Operational Responses to Insecticide Resistance

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Center for Medical, Agricultural, and Veterinary Entomology, Mosquito and Fly Research Unit
Gainesville, FL

RECAP

- IR is increasing worldwide
- Types of resistance mechanisms
- Mechanism matters
  - *Ae. aegypti* vs. *Cx. quinqs*

Responding effectively even when resistance is STRONG

- Integrated Vector Management Plan (IVM)

Table 4.2 Methods used to control vector-borne diseases

Category	Question	Chagas disease	Dengue	Trypanosomiasis	Jap.encephalitis	Leishmaniasis	lymphatic filariasis	Malaria	Onchocerciasis	Schistosomiasis	Trachoma
Environmental	Source reduction		+		+		+	+			
	Habitat manipulation						+	+		+	
	Irrigation management & design				+			+	+	+	
	Proximity of livestock				+			+			+
	Waste management						+				+
Mechanical	House improvement	+			+	+		+			
	Removal trapping		+	+		+					
	Polystyrene beads						+				
Biological	Natural enemy conservation		+		+			+		+	
	Biological larvicides		+		+		+	+	+		
	Fungi										
	Botanicals		+					+			
Chemical	Insecticide-treated bednets	+			+	+	+	+			
	Indoor residual spraying	+				+		+			
	Insecticidal treatment of habitat		+	+			+	+	+		
	Insecticide-treated targets			+							
	Biorational methods		+					+			
	Chemical repellents					+	+	+			

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  - Source reduction
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    - Lido Key
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https://amcdsjc.org/wp-content/uploads/2020/07/Containers-brochure.pdf

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Photo by Heidi Kurpiela (https://www.yourobserver.com/news/2023/may/05/an-exploration-of-lidos-mangrove-tunnels-reveals-heart-of-our-coastal-ecosystem)

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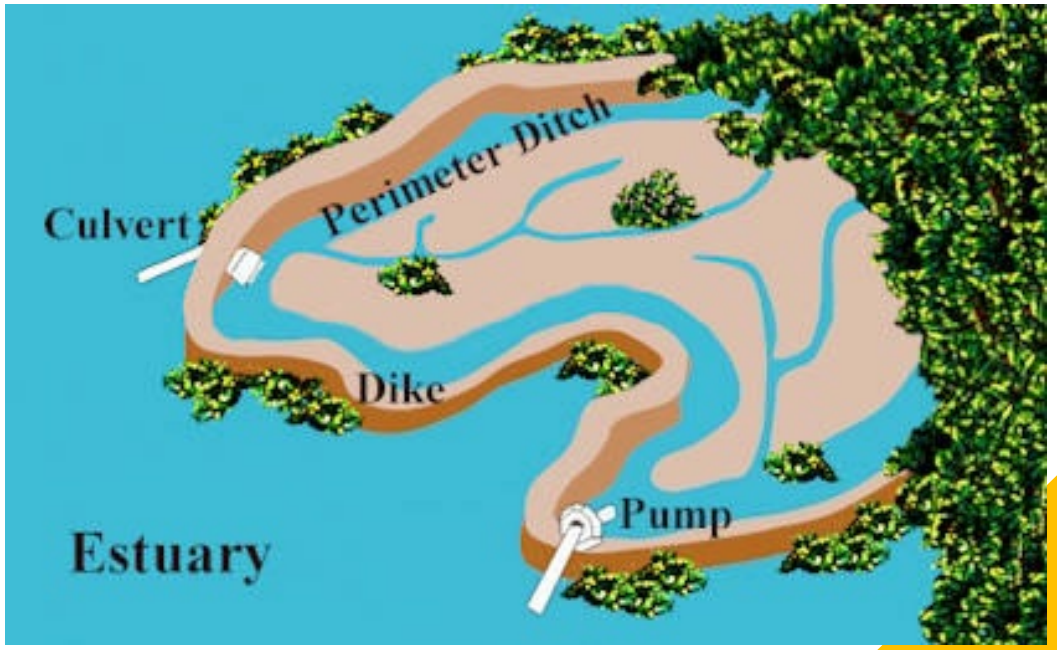

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St Johns NWR Dusky Seaside Sparrow | FWS.gov

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- Integrated Vector Management Plan (IVM)
  - Biological larvicides
    - Target other life stages
    - Bti, *B. sphaericus*
    - Methoprene
  - *Gambusia*

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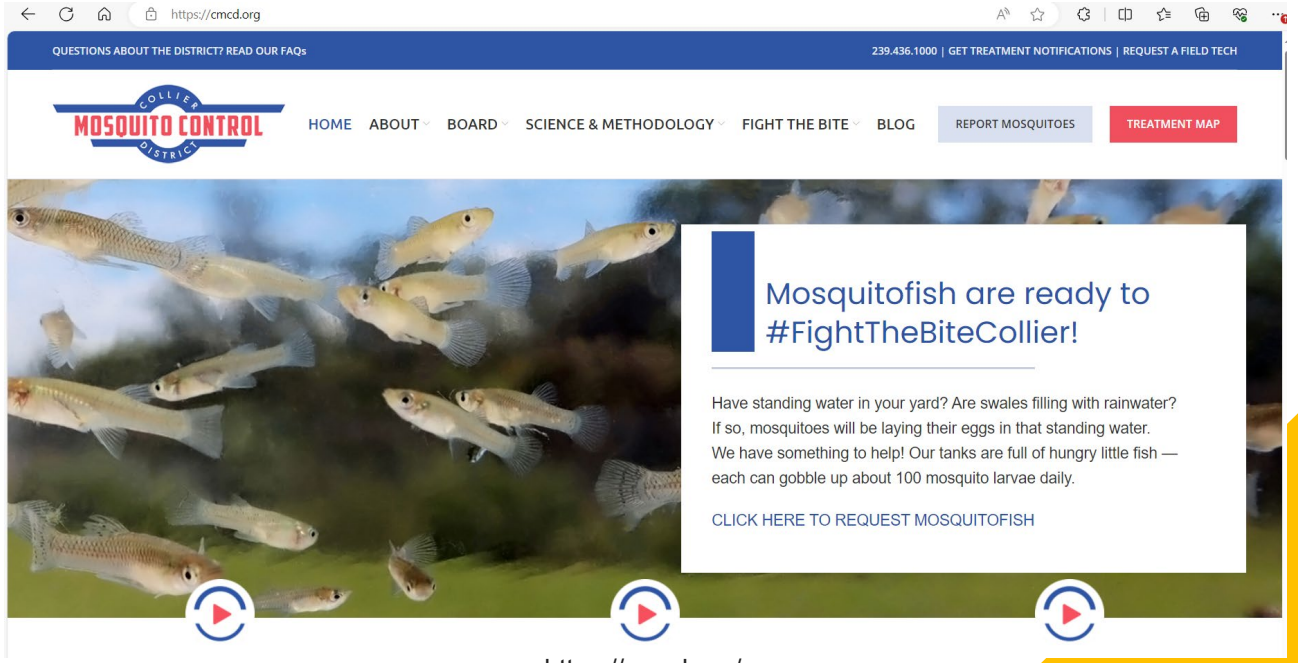

https://cmcd.org/

Responding effectively even when resistance is STRONG

- Integrated Vector Management Plan (IVM)
  - Sterile insect technique
    - Successful against
      - Screw-worm fly (*Cochliomyia hominivorax*)
      - Fruit fly (*Ceratitis capitata* and *Anastrepha ludens*)

By The Mexican-American Commission for the Eradication of the Screwworm - The Mexican-American Commission for the Eradication of the Screwworm, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6996390

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https://eol.org/pages/723951/media

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- Integrated Vector Management Plan (IVM)
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    - Males sterilized by irradiation cannot produce viable sperm
    - Mass release of insects (millions over time)
    - Pilot programs in FL (USDA, Anastasia Mosquito Control)

https://radsource.com/solutions/sterile-insect-technique-sit/

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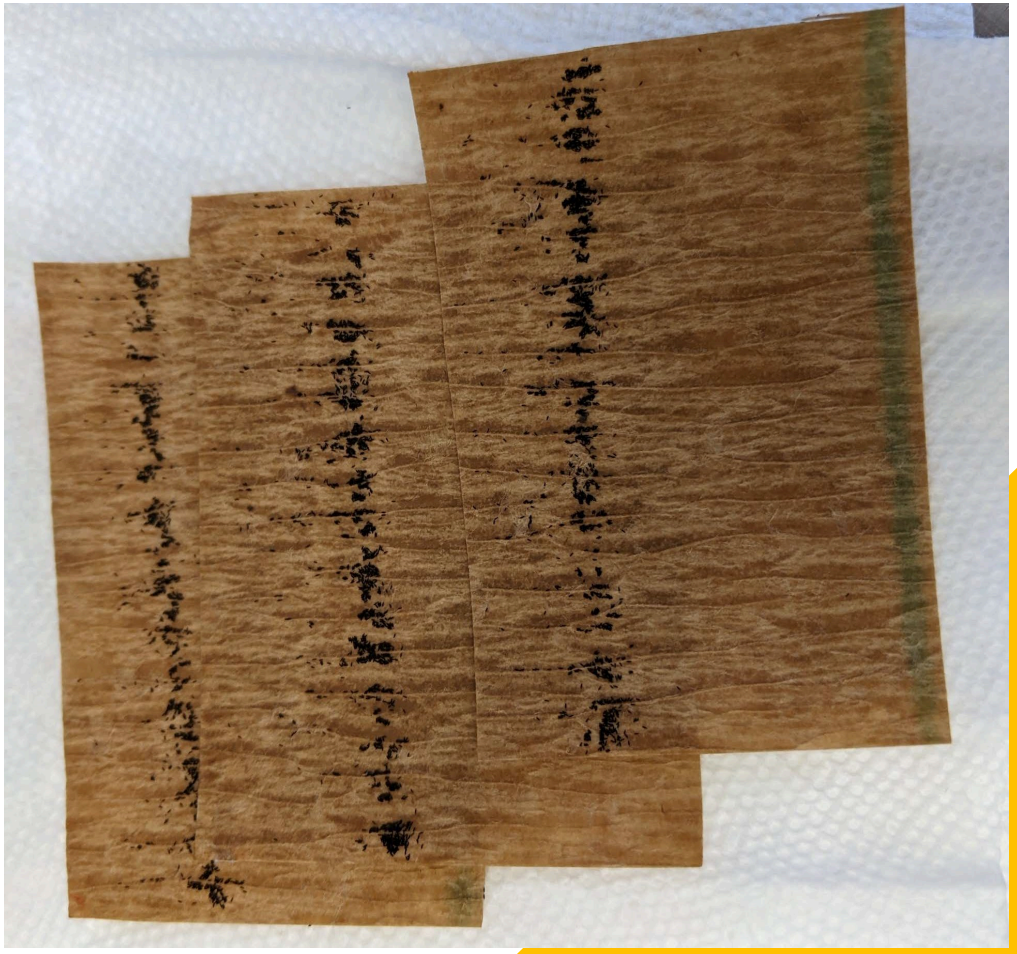

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Moreno, B.J., Aldridge, R.L., Britch, S.C., Bayer, B.E., Kline, J., Hahn, D.A., Chen, C. and Linthicum, K.J., 2021. Preparing irradiated and marked male Aedes aegypti mosquitoes for release in an operational sterile insect technique program. JoVE (Journal of Visualized Experiments), (169), p.e62260.

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- Integrated Vector Management Plan (IVM)
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    - Drawbacks
      - Most effective in small areas
      - Dedicated mass-rearing facility + constant releases = very expensive
      - Impacted by weather

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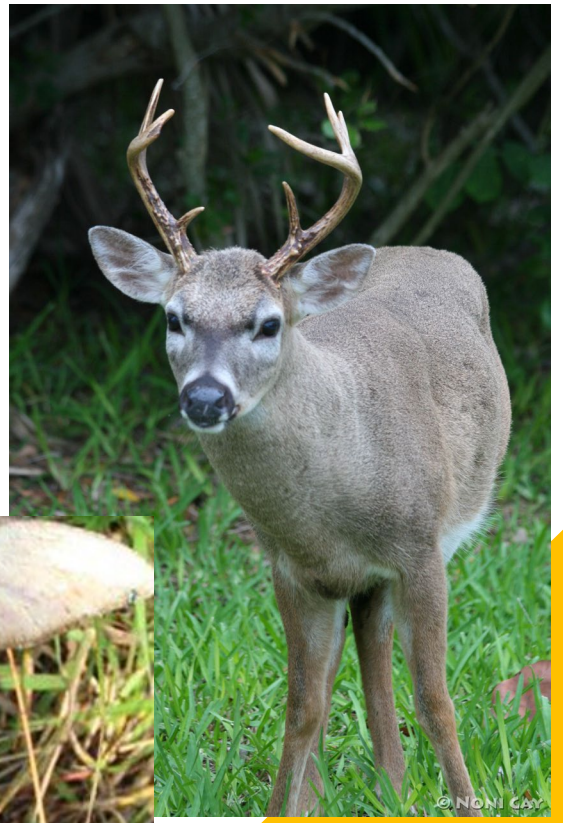

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    - For *Ae. albopictus* (ZAP Males®) or *Ae. aegypti* (Debug)
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ARTICLES
https://doi.org/10.1038/s41587-020-0471-x
nature biotechnology
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Jacob E. Crawford[1✉], David W. Clarke[1], Victor Criswell[1], Mark Desnoyer[1], Devon Cornel[2], Brittany Deegan[2], Kyle Gong[1], Kaycie C. Hopkins[1], Paul Howell[1], Justin S. Hyde[1], Josh Livni[1], Charlie Behling[1], Renzo Benza[1], Willa Chen[1], Karen L. Dobson[3], Craig Eldershaw[1], Daniel Greeley[1], Yi Han[1], Bridgette Hughes[1], Evdoxia Kakani[1], Joe Karbowski[1], Angus Kitchell[1], Erika Lee[1], Teresa Lin[1], Jianyi Liu[1], Martin Lozano[1], Warren MacDonald[1], James W. Mains[3], Matty Metlitz[1], Sara N. Mitchell[1], David Moore[1], Johanna R. Ohm[1], Kathleen Parkes[1], Alexandra Porshnikoff[1], Chris Robuck[1], Martin Sheridan[1], Robert Sobecki[1], Peter Smith[1], Jessica Stevenson[1], Jordan Sullivan[1], Brian Wasson[1], Allison M. Weakley[1], Mark Wilhelm[1], Joshua Won[1], Ari Yasunaga[1], William C. Chan[1], Jodi Holeman[2], Nigel Snoad[1], Linus Upson[1], Tiantian Zha[1], Stephen L. Dobson[3,4], F. Steven Mulligan[2], Peter Massaro[1] and Bradley J. White[1✉]

The range of the mosquito *Aedes aegypti* continues to expand, putting more than two billion people at risk of arboviral infection. The sterile insect technique (SIT) has been used to successfully combat agricultural pests at large scale, but not mosquitoes, mainly because of challenges with consistent production and distribution of high-quality male mosquitoes. We describe automated processes to rear and release millions of competitive, sterile male *Wolbachia*-infected mosquitoes, and use of these males in a large-scale suppression trial in Fresno County, California. In 2018, we released 14.4 million males across three replicate neighborhoods encompassing 293 hectares. At peak mosquito season, the number of female mosquitoes was 95.5% lower (95% CI, 93.6–96.9) in release areas compared to non-release areas, with the most geographically isolated neighborhood reaching a 99% reduction. This work demonstrates the high efficacy of mosquito SIT in an area ninefold larger than in previous similar trials, supporting the potential of this approach in public health and nuisance-mosquito eradication programs.

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  - *kdr* testing, wind tunnel, field spray tests

Table 4.2 Methods used to control vector-borne diseases

Category	Question	Chagas disease	Dengue	Trypanosomiasis	Jap. encephalitis	Leishmaniasis	lymphatic filariasis	Malaria	Onchocerciasis	Schistosomiasis	Trachoma
Environmental	Source reduction		+		+		+	+			
	Habitat manipulation						+	+		+	
	Irrigation management & design				+			+	+	+	
	Proximity of livestock				+			+			+
	Waste management						+				+
Mechanical	House improvement	+			+	+		+			
	Removal trapping		+	+		+					
	Polystyrene beads						+				
Biological	Natural enemy conservation		+		+			+		+	
	Biological larvicides		+		+		+	+	+		
	Fungi										
	Botanicals		+					+			
Chemical	Insecticide-treated bednets	+			+	+	+	+			
	Indoor residual spraying					+		+			
	Insecticidal treatment of habitat		+	+			+	+	+		
	Insecticide-treated targets			+							
	Biorational methods		+					+			
	Chemical repellents					+	+	+			

World Health Organization, 2012. *Handbook for integrated vector management*. World Health Organization.

Responding effectively even when resistance is STRONG

- Integrated Vector Management Plan (IVM)
  - Adulticides effective if IVM is DATA DRIVEN
  - *kdr* testing, CDC bottle bioassay, wind tunnel, field spray tests

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	Polystyrene beads						+				
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Applying data driven IVM to manage different species with differing resistance profiles

- *Aedes aegypti*
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    - Moderate > Strong
    - Mechanism – Genetic SNPs (*kdr*)
  - OP resistance
    - Weak
- *Aedes albopictus*
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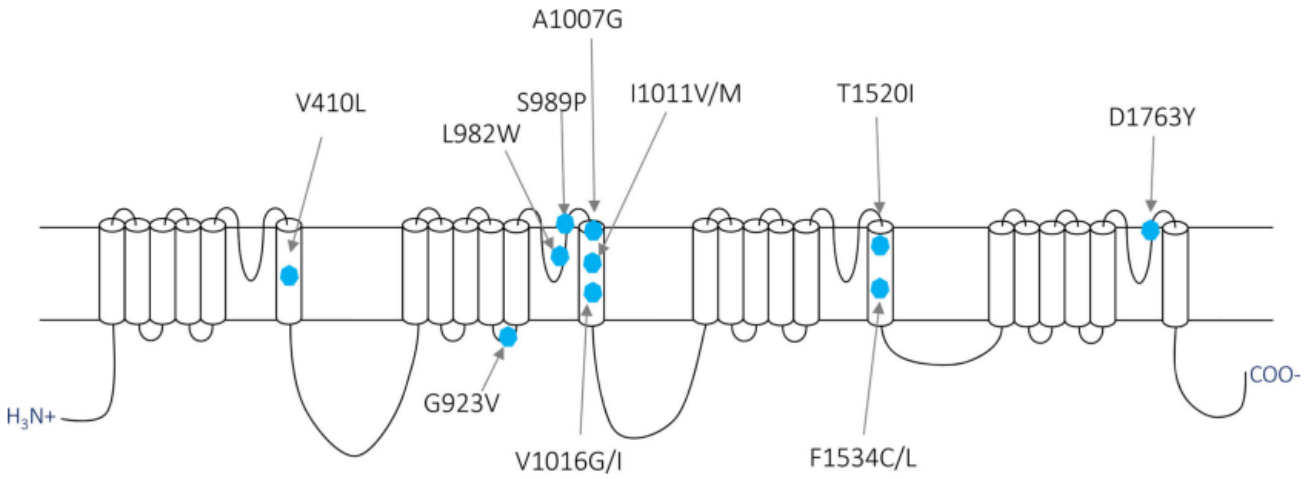

Chen, M., Du, Y., Nomura, Y., Zhorov, B.S. and Dong, K., 2020. Chronology of sodium channel mutations associated with pyrethroid resistance in Aedes aegypti. *Archives of insect biochemistry and physiology*, *104*(2), p.e21686.

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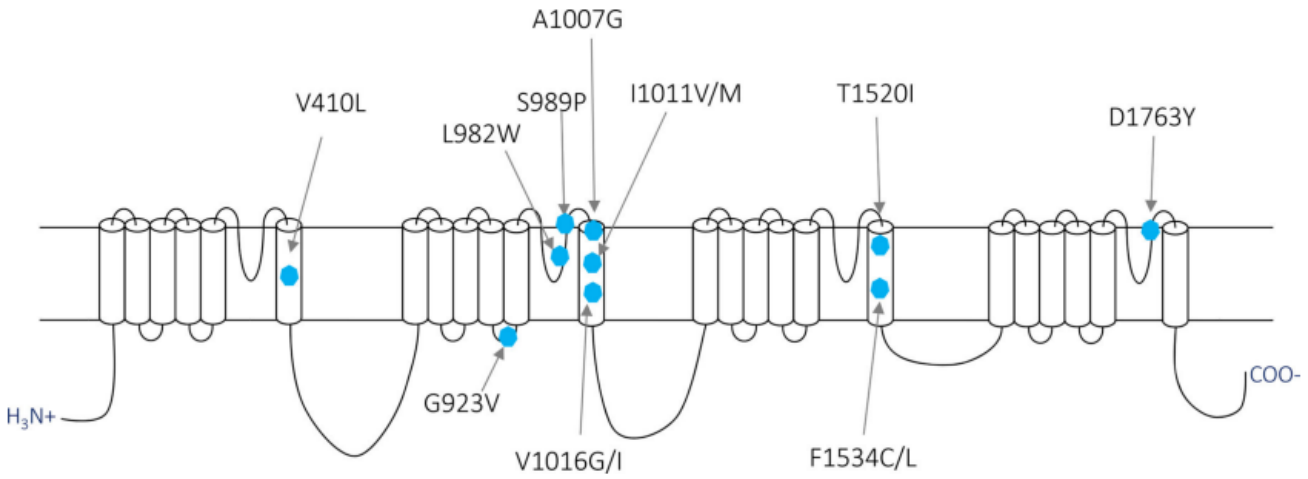

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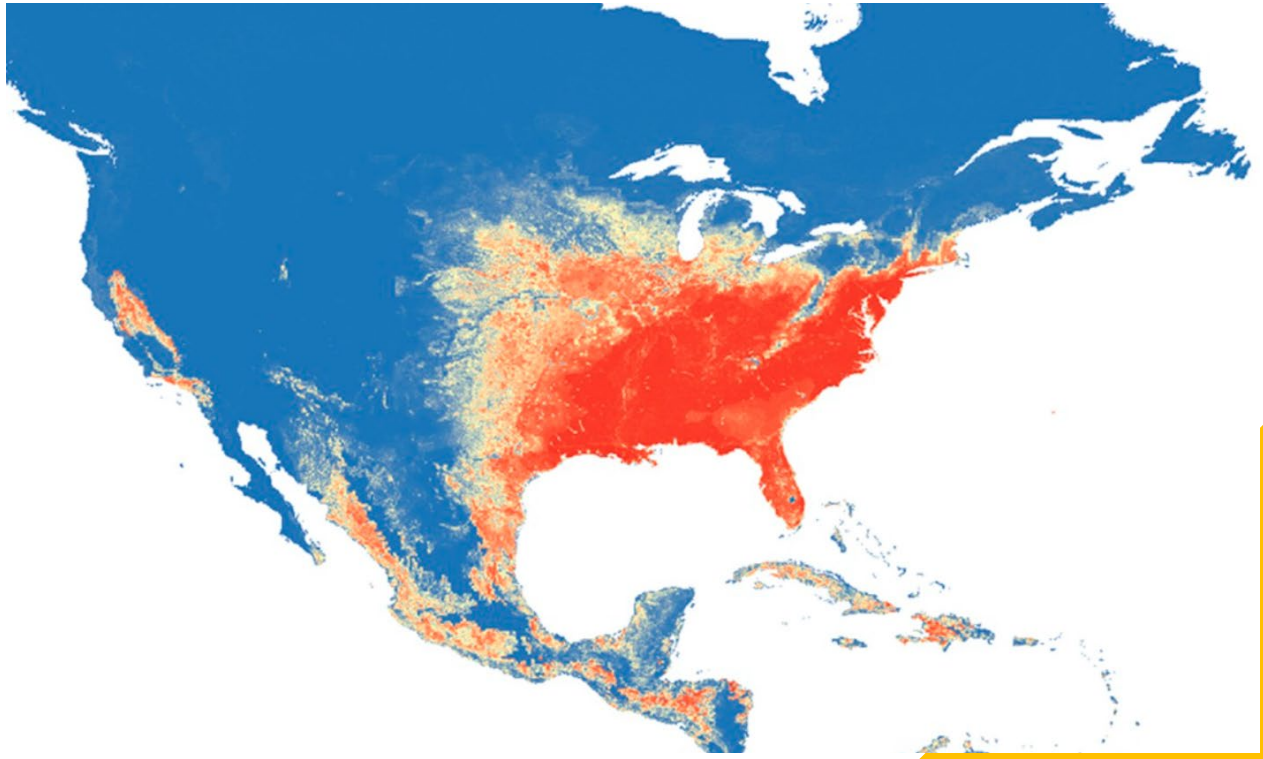

Kraemer, M.U., Sinka, M.E., Duda, K.A., Mylne, A.Q., Shearer, F.M., Barker, C.M., Moore, C.G., Carvalho, R.G., Coelho, G.E., Van Bortel, W. and Hendrickx, G., 2015. The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus. elife, 4, p.e08347.

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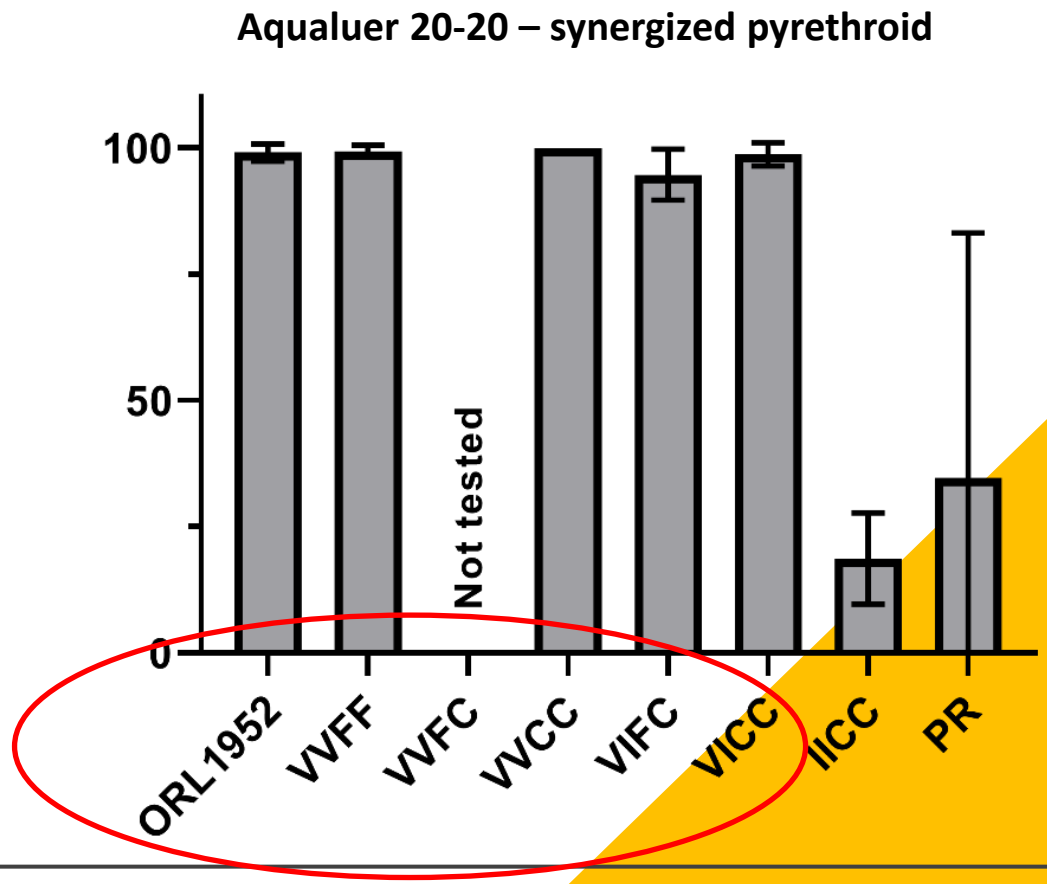

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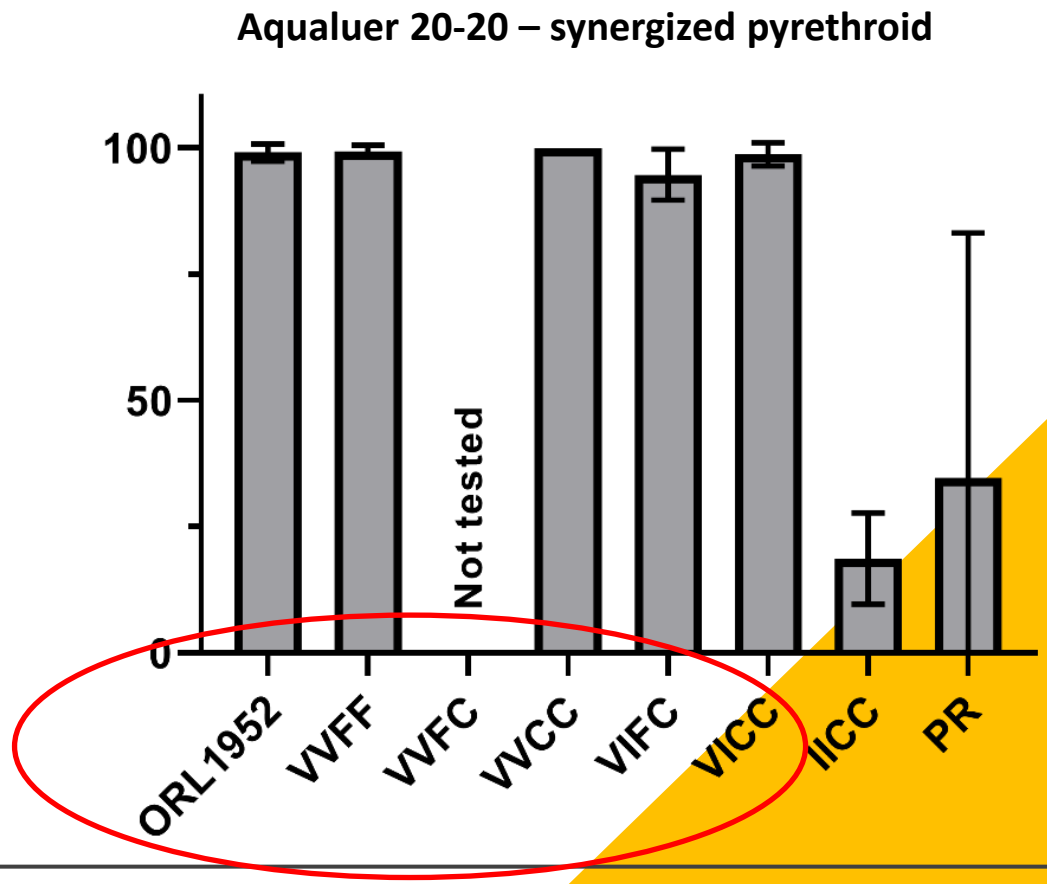

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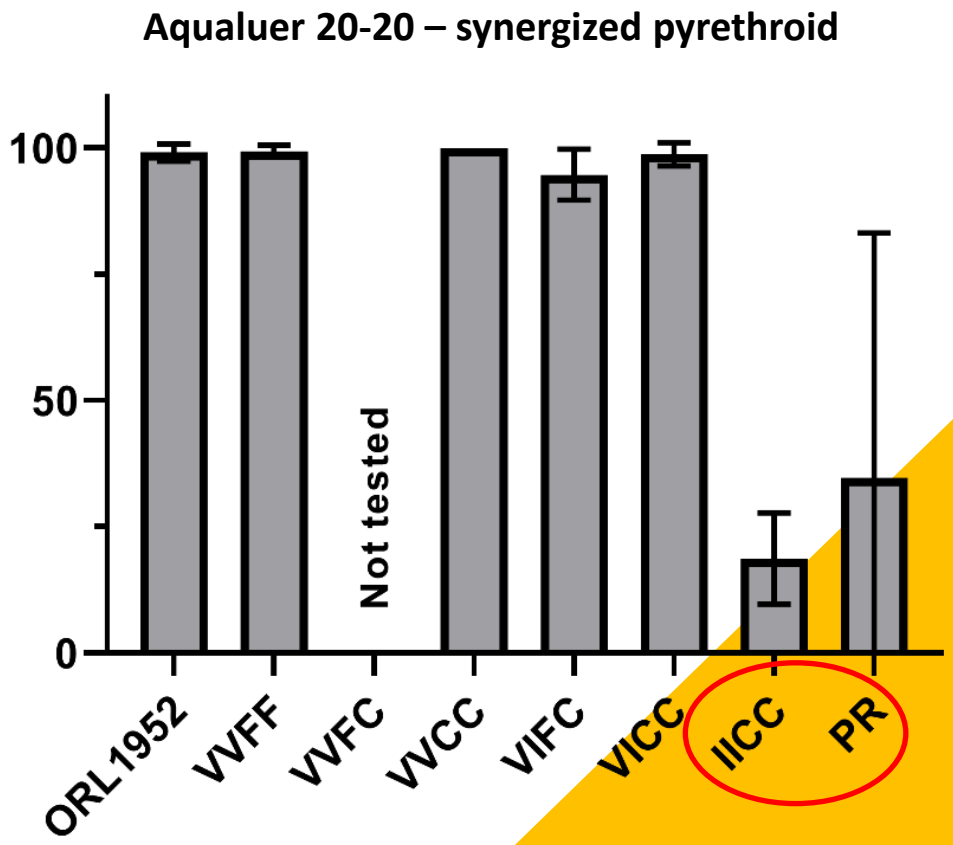

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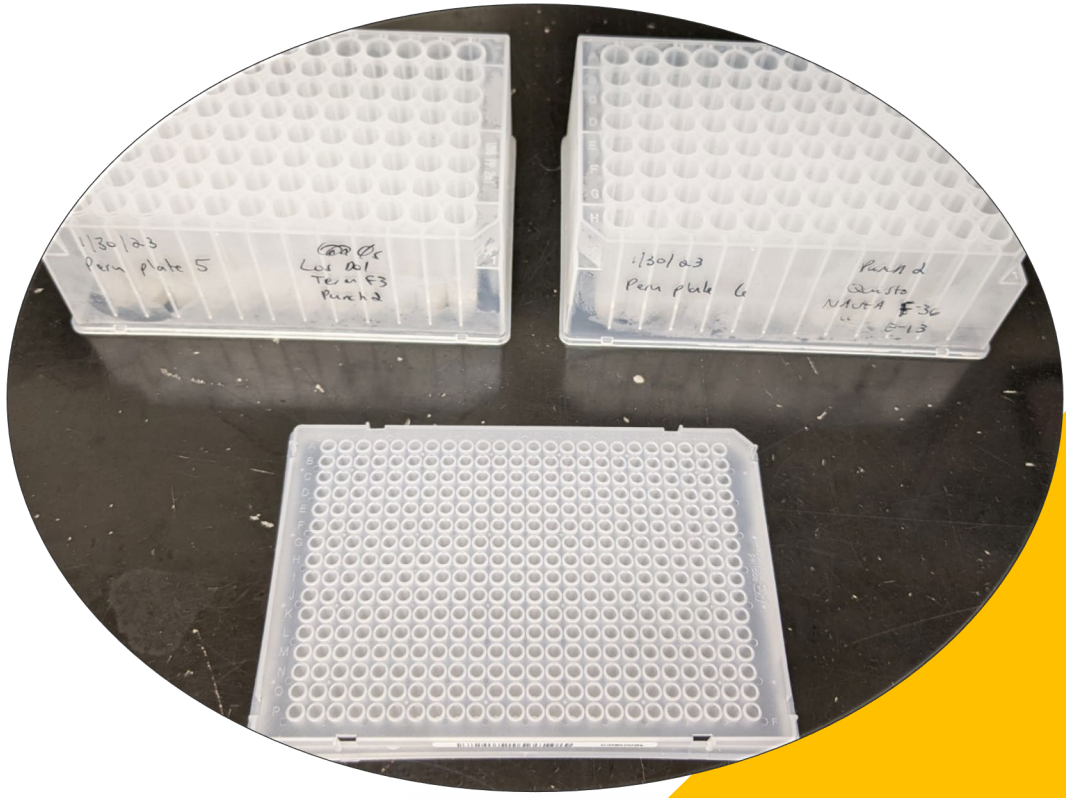
  - high-throughput
  - fast
  - cheap
  - works on all sample types



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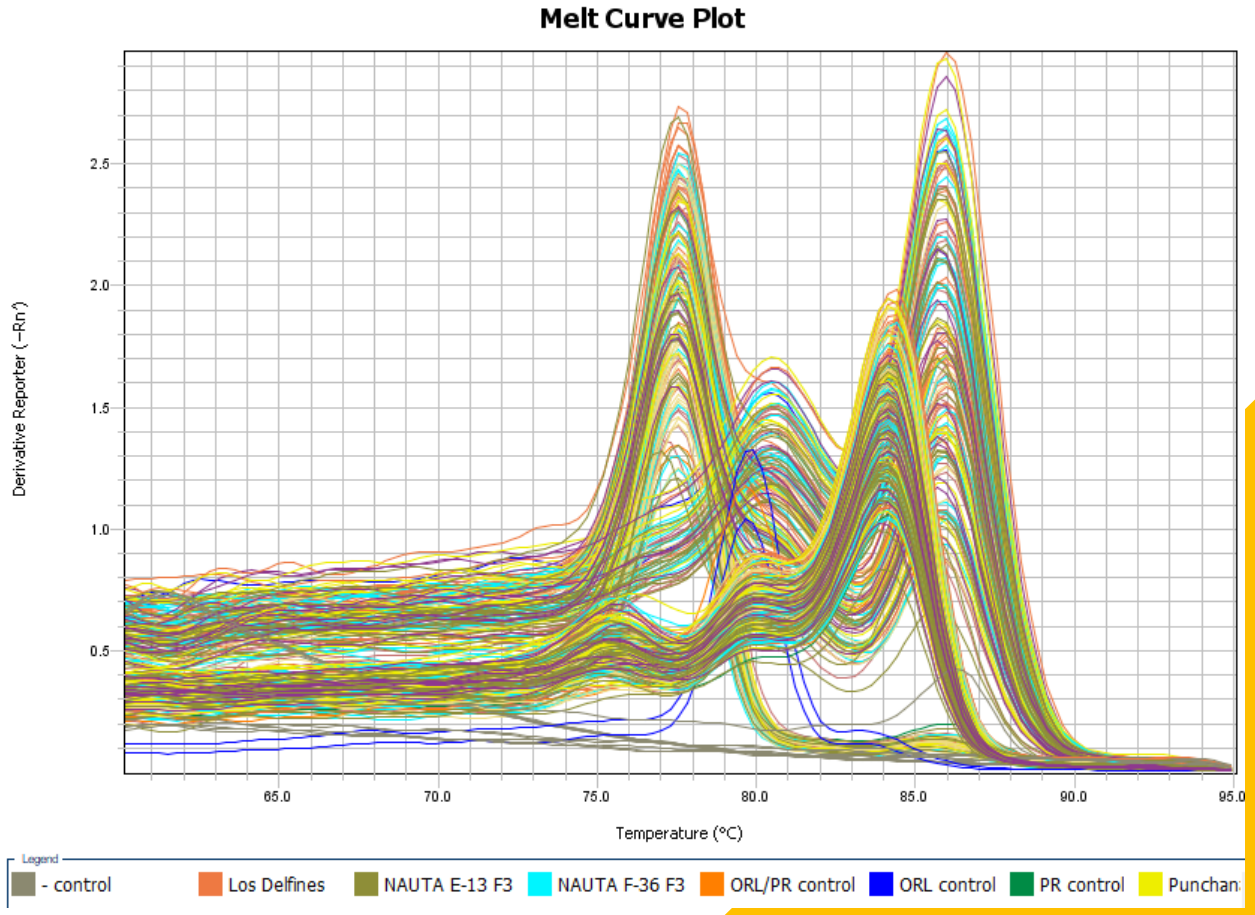
  - Low IICC frequency – synergized pyrethroids
  - High IICC frequency – OPs



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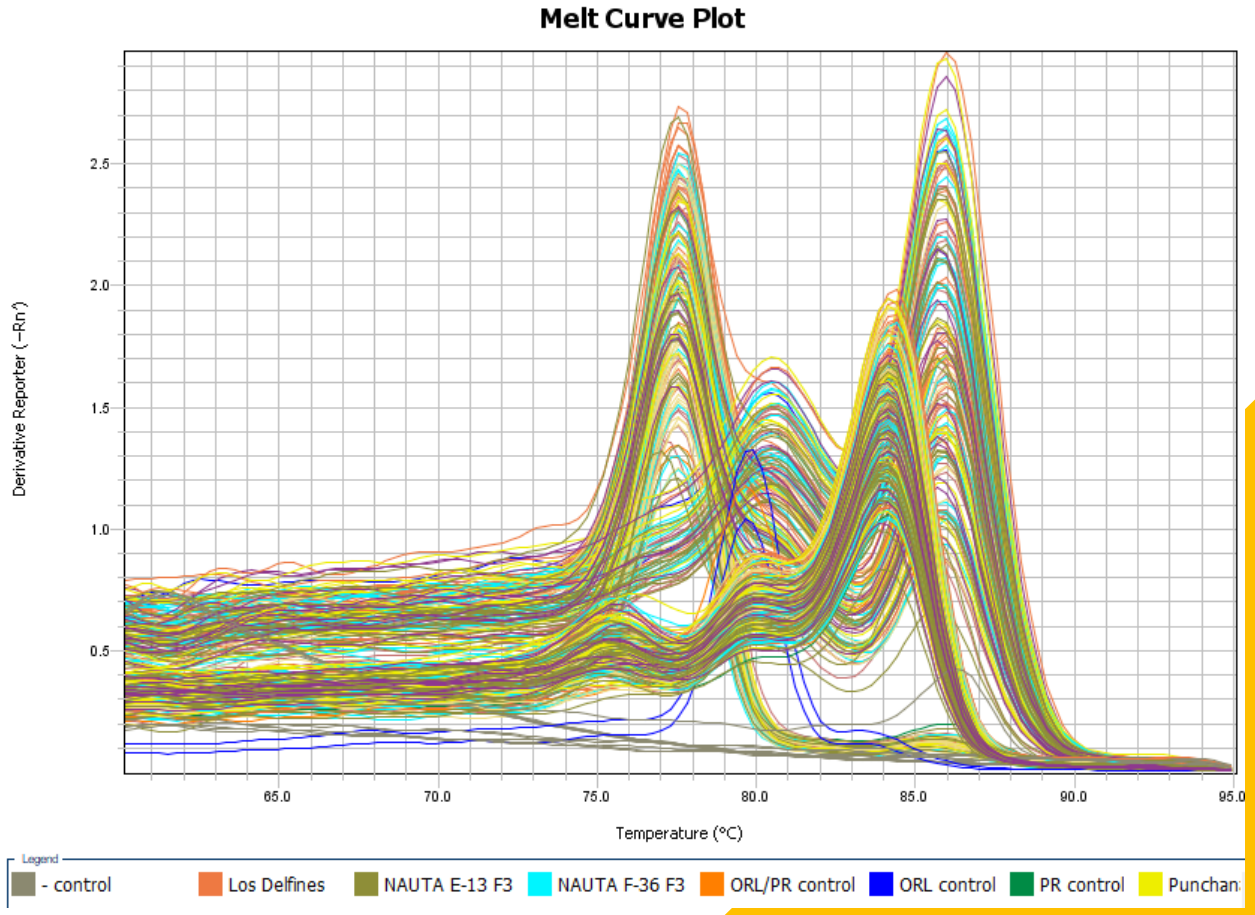

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- *Culex quinquefasciatus*
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  - OP resistance
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    - Mechanism – enzymatic detoxification?
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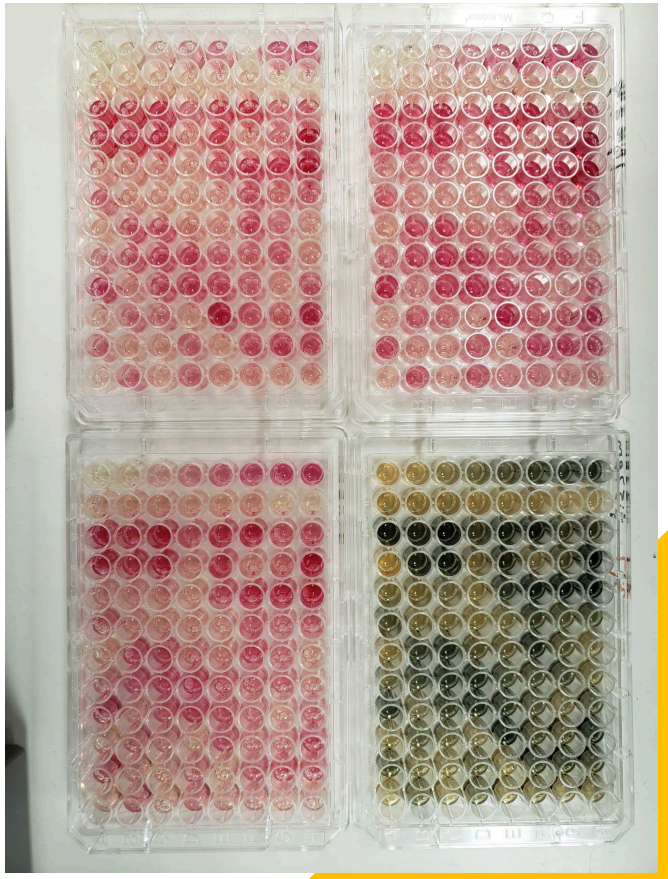

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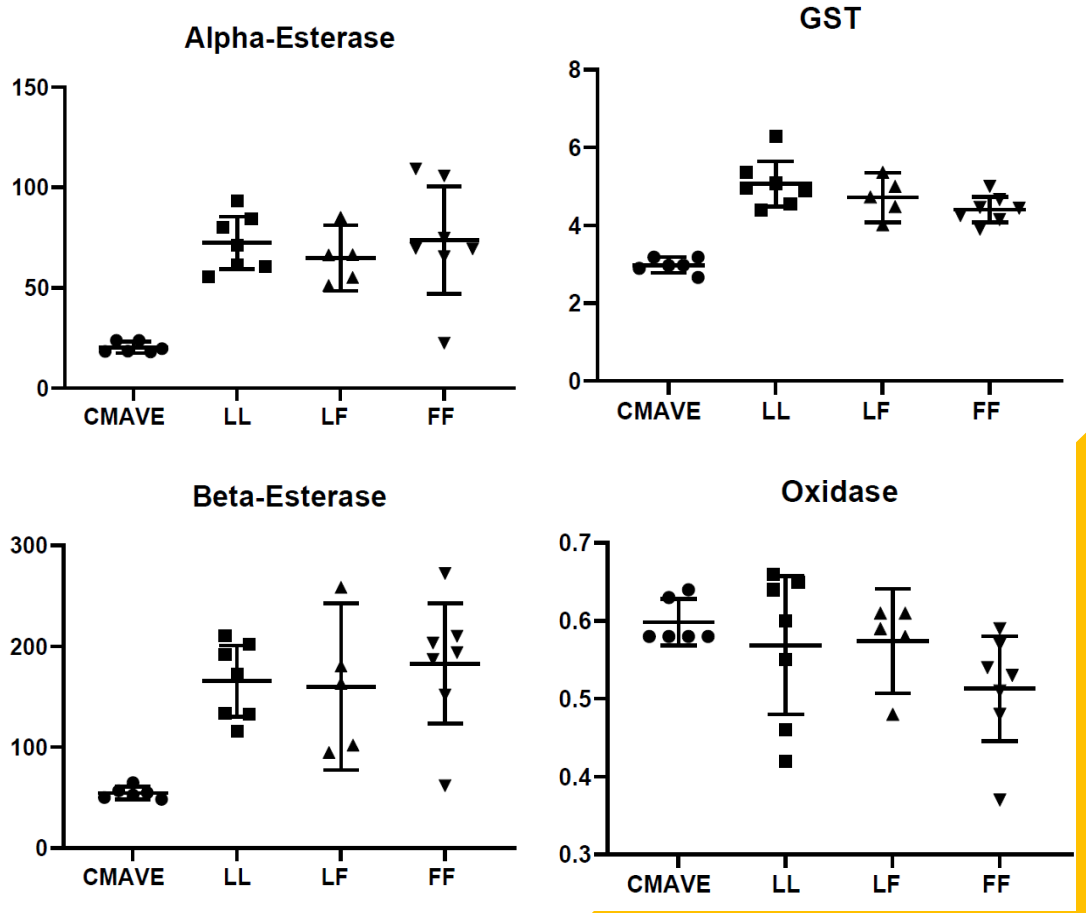

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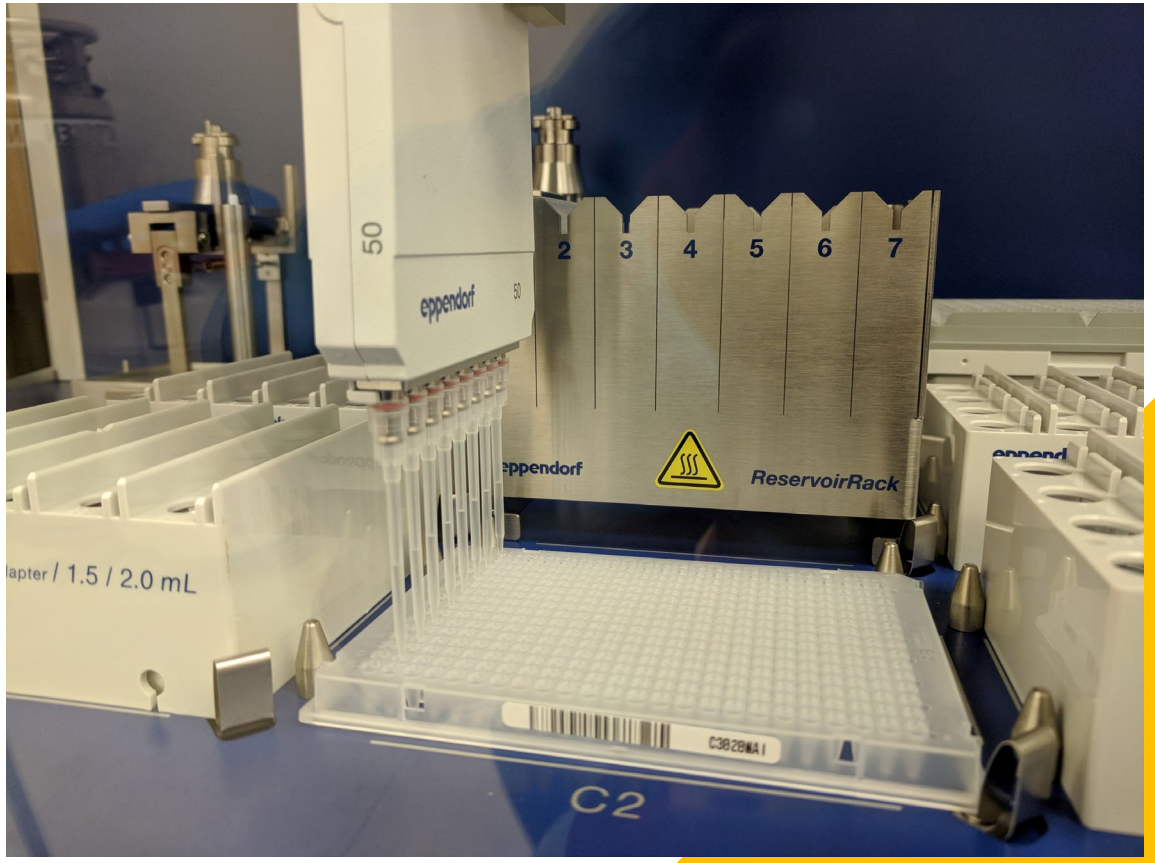

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https://entomologytoday.org/2021/03/23/study-confirms-mosquitoes-midges-dont-transmit-coronavirus-covid-19/culex-tarsalis-2/

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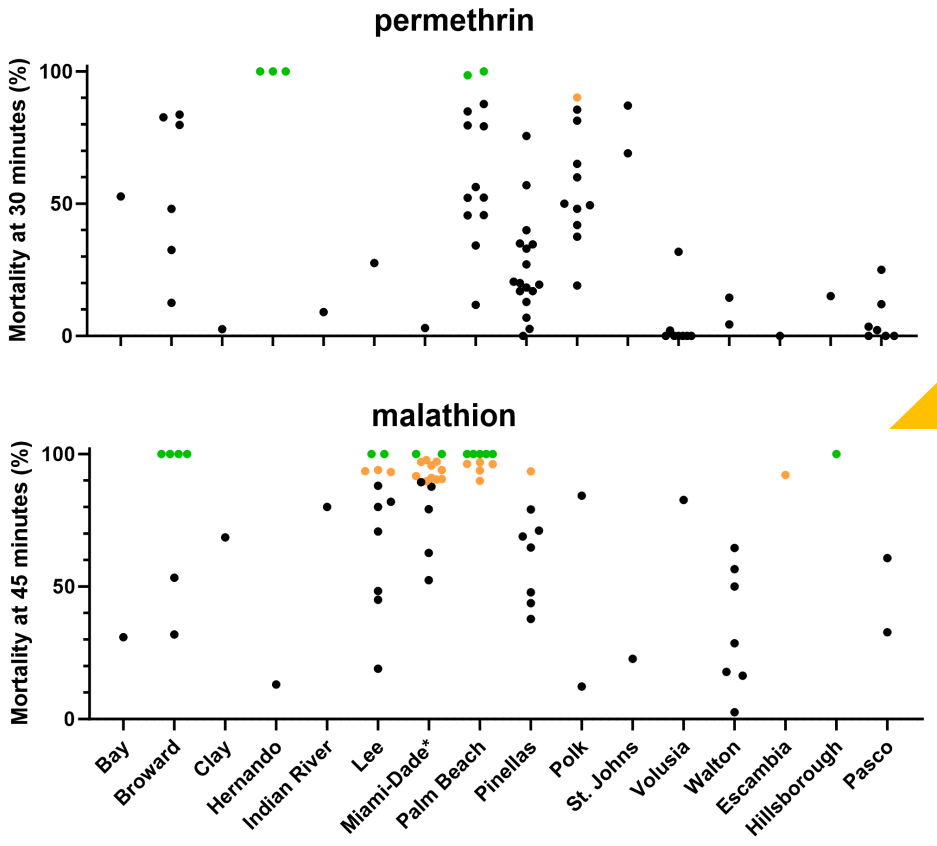

Managing resistance in public health vectors when vector control is not the only source of pressure

- Residential spraying
- Nurseries
- Farms
  - Miami-Dade – 6/7 OP resistant populations from ag locations

https://www.nbcnews.com/science/environment/backyard-mosquito-spraying-booms-may-deadly-rcna43945

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iStockphoto.com by Getty Images

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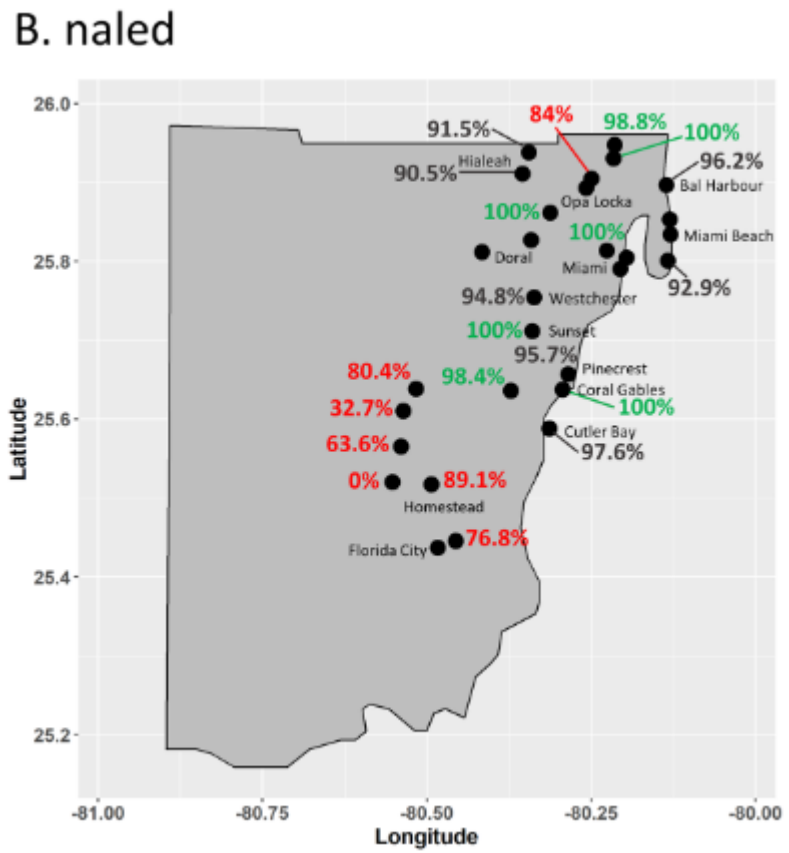

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- IVM is ***always*** the answer
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Photo credits: Nicole Graves

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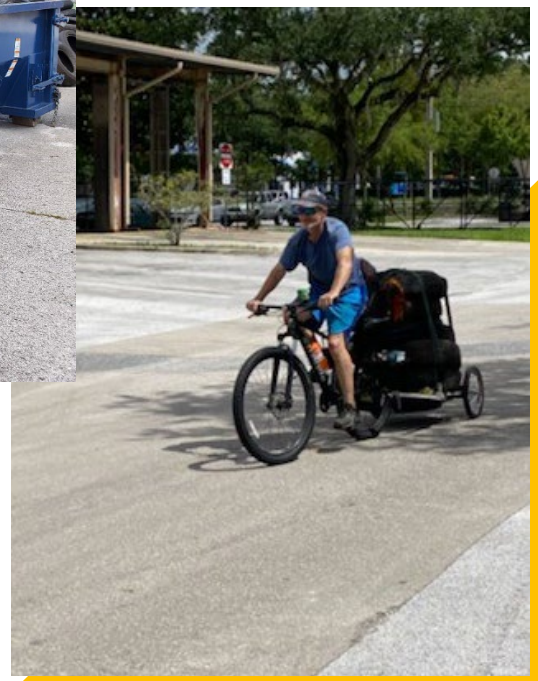

Photo credits: Peter Jiang

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https://www.prnewswire.com/news-releases/perdue-farms-outpaces-industry-in-raising-chickens-with-outdoor-access-expands-free-range-offerings-301007578.html

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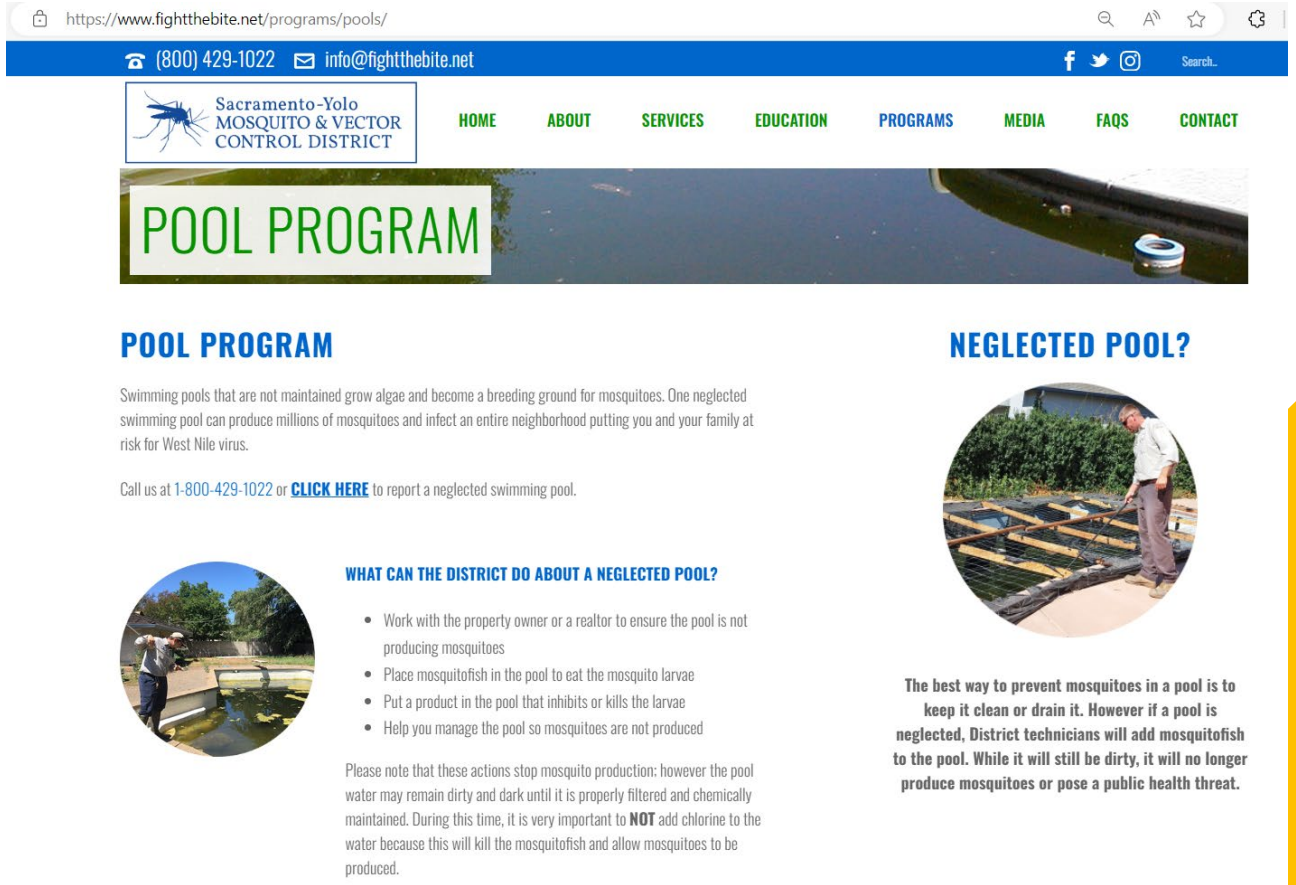

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New tools for vector control to add to an IVM

- Drones
  - Marsh/swamps hard to reach
  - Affordable
- New actives – ReMoa Tri
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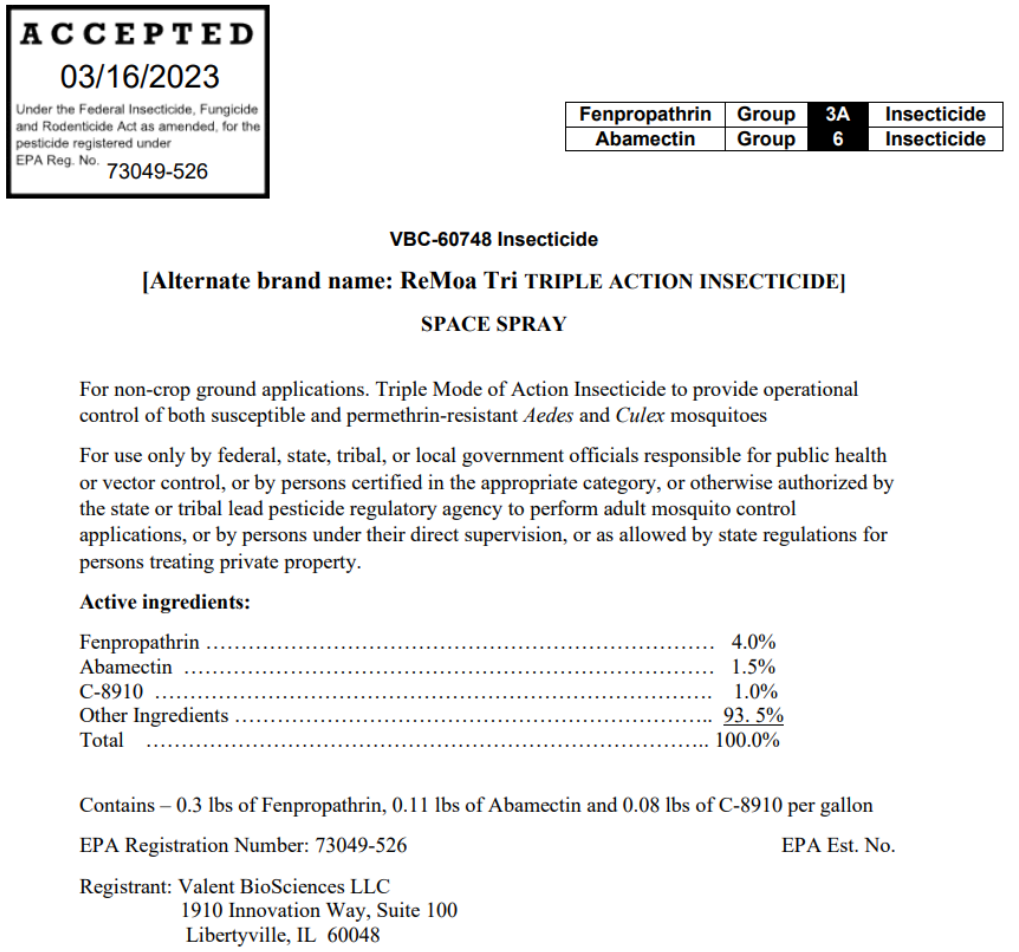

ACCEPTED
03/16/2023
Under the Federal Insecticide, Fungicide and Rodenticide Act as amended, for the pesticide registered under
EPA Reg. No. 73049-526

Fenpropathrin	Group	3A	Insecticide
Abamectin	Group	6	Insecticide

VBC-60748 Insecticide

[Alternate brand name: ReMoa Tri TRIPLE ACTION INSECTICIDE]

SPACE SPRAY

For non-crop ground applications. Triple Mode of Action Insecticide to provide operational control of both susceptible and permethrin-resistant *Aedes* and *Culex* mosquitoes

For use only by federal, state, tribal, or local government officials responsible for public health or vector control, or by persons certified in the appropriate category, or otherwise authorized by the state or tribal lead pesticide regulatory agency to perform adult mosquito control applications, or by persons under their direct supervision, or as allowed by state regulations for persons treating private property.

Active ingredients:

Fenpropathrin	4.0%
Abamectin	1.5%
C-8910	1.0%
Other Ingredients	93. 5%
Total	100.0%

Contains – 0.3 lbs of Fenpropathrin, 0.11 lbs of Abamectin and 0.08 lbs of C-8910 per gallon

EPA Registration Number: 73049-526 EPA Est. No.

Registrant: Valent BioSciences LLC
1910 Innovation Way, Suite 100
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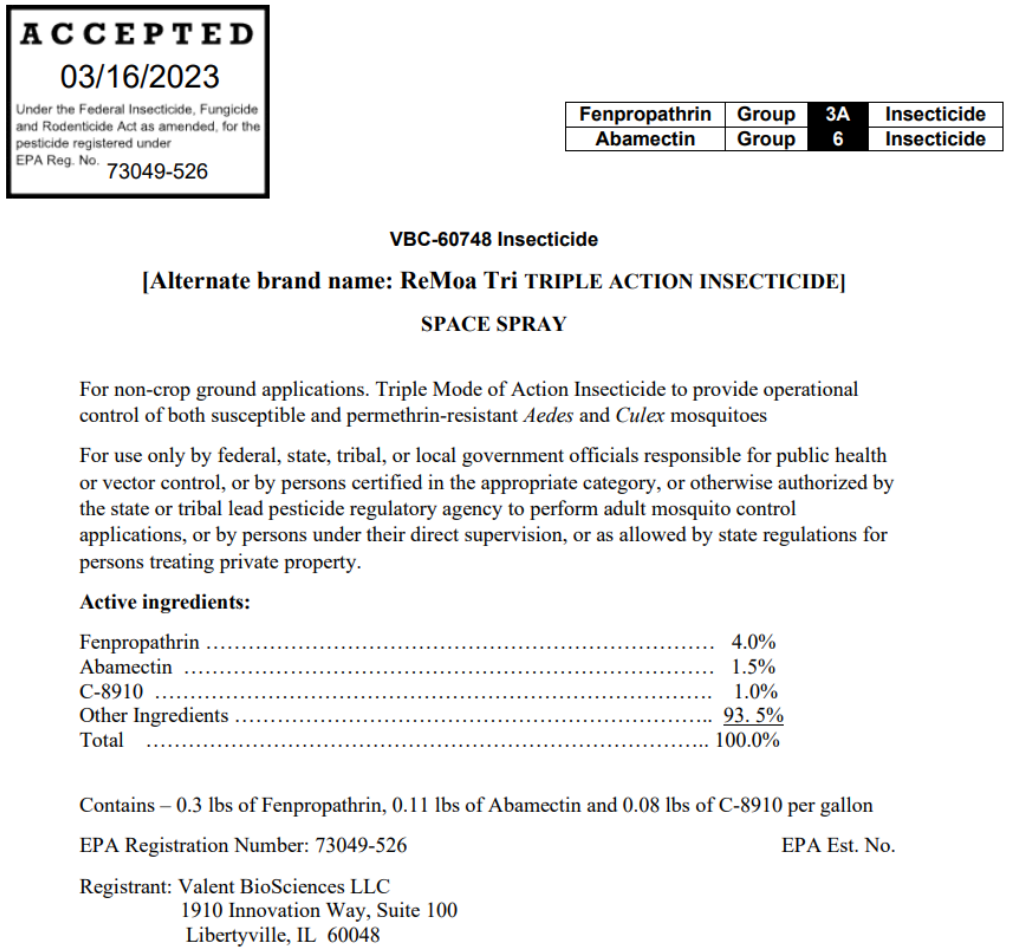

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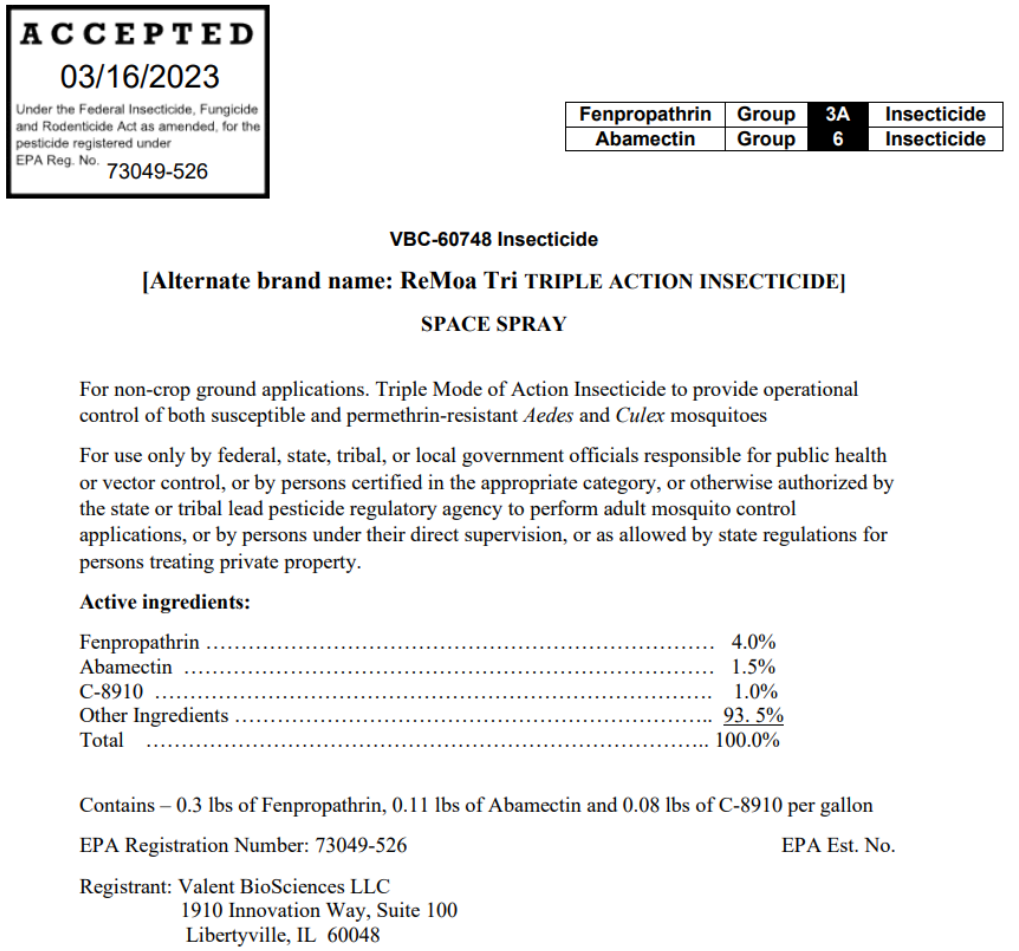

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Operational Responses to Insecticide Resistance

- Responding effectively even when resistance is STRONG
  - Environmental - Source reduction, habitat manipulation
  - Biological – larvacides, mosquitofish, SIT
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https://swampfeverairboatadventures.com/swamps-in-florida/

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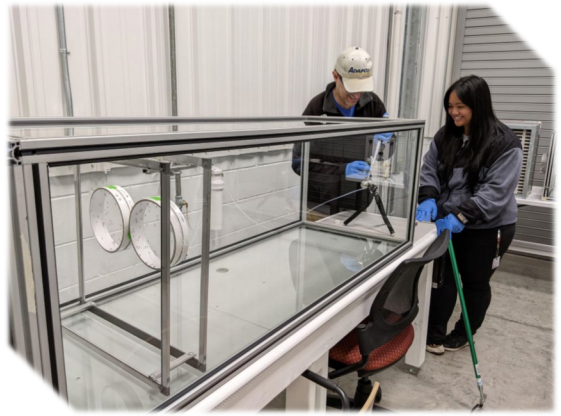

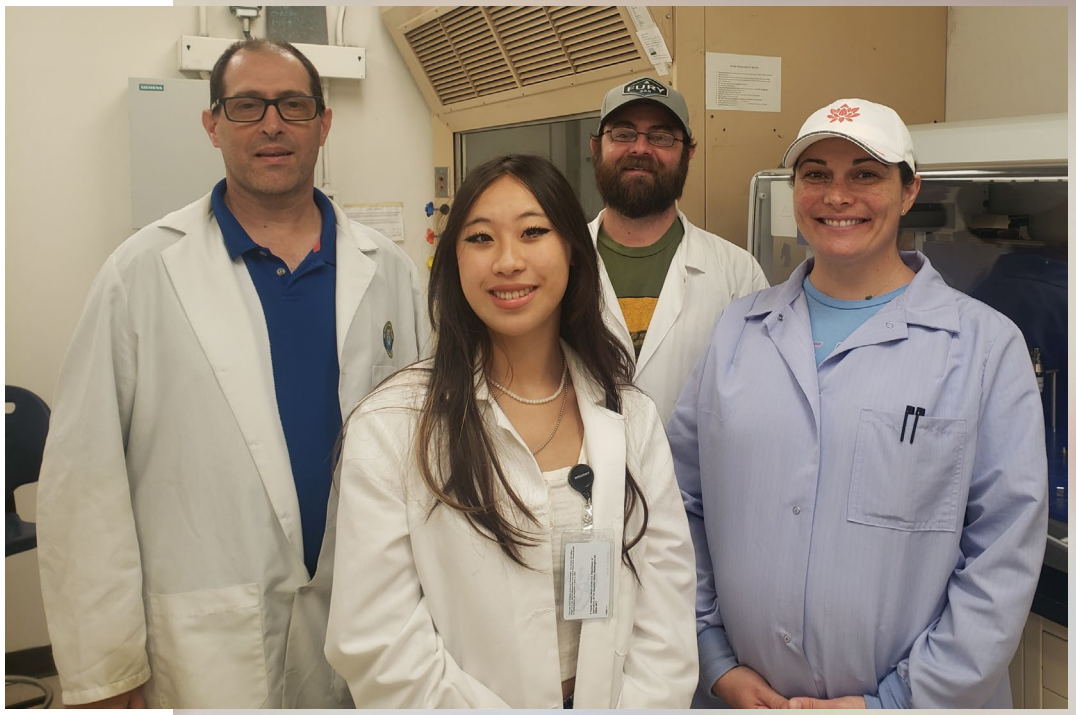

Thank you!
Questions?

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neil.sanscrainte@usda.gov

Alden Estep – Research Entomologist
Neil Sanscrainte – Molecular Biologist

USDA ARS Center for Medical Agricultural & Veterinary Entomology

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