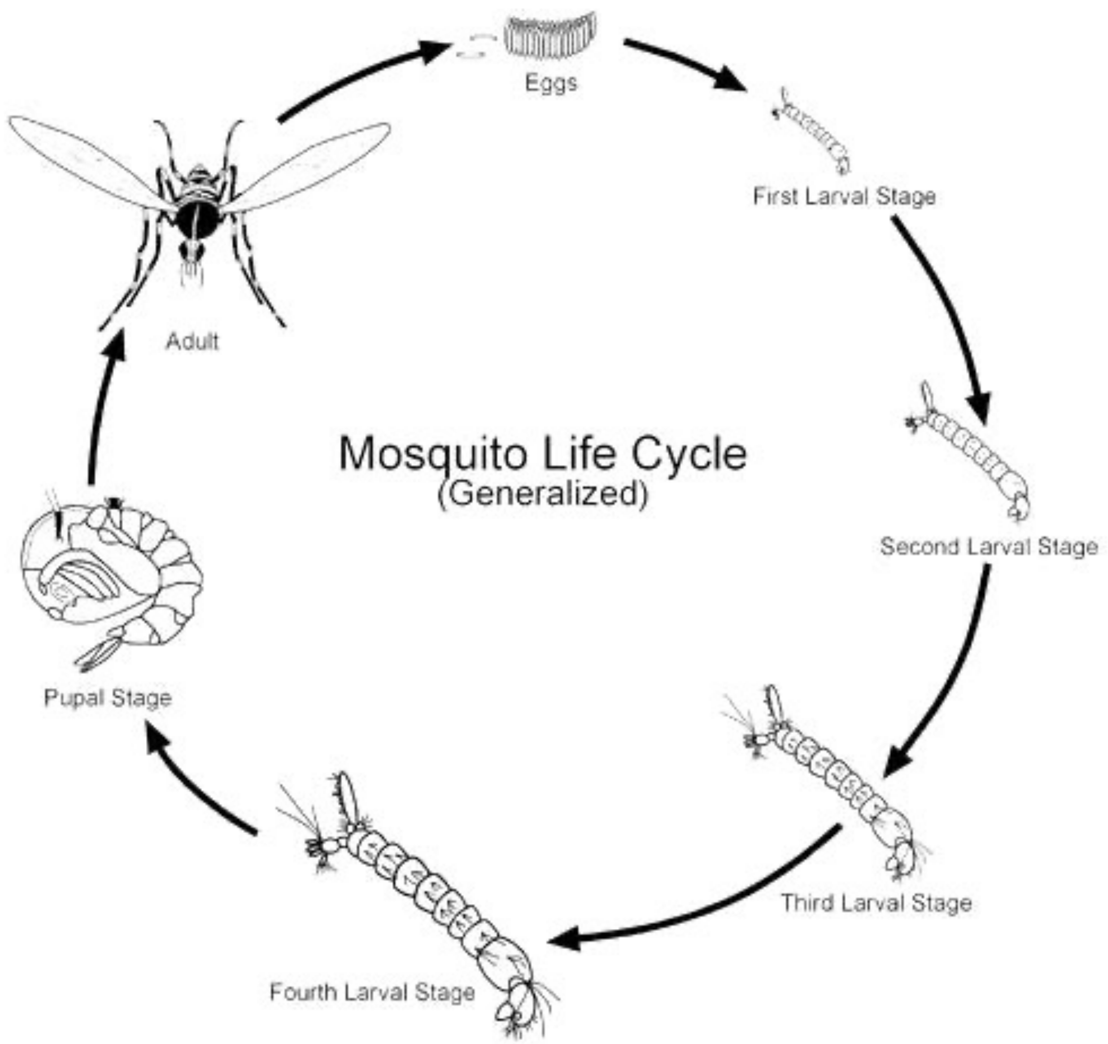
Integrated Mosquito Management

GMCA/ Rosmarie Kelly / Oct 19, 2023

Mosquito Life Cycle

- Egg
- Larva
    - A variety of control options
- Pupa
    - Limited control option
- Adult
    - ULV spray
    - Thermal fogging
    - Barrier spray



Mosquito Control Goals

The 4 overlapping aims of mosquito control are to:

- Keep mosquito populations at acceptable densities
  - Prevent mosquito bites
  - Minimize mosquito-vertebrate contact
- Reduce the longevity of female mosquitoes

Integrated Mosquito Management

- Surveillance – larval & adult
    - Trapping
    - Landing rates
    - Complaints
- Source Reduction – tip & toss
- Larviciding
    - Biological
    - Chemical
- Adulticiding
    - ULV
    - Thermal fogging
    - Barrier spray
- Education & Communication
    - Neighborhood door-to-door
    - Community presentations
    - Media events
    - other
- Mapping
    - A picture is worth 1000 words
    - There are a lot of mapping options out there
- Record Keeping – legal reasons

A Useful Approach

- Proactive Measures
  - Inspection: breeding sites, resting areas, potential concerns
  - Identification: area needing treatment, mosquito species, and any current breeding sites
  - Source reduction: eliminating breeding sites and the success rate of mosquito breeding on property
  - Larvicide treatment: targets standing water or areas where potential breeding exists
- Reactive Measures
  - Adulticide treatment: targets adult mosquito resting areas (barrier spray) or host seeking (ULV)

Mosquito Surveillance

- Trap types
  - Gravid traps attract container- breeding mosquitoes that have had a blood meal and are looking for a place to lay eggs.
  - Light traps attract mosquitoes looking for a blood meal.
- Mosquitoes caught in these traps are counted and identified, then (when possible) pooled according to date, species, and location and sent to a lab for arboviral testing.
- Data sent to DPH are used in summaries sent out to collaborators and others.

Most Commonly Used Trap Types

GRAVID TRAP

This trap selectively attracts container-breeding mosquitoes that lay eggs in stagnant organically rich water. These mosquitoes will have had at least one blood meal, so may possibly have picked up an infected blood meal if there are WNV-positive birds in the area.

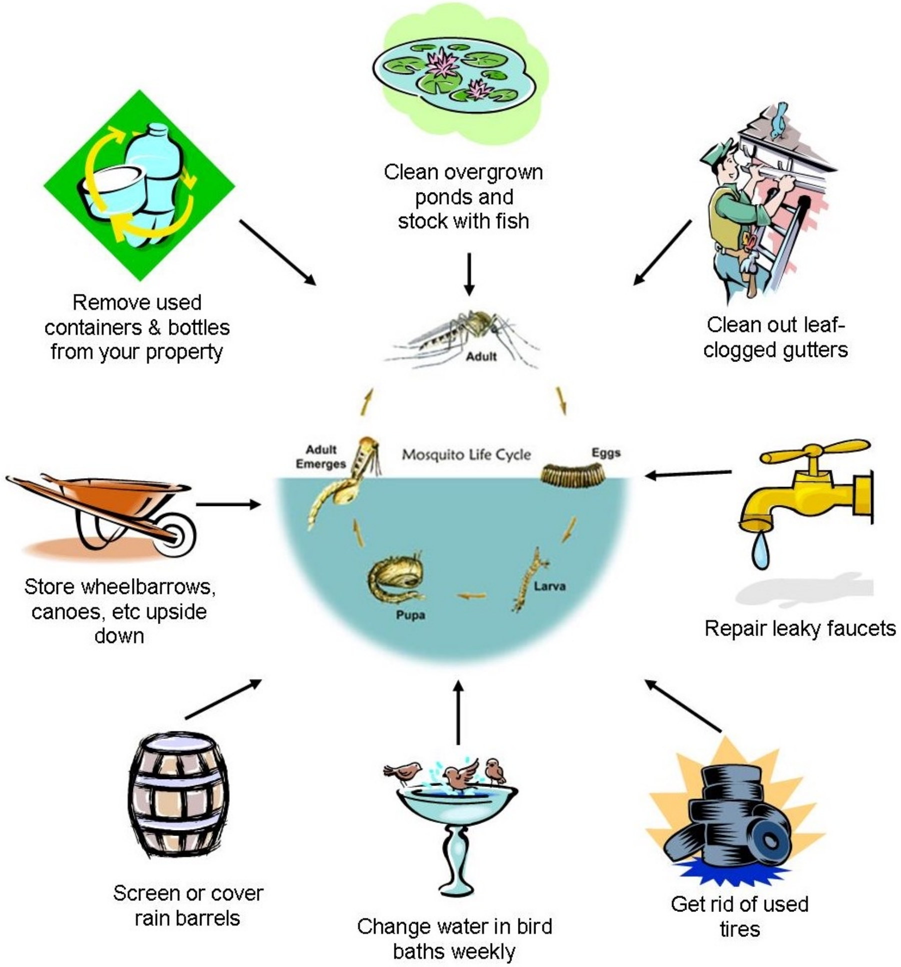
LIGHT TRAP

Light traps attract mosquitoes looking for a blood meal. The attractants used are light and CO_2, in the form of dry ice or as compressed gas in canisters. These traps are useful for providing information about the mosquito species found in the area under surveillance. Because they attract mosquitoes looking for a blood meal that may have just emerged and never had a blood meal previously, the likelihood of finding virus in these mosquitoes is much reduced.

Source Reduction - Eliminate Standing Water

On July 5, 2013, there were 6,346 immature mosquitoes in this rainwater-filled frying pan.

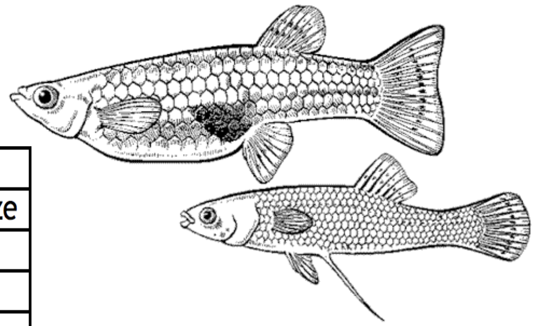
Other Problem Sites



Controlling Mosquito Larvae

- Larvicide treatment of breeding habitats help reduce the adult mosquito population in nearby areas
- Biocontrol
    - Stock mosquitofish

General Stocking Recommendations	
Ornamental pond (depending on size)	35 -100 fish site depending on size
Storm water facilities	1000 fish per acre
Drainage ditches (3-6 ft. wide)	1 fish/every 3 ft. of ditch length
Sedimentation ponds, wastewater ponds	1000 fish per acre



- Chemical control
    - Larvicides include biorational insecticides, such as the microbial larvicides *Bacillus sphaericus* and *Bacillus thuringiensis israelensis*, as well as spinosad
    - Larvicides also include other pesticides, such as temephos (OP), methoprene (IGR), oils, and monomolecular films

Controlling Adult Mosquitoes

- Treatment of adult mosquitoes (adulticiding) is the most visible practice exercised by mosquito control operations.
- This option is usually reserved for managing mosquito populations that have reached the adult stage in spite of efforts to intervene in the larval stage or when such treatments have not, or cannot, be conducted.

Adulticides can be applied as area sprays for rapid knockdown and kill, or barrier sprays for longer control.

ULV Area Sprays

- Mosquito adulticides are usually applied as ultra-low volume (ULV) sprays.
- Adulticides are applied when mosquitoes are active.
- ULV sprayers dispense very fine aerosol droplets that stay aloft and kill flying mosquitoes on contact.
- ULV applications involve small quantities of pesticide active ingredient in relation to the size of the area treated, typically less than 3 ounces per acre, which minimizes exposure and risks to people and the environment.

Thermal Fogging

- Mosquitoes must be present
- The fog created is very thick
- The fog is very susceptible to wind and thermal air currents
- Thermal fogs are good at penetrating heavy vegetation
- Same active ingredients as ULV but with an oil carrier – product must be labeled for use in a thermal fogger

Barrier Treatments

- Mosquitoes are at rest most of the time on plants and protected surfaces
- Mosquitoes feed on plant sugars
- Treating plant surfaces reduces adult mosquito numbers
- Product should NOT be dripping off the surfaces
- Product should NOT be applied to flowers to protect pollinators

Note: Mosquitoes flying in from outside don't always rest on the treated plant surfaces so may not be affected by the barrier spray

This method is primarily used by commercial applicators.

What pesticides are available for adulticiding?

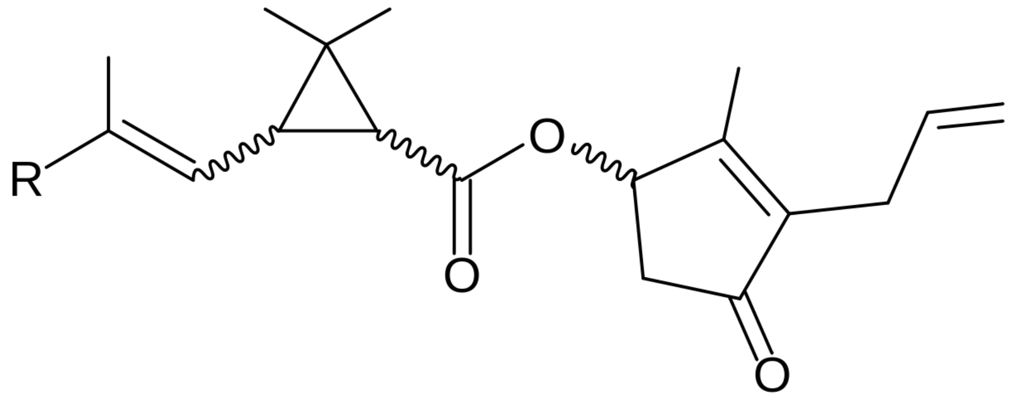
Organophosphates

- Naled (usually only by aircraft)
- Malathion

Pyrethroids

- Permethrin
- Resmethrin
- Sumithrin
- Bifenthrin
- Deltamethrin
- Prallethrin

Zenivex (etofenprox) - non-ester pyrethroid



The label is the law! Not all products are labeled for all application types, so it is important to read and follow the label before using any pesticide.

Pesticide active ingredients types should be rotated at least yearly to reduce pesticide resistance. This is extremely difficult to do in practice.

Why not just larvicide?

- Larviciding is not effective against adult mosquitoes.
- The detection of arboviral-positive adult mosquitoes means that there is an increased risk of human disease in the area.
- The mosquito that carries WNV is a container breeder and is difficult to control using just larvicide.
- Are all items in your yard that can hold water even temporarily dumped out at least weekly or stored appropriately? What about vacant lots and commercial sites?
    - Without the help of <u>everyone</u> in the community, larviciding can not prevent the emergence of adult container-breeding mosquitoes.

Detailed information on WNV vector management experience

Table 6. Detailed information on WNV vector management experience presented by case study

Case Studies	Types of interventions	Timing of interventions	Efficacy evaluation (*Culex* spp.)	Impact on WNV circulation levels (circulation in mosquitoes, enzootic circulation, human cases)
1. St. Tammany Parish, LA, USA [16]	Intensive larviciding in combination with ground and aerial ULV adulticiding	2002 season - Intensive larviciding since March (46% increase compared to the five-year average). - Initiation of ground and aerial ULV adulticiding in June following the first human case (63% and 450% increase, respectively, compared to the five-year average).	- Comparing adult mosquito abundance, infection rates, chicken seroconversions before and after adulticiding treatments across the season. - Comparing mosquito larval abundance before and after larviciding treatments across the season. - Comparing monthly adult and larval mosquito abundance means from 2002 with the five-year abundance average for that period.	- Despite the early intensification of larviciding operations in March, WNV circulation levels increased in early June and spread rapidly across the region. - Larval abundance indices showed an eight-fold decline against the five-year average two-fold decrease. - Adulticiding treatments in combination with larviciding treatments resulted in a 10-fold reduction in *Culex* abundance from May to August. This reduction was not observed in the five-year average abundance curves, which in contrast remained constant. - Rapid decrease in human cases in August followed the rapid decline of *Culex* populations (this pattern was not observed in other regions of the state).
2. Sacramento and Yolo Counties, CA, USA [17-20]	- Intensive larviciding and public education. - Ground ULV adulticiding. - Aerial ULV adulticiding.	2005, 2006, 2007 seasons - Intensive larviciding and public education since March. - Initiation of ground ULV adulticiding June-July (in response to infection rates). - Aerial ULV adulticiding late July-August (in response to human cases).	2005, 2006, 2007 seasons - Mosquito abundance, infection rates and chicken seroconversions were used to monitor overall efficacy of control operations across the season. For larviciding/public education no control area was available (all areas with WNV activity were treated). Non-treated areas were available for aerial ULV adulticiding treatments, allowing for additional comparisons between treated and untreated blocks (pre- and post-trapping, sentinel cages). 2005 season - Aerial ULV adulticiding impact on human cases was quantified by comparing proportion and incidence of human cases between treated and untreated blocks.	- Despite the intensive larviciding, public education and ground adulticiding [illegible] (for three consecutive years) the district reached epidemic levels in la[illegible] August (as evidenced by high infection rates, chicken seroco[illegible] cases). - Evidence for all three seasons (200[illegible] adulticiding interventions sig[illegible] infection rates and positive mosquito pools of *Culex* [illegible] within the treatment areas. - Evidence from the 2005 season indicated that aerial ULV adulticiding reduced the number of human cases within the treatment sites compared to the untreated sites and that the odds of infection after spraying were six times higher in the untreated areas compared to the treated ones.
3. Coachella Valley, CA, USA [21]	- Routine larviciding. - Ground ULV adulticiding and aerial ULV adulticiding (singly or in combination).	- Routine larviciding was conducted for all three seasons from early spring. - 2004 season: intensive ground ULV adulticiding started in June. - 2005 season: ground and aerial ULV adulticiding started in June and July, respectively, in response to human cases. - 2006 season: Early (April) aerial ULV adulticiding (with some spot ground ULV treatment) in response to positive mosquitoes.	- Comparing adult mosquito abundance and WNV infection rates between treated and untreated (control) areas, before and after ground and aerial ULV adulticiding treatments. - Geometric means of adult mosquito abundance were compared across four years (2003–2006) with different vector control strategies.	2004 season: Despite routine larviciding and additional intensive ground adulticiding treatments in early spring, WNV dispersed throughout the valley as evidenced by positive mosquito pools, chicken seroconversions and human cases. 2005 season: Interventions were conducted late and virus could not be contained but allowed for optimisation of aerial adulticiding methods. 2006 season: - Aerial ULV adulticiding treatments resulted in significant reductions of adult abundance and WNV activity, as evidenced by the reduced WNV infection rates in mosquitoes and seroconversion rates in sentinel chickens post-treatment. - Geometric abundance means in 2006 were significantly lower than in 2003, 2004, and 2005 seasons when early adulticiding was not conducted. These patterns were not observed in adult mosquito populations from the control area, where *Culex* sp. abundance and WNV activity was greater in 2006 than in previous years.

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mosquito pools of *Culex* spp. mosquitoes within the treatment areas.

ECDC Technical Report
Vector control practices and strategies against West Nile virus

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4. Central Macedonia Region, Greece [22]	- Routine ground and aerial larviciding targeting urban/suburban and rural/agricultural areas, respectively. - Aerial ULV adulticiding.	2011 season - Routine control treatments were initiated in May. - Despite the detection WNV circulation in late June (mosquitoes, sentinel chickens) aerial ULV was conducted in August in response to human cases.	- Comparing adult mosquito abundance and sentinel chicken seroconversions before and after the treatments between treated (rural areas of West Thessaloniki) and untreated areas (rural areas East Thessaloniki).	- Aerial ULV adulticiding interventions significantly reduced *Culex* spp. abundance and sentinel chicken seroconversion rates within the treatment areas. - No such reductions were observed in the untreated areas of the city where, on the contrary, an increase in abundance was observed immediately post-treatment followed by an increase in chicken seroconversions.
5. North Central Texas (Collin, Dallas, Denton, Tarrant Counties) TX, USA [23,24]	- Ground larviciding and ground ULV adulticiding. - Aerial ULV adulticiding.	2012 season - Ground larviciding and adulticiding were applied in response to increased WNV circulation in July. - Aerial ULV adulticiding was applied in response to human cases in August.	- Aerial ULV adulticiding impact on humans cases was evaluated by calculating incidence rate ratios (IRRs) in treated (Dallas, Denton) and untreated (Collin, Tarrant) counties by comparing incidence before and after aerial spraying.	- Aerial ULV adulticiding was associated with a reduction in WNV neuroinvasive disease. Given that aerial spray events were conducted late during the outbreak, disease incidence decreased during the after spray period in both treated and untreated areas. However, the relative change was significantly larger in areas sprayed by air.
6. City of Chicago, IL, USA [25]	Ground ULV adulticiding (single, versus sequential applications)	2005 season - Treatments were conducted in July-August in areas with high WNV infection rates in mosquitoes.	- Comparing adult mosquito abundance pre and post treatments and across treated and control areas.	- Significant *Culex* population reductions were observed post ground ULV treatments. Specifically, two sequential ULV treatments decreased m[illegible] abundance by 54%, whereas mosquito abundance increased by [illegible] sprayed areas. - The highest reduction was observed at the trap sites [illegible] [illegible]ential treatments, indicating that serial treatments are m[illegible] single applications. - WNV minimum infection rates varied w[illegible] treated and untreated areas, indicating that ground adulticide tre[illegible] had no direct effect on WNV infection rates.
7. Atlanta (Dekalb and Fulton Counties), GA, USA [26]	Larviciding applications targeting catch-basins.	Two different timing scenarios were tested: - 2015 season: larvicides were applied during the epidemic period of WNV (July–September). - 2016 season: larvicides were applied at the beginning of *Culex* spp. breeding season (March–May).	- Comparing abundance of mosquito larvae, pupae and resting adults associated with treated catch basins before, during and after treatments in comparison with abundance data from untreated (control) catch basins. - Comparing adult mosquito abundance trapped in treated versus untreated areas before, during and after the applications, in an attempt to link larval productivity to adult population collections. - Comparing WNV infection rates in adult mosquitoes (from both catch basins and traps) in treated and untreated areas before, during and after treatments.	- More than 90% reducti[illegible] larval/pupal collections in treated catch basins was recorded. - No significant reduction was observed in adult *Culex* spp. populations collected with traps in proximity to treated catch basins or in adults collected resting in catch basins. - WNV infection prevalence between treated and untreated sites was similar. - On the scale and frequency applied in this study, larval control alone did not lead to meaningful reductions in adult populations and WNV prevalence.
8. Fort Collins, CO, USA [27]	- Ivermectin-treated bird feed stations.	2017 season - Field treatments commenced in early June and continued until early September in areas with high circulation of WNV.	- Comparing adult mosquito abundance between control and treated sites. - Comparing adult mosquito abundance between treated sites and historical data from the same sites from 2006-2016 (no treatment years). - Comparing WNV infection rates/number of WNV-positive pools between treatment and control sites.	- Birds captured and tested around the treated bird feeders had detectable levels of ivermectin in their blood. - *Culex* abundance was similar between treated and untreated sites and between treated and untreated seasons. - No significant difference was observed in the number of positive mosquito pools between treated and untreated sites.

With larviciding of catch basins only, > 90% reduction in larvae/pupae was recorded. No significant reduction was observed in adult *Culex* spp. populations collected resting in catch basins. WN infection in treated and untreated area was similar. Larval control alone did not lead to meaningful reductions in adult populations and WNV prevalence.

ECDC Technical Report
https://www.ecdc.europa.eu/sites/default/files/documents/Vector-control-practices-and-strategies-against-West-Nile-virus.pdf

Atlanta Case Study (2015-2016)

- Larviciding in catch basins resulted in more than 90% reduction in larval/pupal collections in treated sites.
- Even though larvicides were effective in suppressing larval and pupal populations, no significant reduction was observed in adult *Culex* spp collected with traps in the proximity of the treated catch basins or in adults collected resting in catch basins.
- In addition, WNV infection prevalence between treated and untreated sites was similar.
- The authors conclude that, on the scale and frequency applied in this study (0.21-0.37 km^2 study sites, larviciding periods 8-14 weeks), larval control alone may not lead to meaningful reductions in adult populations and WNV prevalence.

Connecticut Case Study (2019-2020)

BACKGROUND: Mosquito larval control through the use of insecticides is the most common strategy for suppressing West Nile virus (WNV) vector populations in Connecticut (CT), USA. To evaluate the ability of larval control to reduce entomological risk metrics associated with WNV, we performed WNV surveillance and assessments of municipal larvicide application programs in Milford and Stratford, CT in 2019 and 2020. Each town treated catch basins and non-basin habitats (Milford only) with biopesticide products during both WNV transmission seasons. Adult mosquitoes were collected weekly with gravid and CO2-baited light traps and tested for WNV; larvae and pupae were sampled weekly from basins within 500 m of trapping sites, and *Culex pipiens* larval mortality was determined with laboratory bioassays of catch basin water samples.

RESULTS: Declines in 4th instar larvae and pupae were observed in catch basins up to 2-week post-treatment, and we detected a positive relationship between adult female *Cx. pipiens* collections in gravid traps and pupal abundance in basins. We also detected a significant difference in total light trap collections between the two towns. Despite these findings, *Cx. pipiens* adult collections and WNV mosquito infection prevalence in gravid traps were similar between towns.

CONCLUSION: Larvicide applications reduced pupal abundance and the prevalence of host-seeking adults with no detectable impact on entomological risk metrics for WNV. Further research is needed to better determine the level of mosquito larval control required to reduce WNV transmission risk.

ULV Adulticiding & WNV Reduction

2018 Study in Des Plaines, Illinois

- 4 study sites
  - Catch basins and known breeding sites were larvicided
  - Sites had not had an adulticide treatment
- Treatment
  - Control sites received 1 ULV adulticide application per district policy
  - Treatment sites received 5 sequential weekly ULV adulticide applications
- Data collected
  - Mosquito population data
  - Parity information (age of the mosquito)
  - Viral testing

ULV Adulticiding & WNV Reduction

- Results
  - There were no consistent short-term reductions in *Culex* populations
  - Long-term reduction was also inconsistent
  - Mosquitoes in the treatment areas were significantly younger than those in the control area; younger mosquitoes are less likely to have blood fed
  - WNV infection rates were lower in treatment sites

The goal of an adulticide application is to reduce transmission of pathogens. To reduce WNV transmission, it is beneficial for a large proportion of the mosquito population to be nulliparous (never blood fed/young), even if population abundance remains high.

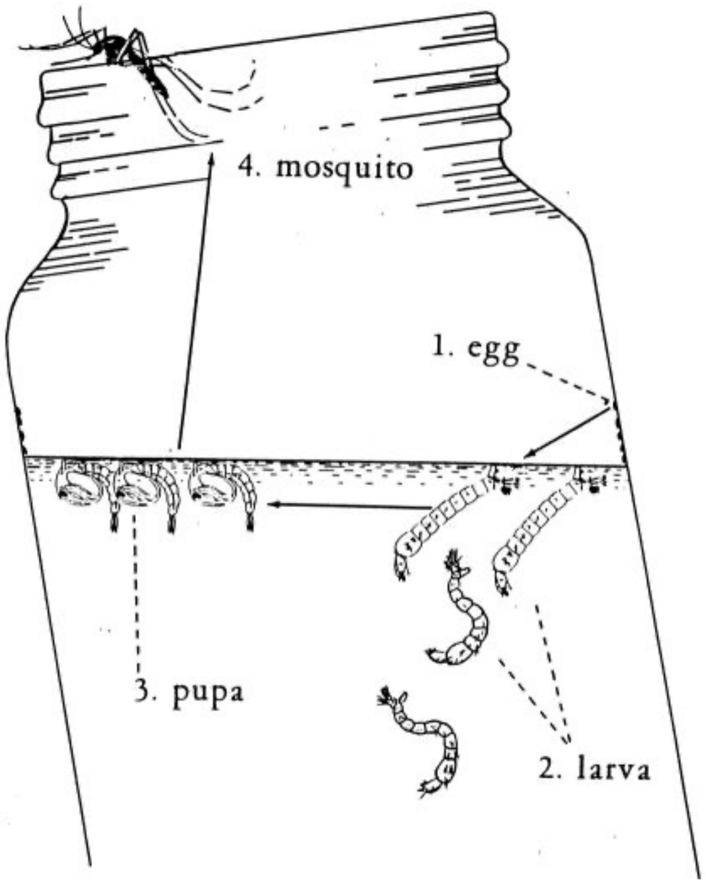
Conclusions & Recommendations

- Consistent WNV surveillance is the driver for vector control decisions
- Source reduction and public education campaigns are essential vector control measures
- Larviciding is important, but has limitations:
    - Patchy applications are likely due to large or inaccessible areas
    - Larviciding alone is extremely unlikely to reduce *Culex* populations enough to prevent WNV transmission
- Other methods, including adulticiding, need to be applied as well to reduce the risk of WNV. This is especially true when source reduction and larval control have failed or are not feasible.

Vector control practices and strategies against West Nile virus

ECDC Technical Report

Disease Prevention



The ability of mosquito control to affect disease transmission depends on:

- The vector involved
- The ability/desire/time to educate the population
- The size of the area to be controlled
- The scope of the control program
- The consistency and amount of funding
- The willingness of Public Health, commercial programs, and Mosquito Control Districts to work together

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ANY QUESTIONS?