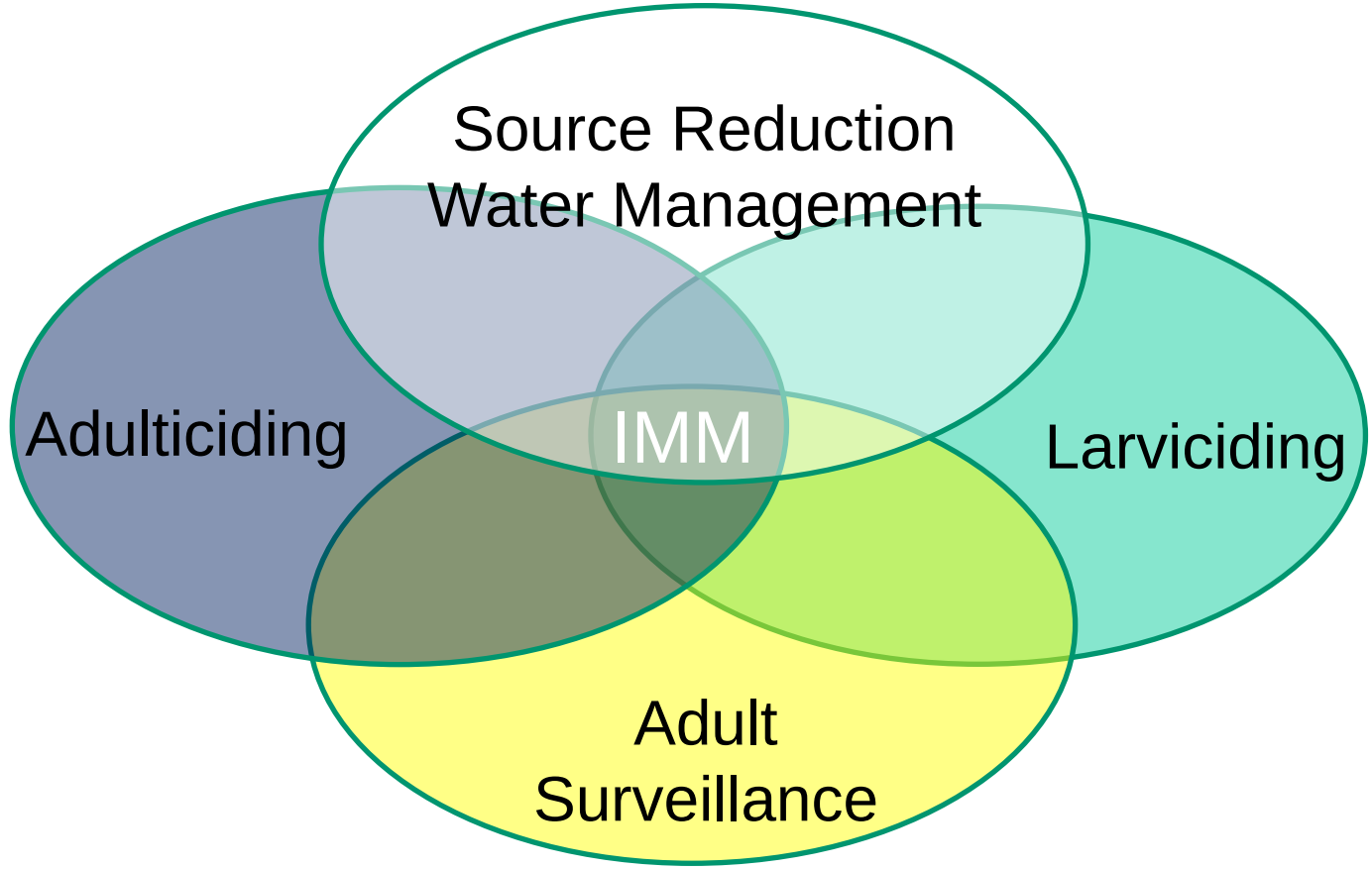
"A comprehensive mosquito prevention and control strategy that utilizes all available mosquito control methods, either singly or in combination, to exploit the known vulnerabilities of mosquitoes to reduce their numbers while maintaining a quality environment."

-- Best Practices for Mosquito Management: A Focused Update (American Mosquito Control Association Technical Report 2017)

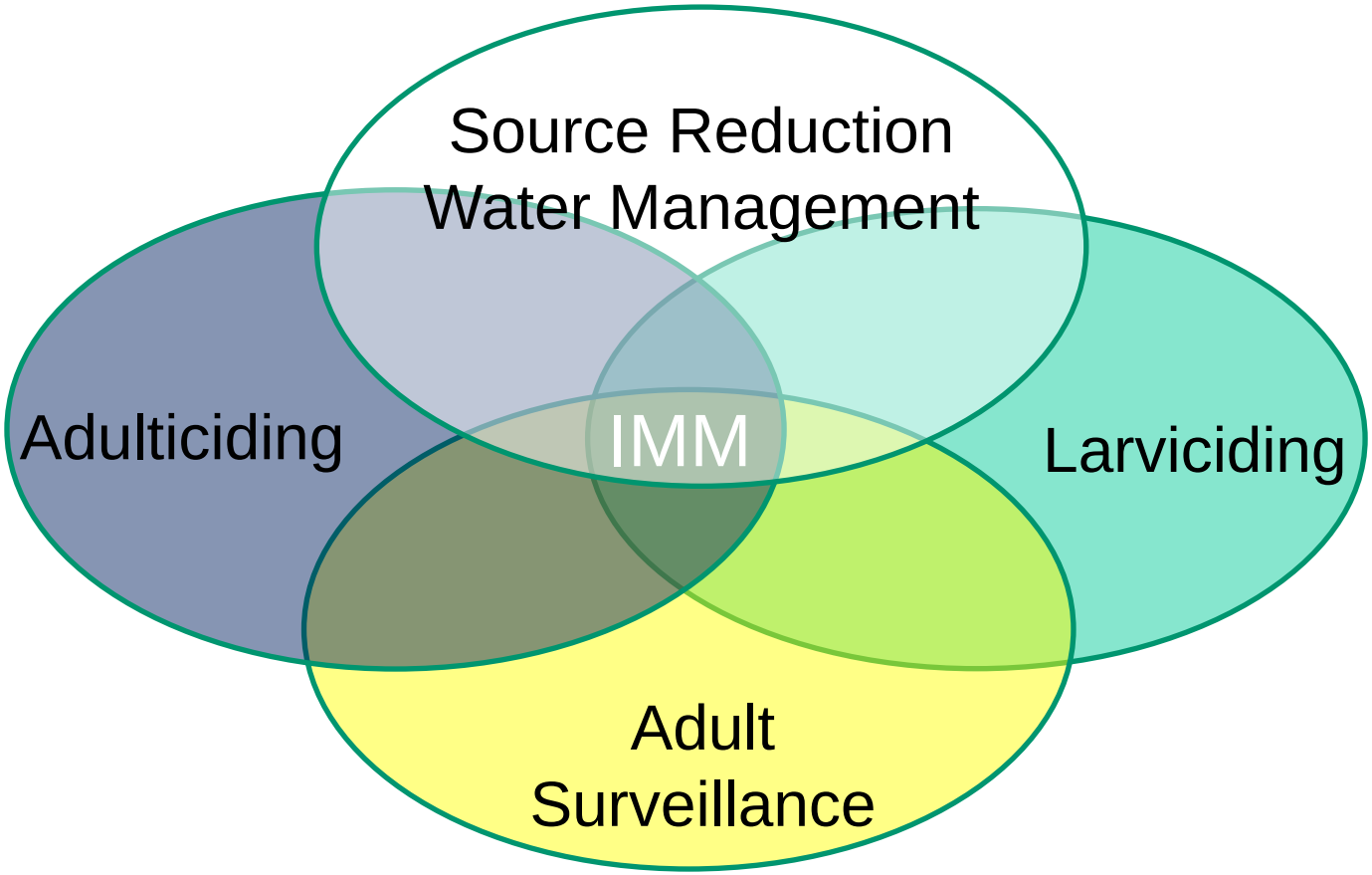
"…applying any mosquito control measure on a predetermined schedule, absent a documented need, is not an acceptable practice."

-- Best Practices for Mosquito Management: A Focused Update (American Mosquito Control Association Technical Report 2017)

Integrated Mosquito Management



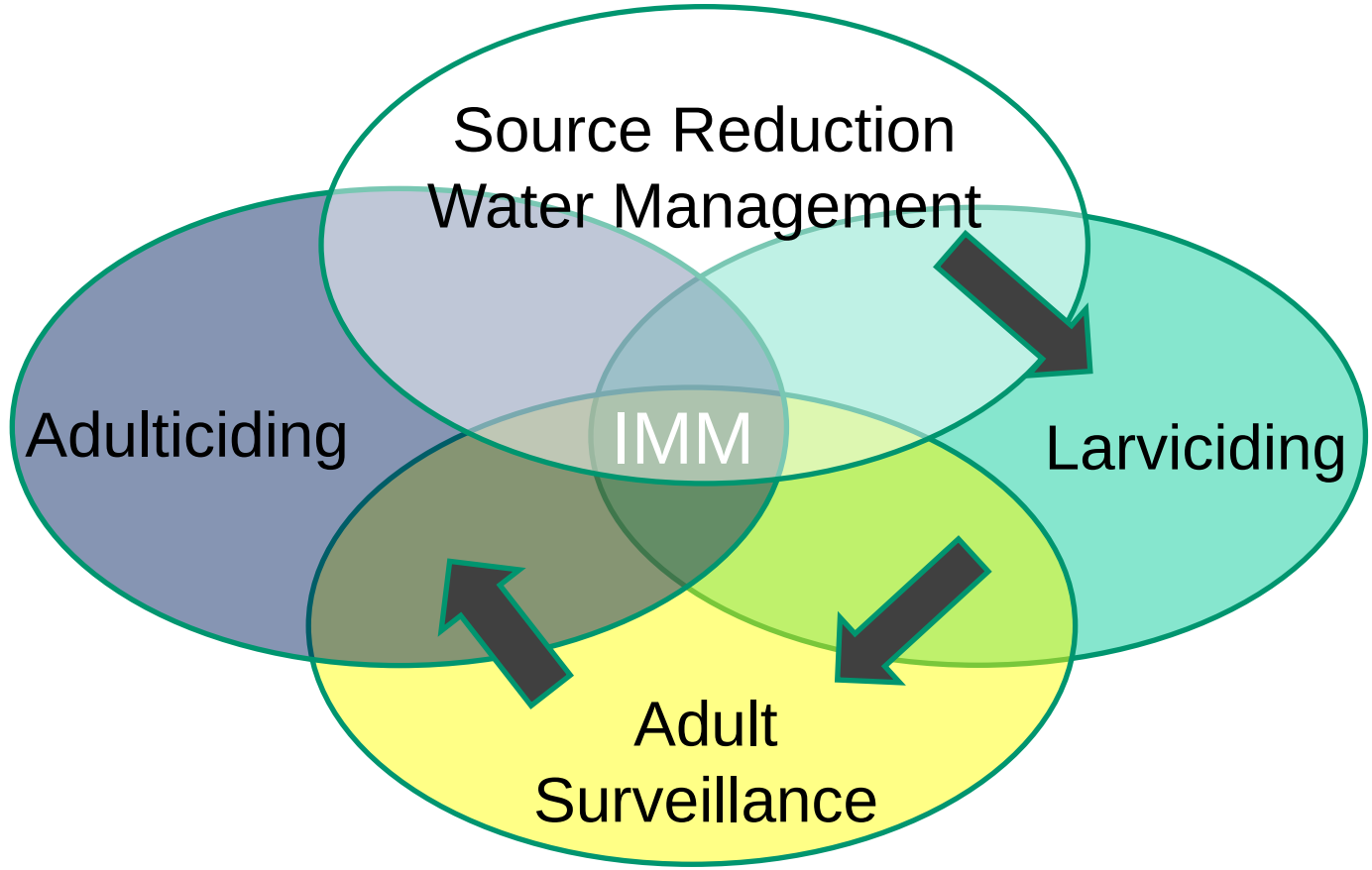
Integrated Mosquito Management



Human
Avoidance

- Repellent
- Screens
- Clothing
- Indoors

Integrated Mosquito Management



What's Your Mosquito Game Plan?

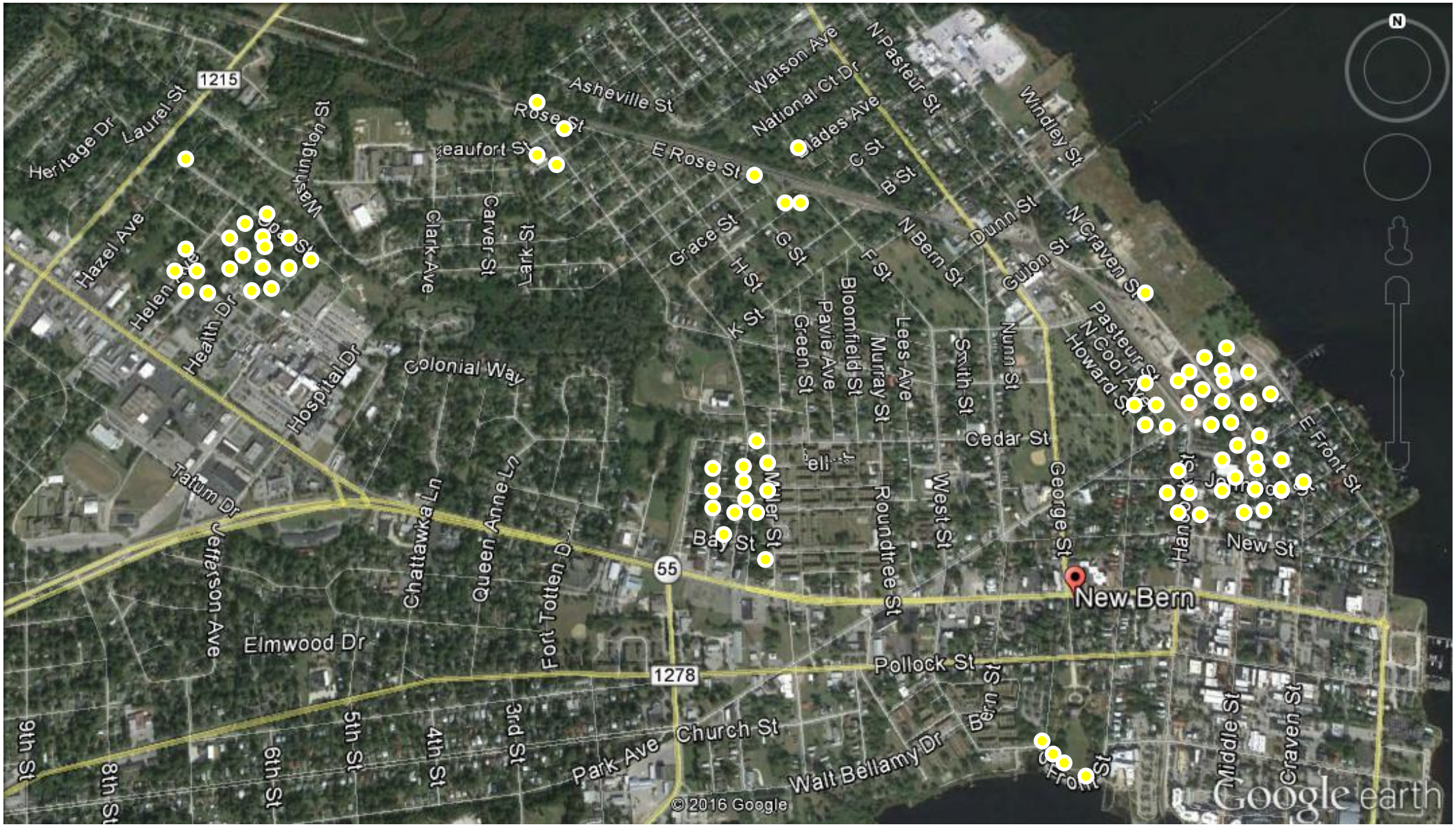
- **Public education**: Mosquito control (chemical & non-chemical) requires a community effort or it **WILL** fail to meet expectations
- **Source reduction**: Remove/reduce mosquito breeding sites.
- Effective <u>long-term</u> strategy.

Mosquito Surveillance

Mosquito Survey & Surveillance

Collection, Identification & Testing

State Lab of Public Health (SLPH) currently tests ~500 mosquito “pools” a year, from 3 counties



Identify the problem: Map out your "hot spots"

SOURCE RECUCTION & REMOVAL

Source Reduction

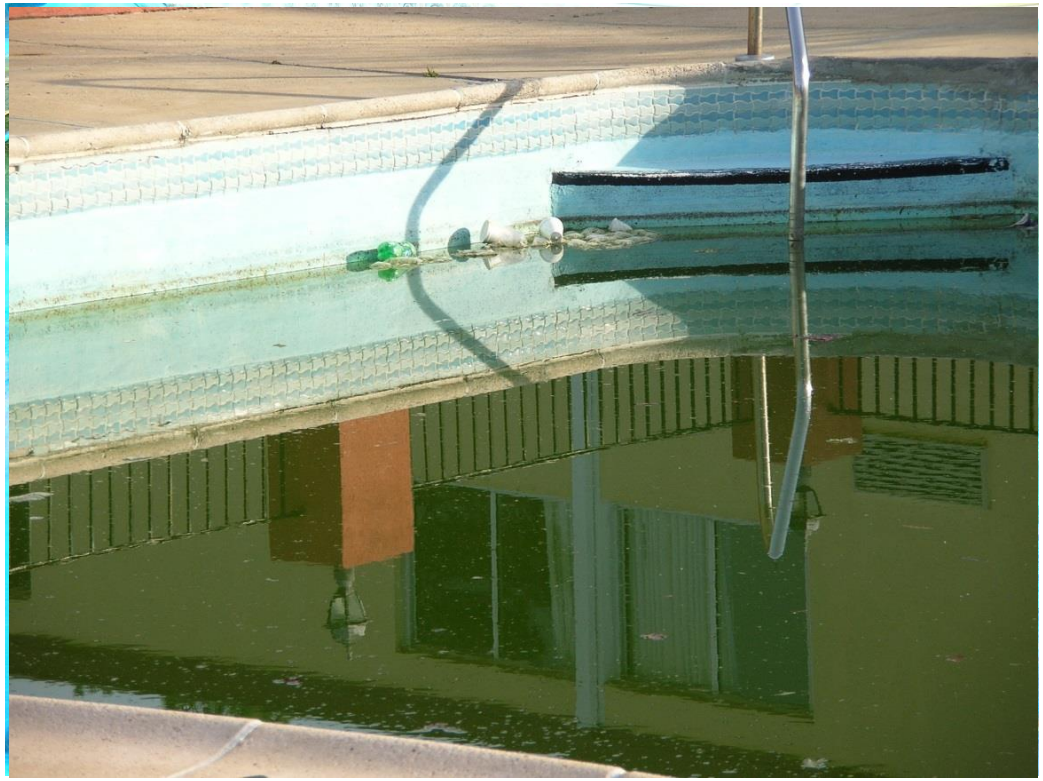
“Tip & Toss”

- Empty or (preferably) eliminate temporary water sources.
- Who is responsible for it?
- What can be done by the property occupant/owner?
- What can/should be done by governmental agencies?

Containers used as breeding sites by *Aedes albopictus*

Misc. Containers			Buckets			Dishes beneath plants			Tree Holes		
No. +	No. -	% Pos	No. +	No. -	% Pos	No. +	No. -	% Pos	No. +	No. -	% Pos
92	56	62.2	24	15	61.5	33	15	68.8	7	1	87.5
Plastic Film			**Bird Baths**			**Tires**			**Toys**		
No. +	No. -	% Pos	No. +	No. -	% Pos	No. +	No. -	% Pos	No. +	No. -	% Pos
8	3	**72.7**	8	19	29.6	11	9	55.0	8	6	61.5

Source Reduction



Source Reduction

- Drain abandoned/unused swimming pools (including kids' pools)
- Tree holes (fill with expanding foam; not concrete)

LARVICIDING

Mosquito Breeding Sites

Mosquito Breeding Sites

Mosquito Breeding Sites

Larviciding Programs

- Target sites that are too difficult drain or refill with water by design.
- Use bacterial pesticides (Vectobac®) or IGRs (insect growth regulator - Altosid®)

sunandshadegardening.com

Larvicides: granules by hand and backpack

- Short-term (days to a week)
- Long-term (1-6 months)

A Large Scale Biorational Approach Using *Bacillus thuringiensis israeliensis* (Strain AM65-52) for Managing *Aedes aegypti* Populations to Prevent Dengue, Chikungunya and Zika Transmission

- Aerially released Vectobac WG droplets can penetrate through dense canopy to reach small containers.

Pruszynski CA, Hribar LJ, Mickle R, Leal AL (2017) PLoS ONE 12(2): e0170079.

78

Larvicides: large-scale liquid by truck

79

Mosquito Predators

- *Gambusia* ("Mosquito fish") can be introduced into permanent water sources (pond or lake)
- Need NCWRC permit if the pond/lake connects to a public waterway
- Aggressive – eats other fish, aquatic insects
- Can displace native fish
- Winter die-off can be a problem in some areas

ADULTICIDING

Adulticide Treatments for Mosquitoes

"Barrier Spray" adulticides in residential areas

- What is the source of your mosquito populations?
- Ideal for removing "old" infected adult mosquitoes
- Provides longer term reduction in populations
- Commonly done by private contractors
- Done in disease situations and for special events by gov't
- Higher environmental cost

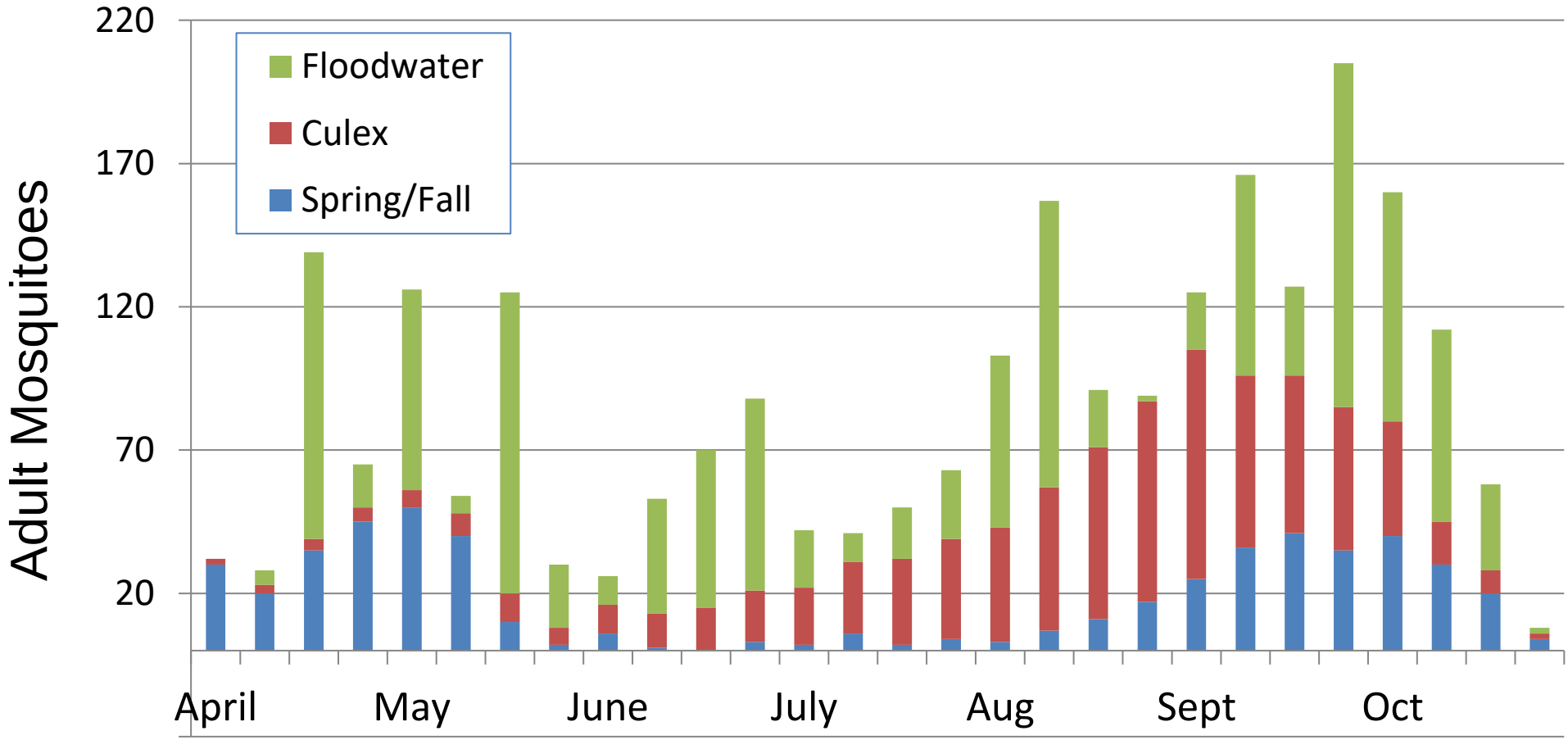

STIHL
DO NOT SPRAY
FLOWERING VEGETATION
www.getyouryardback.com

Adulticide Treatments for Mosquitoes

ULV (ultra low volume) insecticides in residential areas

- What is the source of your mosquito populations?
- Ideal for removing “old” infected adult mosquitoes
- Provides temporary reduction in populations
- New adults will emerge over time
- Requires repeated applications for some species

Seasonal Population Differences

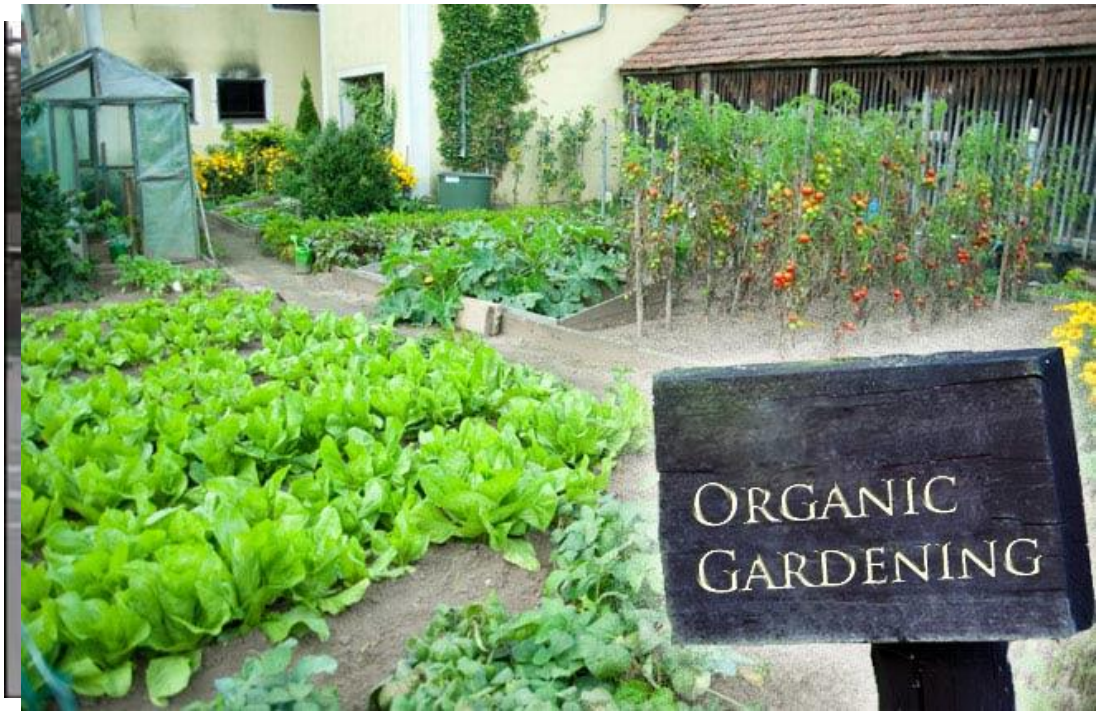


Chemical Control Requires Planning AND Communication

- Chemically sensitive individuals
- People objecting to any spraying
- Honey bees and other pollinators

Chemical Control Requires Planning AND Communication

- Outdoor pets
- Children's toys
- Organic gardens

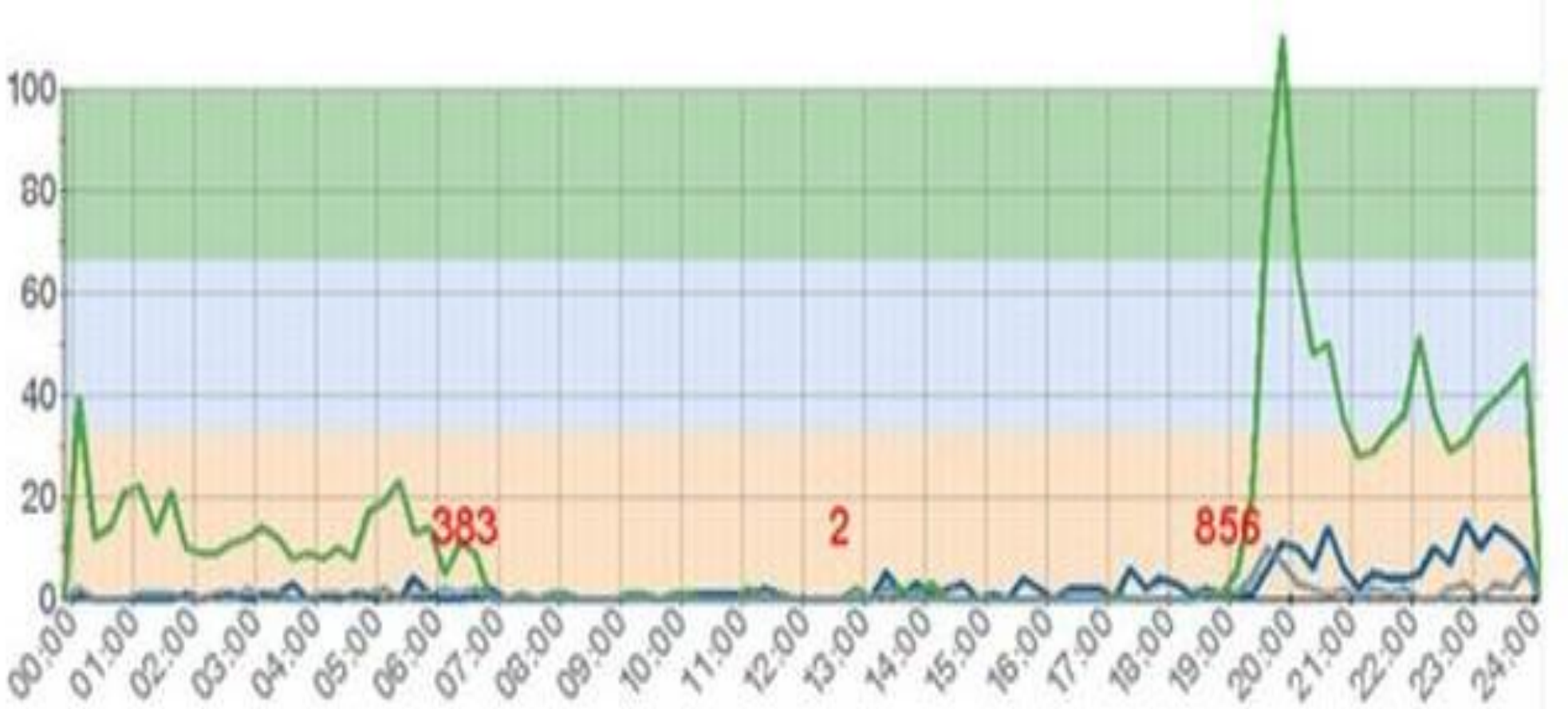


EFFECTS OF BIOLOGY ON SUPPRESSION EFFORTS

Flight Range Differences

Source: Google Earth

Human Host Seeking Time Differences



BG-Counter Results -- Trap O38
Marie Hemmen, New Hanover County, NC
(424 ml CO2/min)

University Collaboration Updates

Journal of Medical Entomology, 2018, 1–13

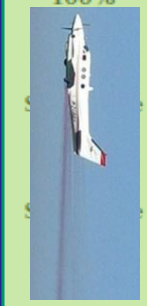
Vector Control, Pest Management, Resistance, Repellents

Research

Evaluation of Insecticide Resistance in *Aedes albopictus* (Diptera: Culicidae) in North Carolina, 2017

Stephanie L. Richards, Avian V. White, Brian D. Byrd, Michael H. Reiskind, and Michael S. Doyle

Table 2. Comparative susceptibility/resistance of *Aedes albopictus* North Carolina mosquito populations to eight active ingredients based on CDC guidelines

County (generation)[a]	Bifenthrin	Permethrin	Sumethrin + Prallethrin	Deltamethrin	Tau-fluvalinate	Chlorpyrifos	Malathion	Naled
Buncombe (F_2)	**Susceptible 100% N = 33[b]**	**Susceptible 100% N = 33**	**Susceptible 100% N = 25**	**Susceptible 100% N = 33**	**Susceptible 97% N = 29**	Developing Resistance 92% (83–100%) N = 25	Developing Resistance 96% (89–100%) N = 51	**Susceptible 100% N = 25**
Transylvania (F_1)	**Susceptible 98% N = 50**	**Susceptible 100% N = 55**	**Susceptible 100% N = 51**	**Susceptible 100% N = 51**	**Susceptible 100% N = 54**	Resistant[c] 49% (32–66%) N = 49	Developing Resistance 90% (80–100%) N = 50	**Susceptible 100% N = 47**
Forsyth (F_3)	**Susceptible 100% N = 17**	**Susceptible 100% N = 18**	**Susceptible 100% N = 25**	**Susceptible 100% N = 26**	**Susceptible 100% N = 44**	Resistant[c] 22% (7–35%) N = 19	Developing Resistance 94% (86–100%) N = 34	**Susceptible 100% N = 24**
Mecklenburg (F_4)	**Susceptible 100% N = 15**	**Susceptible**	**Susceptible**	**Susceptible**		Resistant[c] 40% (23–57%) N = 15	Resistant[c] 10% (0–22%) N = 18	**Susceptible 100% N = 15**
Wake (F_2)	**Susceptible 100% N = 38**	**Su**		**le**		Resistant[c] 63% (44–78%) N = 41	Developing Resistance 94% (87–100%) N = 37	**Susceptible 100%**
Brunswick (F_2)		**Su**		**le**	**Resistant[c] 66% (59–89%) N = 34**	Resistant[c] 39% (29–63%) N = 36	Resistant[c] 32% (16–47%) N = 35	
Pitt (F_1)		**Developing Resistance 91% N = 47**	**Susceptible 100% N = 48**	**Susceptible 100% N = 43**	**Susceptible 100% N = 55**	Resistant[c] 28% (13–43%) N = 50	Resistant[c] 62% (44–78%) N = 54	

Susceptible populations in bold.

[a]All mosquitoes in control bottles remained alive for the duration of the bioassay. Three to four control bottles and four treatment bottles were included for each bioassay.

[b]*N* = number of mosquitoes tested including all replicates for each AI, location, and mosquito population. Percent is an average of rates between bottles. 95% confidence intervals are included for populations classified as resistant or developing resistance.

[c]Significant (95% confidence interval boundaries below CDC 'Resistant' threshold). Generation of field colony is listed; mosquitoes propagated in the laboratory for 1–4 generations prior to bioassay.

Applies to Ae. albopictus "Asian tiger mosquito" ONLY

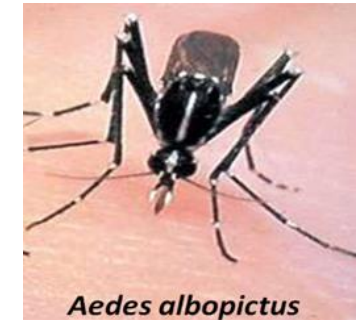


Table 4. Comparative susceptibility

Source	Species	Malathion		Etofenprox		Bifen.	Perm.	Phen	Deltamethrin.	
		100 µg/ml	250 µg/ml	6 µg/ml	15 µg/ml	12.6 µg/ml	15 µg/ml	23 µg/ml	5 µg/ml	10 µg/ml
St. Paull MN	Cx Pip (F_0)	Resistant 64% N=17	Possible Resistance 94% N=17	Resistant 0% N=17	Resistant 29% N=17	Possible Resistance 89% N=17	Resistant 48% N=21	Possible Resistance 90% N=28	Possible Resistance 89% N=16	Susceptible 100% N=17
York, PA	Cx Pip (F_0)	Resistant 61% N=28	Possible Resistance 93% N=27	Resistant 0% N=31	Resistant 30% N=17	Possible Resistance 81% N=25	Resistant 56% N=18	Susceptible 100% N=23	Possible Resistance 95% N=23	Susceptible 100% N=40
Palmetto Fl	Cx Nigr (F_0)	Resistant 0% N=42	Resistant 13% N=33	Resistant 4% N=31	Resistant 31% N=39	Resistant 37% N=36	Resistant 61% N=38	Resistant 37% N=33	Resistant 59% N=37	Resistant 75% N=36
Savannah GA	CxPip/Q (F_0)	Resistant 11% N=19	Resistant 19% N=21	Resistant 5% N=22	Resistant 0% N=20	Resistant 0% N=29	Resistant 3% N=32	Resistant 14% N=26	Resistant 14% N=50	Resistant 35% N=44
Slidell LA	CxP/Q (F_0)	Resistant 0% N=22	Resistant 0% N=22	Resistant 0% N=15	Resistant 0% N=20	Resistant 0% N=24	Resistant 0% N=20	Resistant 0% N=24	Resistant 0% N=24	Possible Resistance 90% N=22
Winterville NC	CxPip/Q	Resistant 40% N=15	Resistant 67% N=15	Resistant 53% N=16	Resistant 78% N=14	Resistant 72% N=14	Resistant 42% N=12	Resistant 72% N=15	Resistant 50% N=14	Possible Resistance 87% N=15
Greenville NC	CxPip/Q	Resistant 11% N=18	Possible Resistance 82% N=17	Resistant 21% N=18	Resistant 0% N=19	Resistant 0% N=18	Resistant 6% N=22	Resistant 16% N=19	Resistant 63% N=16	Resistant 58% N=16
Columbia SC	CxQ	Resistant 70% N=29	Resistant 58% N=24	Resistant 0% N=35	Resistant 3% N=33	Resistant 11% N=36	Resistant 0% N=34	Resistant 0% N=19	Resistant 19% N=38	Resistant 56% N=32
Beaumont TX	CxQ	Resistant 0% N=16	Resistant 0% N=18	Resistant 0% N=31	Resistant 0% N=24	Resistant 35% N=18	Resistant 26% N=26	Resistant 30% N=21	Possible Resistance 81% N=33	Resistant 63% N=16
Dallas, TX	CxQ	Resistant 12% N=68	Resistant 78% N=44	Resistant 4% N=64	Resistant 40% N=43	Resistant 50% N=	Resistant 37% N=46	Resistant 39% N=42	Resistant 56% N=41	Resistant 82% N=42
Dallas, TX	CxQ	Resistant 53% N=60	Resistant 67% N=52	Resistant 0% N=36	Resistant 2% N=42	Resistant 6% N=46	Resistant 14% N=42	Resistant 12% N=48	Resistant 35% N=45	Resistant 72% N=60
Salt Lake City UT	Cx Pip	Resistant 59% N=47	Resistant 30% N=50	Resistant 0% N=32	Resistant 21% N=43	Resistant 16% N=33	Resistant 22% N=26	Resistant 23% N=30	Possible Resistance 87% N=39	Possible Resistance 97% N=38

N indicates the number of mosquitoes tested including all replicates for each AI, location, and species. Susceptible populations in bold.

Mortality:

Susceptible (98-100%)

Possibly Resistant (80-97%)

Resistant (<80%)

Applies to Culex spp. mosquitoes ONLY

Stephanie L Richards, Jo Anne G. Balanay, Avian V. White, Joe Hope, Kurt Vandock, Brian D. Byrd, and Michael H. Reiskind Journal of Medical Entomology, XX(X), 2017, 1-10 DOI 10.1093/jme/tjx198

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95