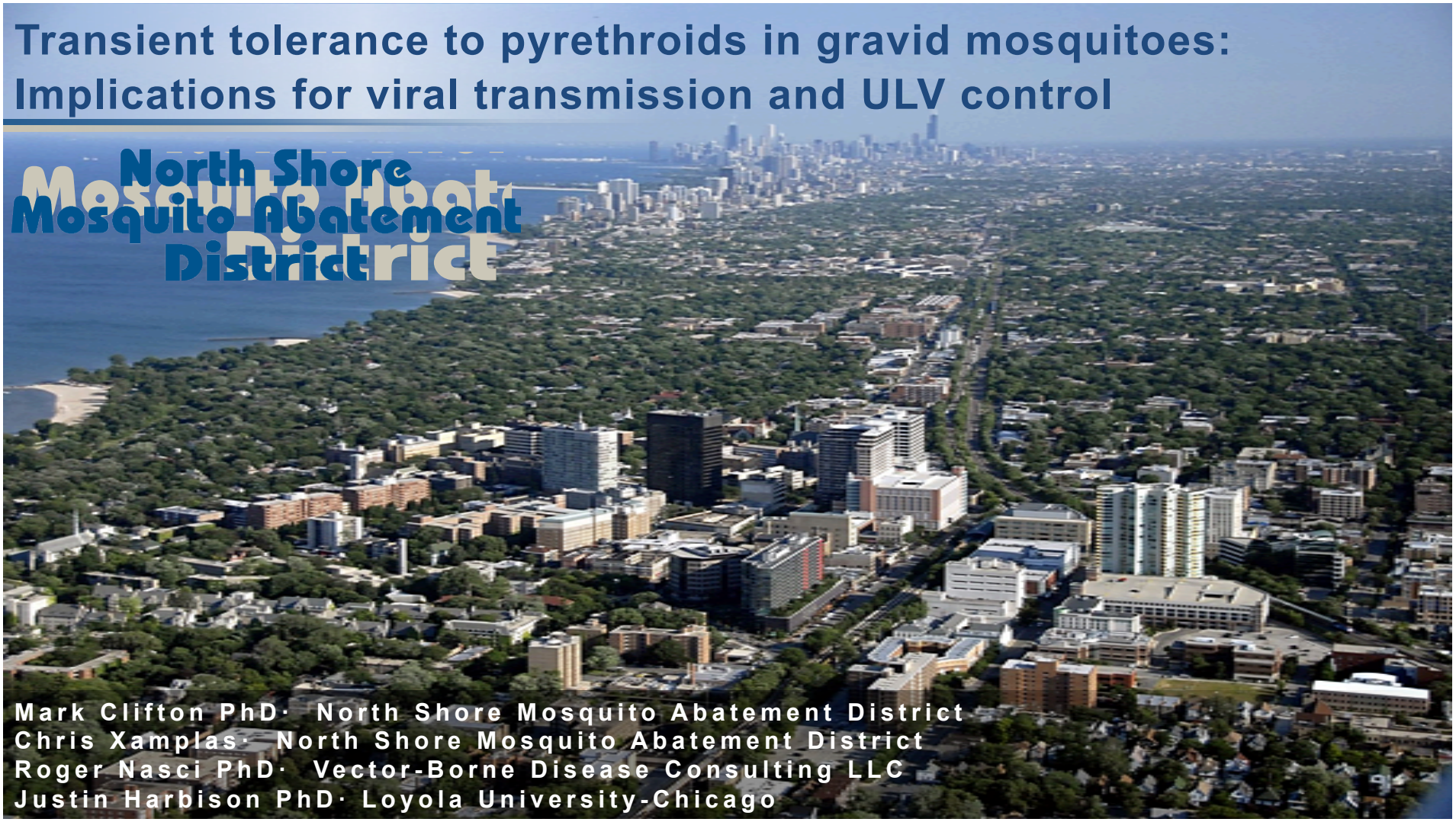
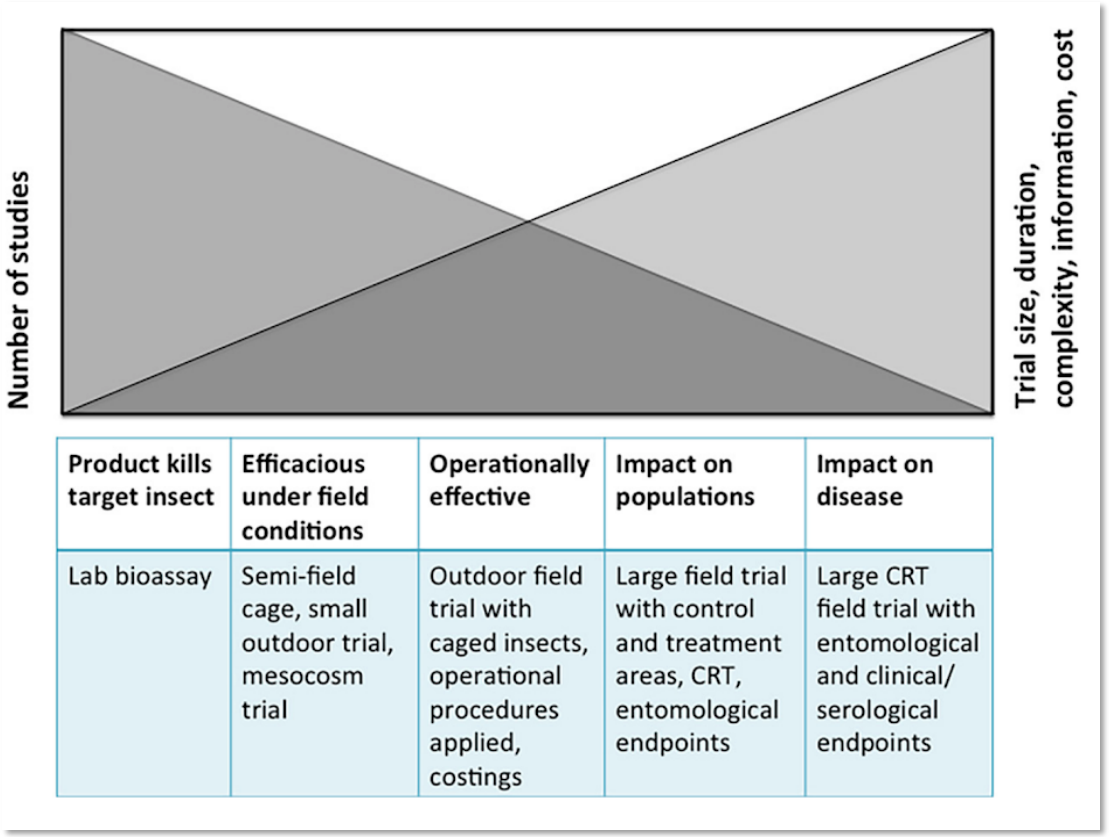
Transient tolerance to pyrethroids in gravid mosquitoes: Implications for viral transmission and ULV control



Mark Clifton PhD· North Shore Mosquito Abatement District
Chris Xamplas· North Shore Mosquito Abatement District
Roger Nasci PhD· Vector-Borne Disease Consulting LLC
Justin Harbison PhD· Loyola University-Chicago

Studies examining the effect of ULV on natural populations are rare



Product kills target insect	Efficacious under field conditions	Operationally effective	Impact on populations	Impact on disease
Lab bioassay	Semi-field cage, small outdoor trial, mesocosm trial	Outdoor field trial with caged insects, operational procedures applied, costings	Large field trial with control and treatment areas, CRT, entomological endpoints	Large CRT field trial with entomological and clinical/ serological endpoints

What makes up a population of mosquitoes?

Ritchie, S. A., & Devine, G. (2016). Conventional vector control: evidence it controls arboviruses. Arboviruses: molecular biology, evolution and control, 281-290.

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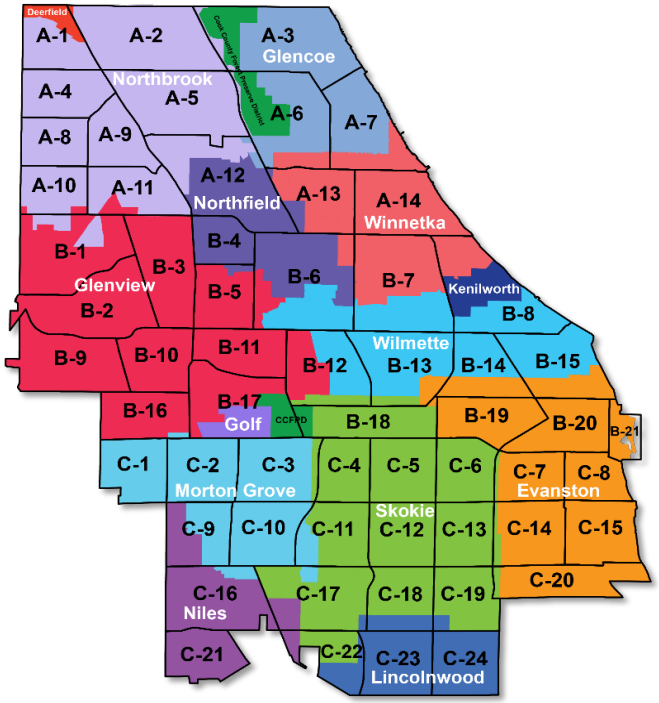
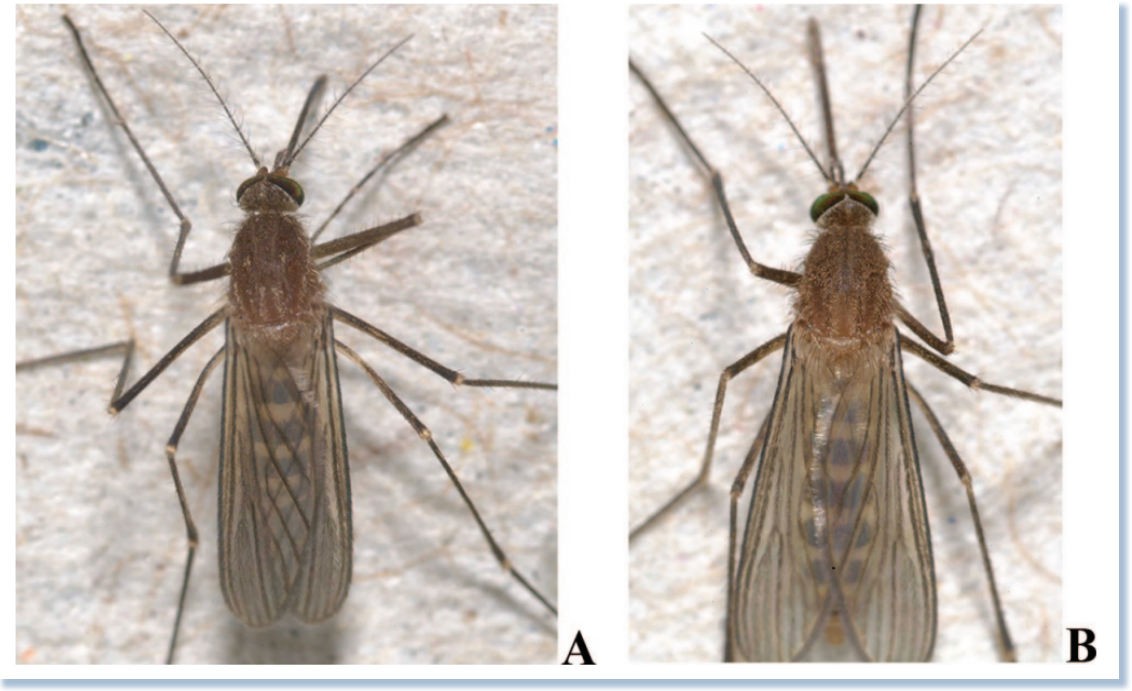
Culex restuans (Theobald) and *Culex pipiens* (Linnaeus)





(A) *Culex restuans* and (B) *Culex pipiens.* Harrington, L.C., & Poulson, R.L. (2008) Considerations for Accurate Identification of Adult *Culex restuans* (Diptera: Culicidae) in Field Studies,1-8.

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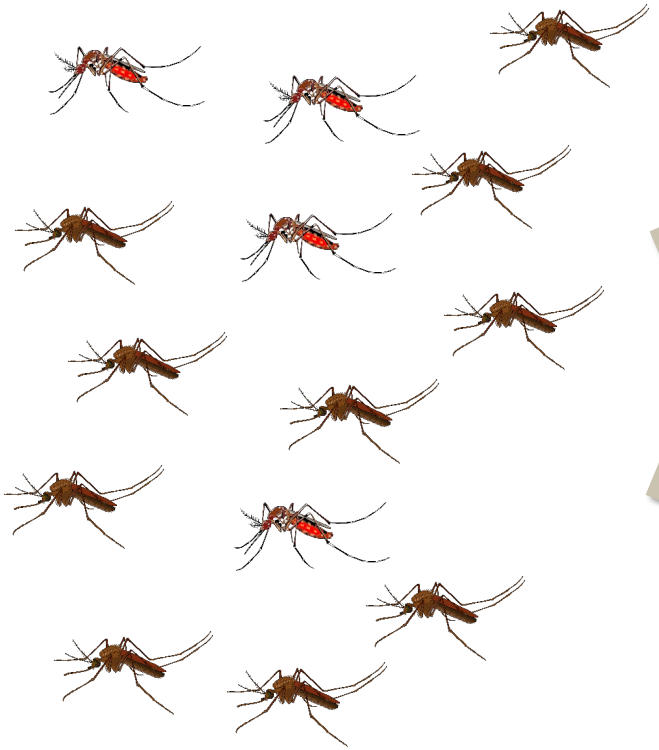
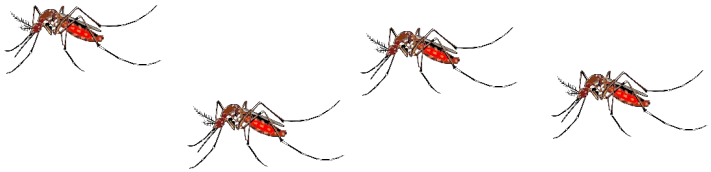
A natural mosquito population consists of many different subpopulations

Entire *Culex* spp. population



Resting Traps

Blood-fed *Culex* spp. population



Gravid-Baited Traps

Gravid *Culex* spp. population

Host-Baited Traps

Host-Seeking *Culex* spp. Population

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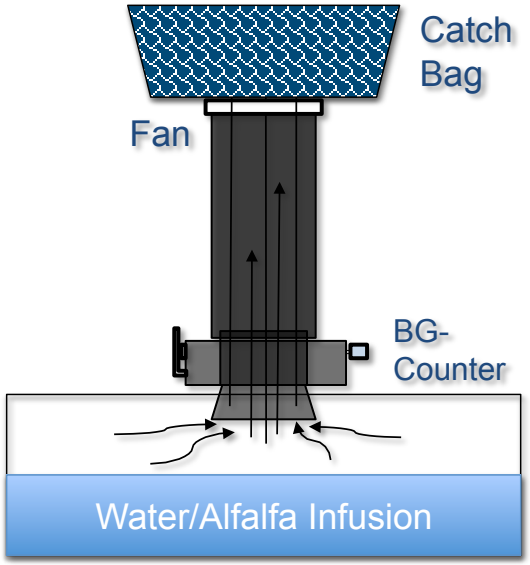
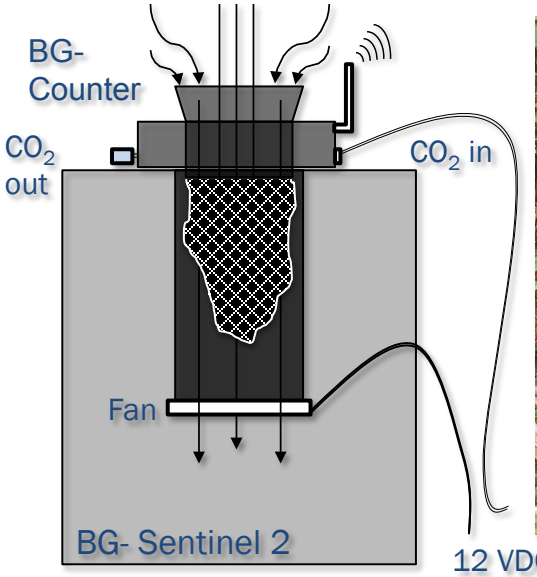
Objective: Observe a “natural population” during and after a ULV treatment

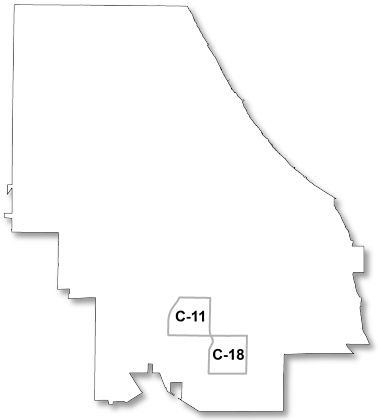
Gravid BG-Counter



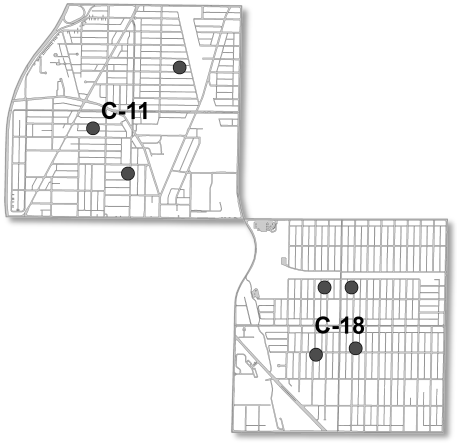
Host-Seeking BG-Counter



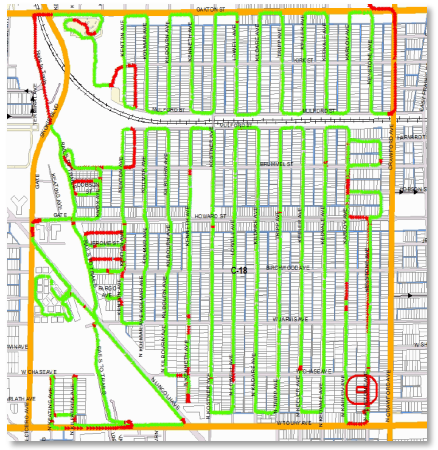
Study location, trap placement, and ULV treatments



NSMAD



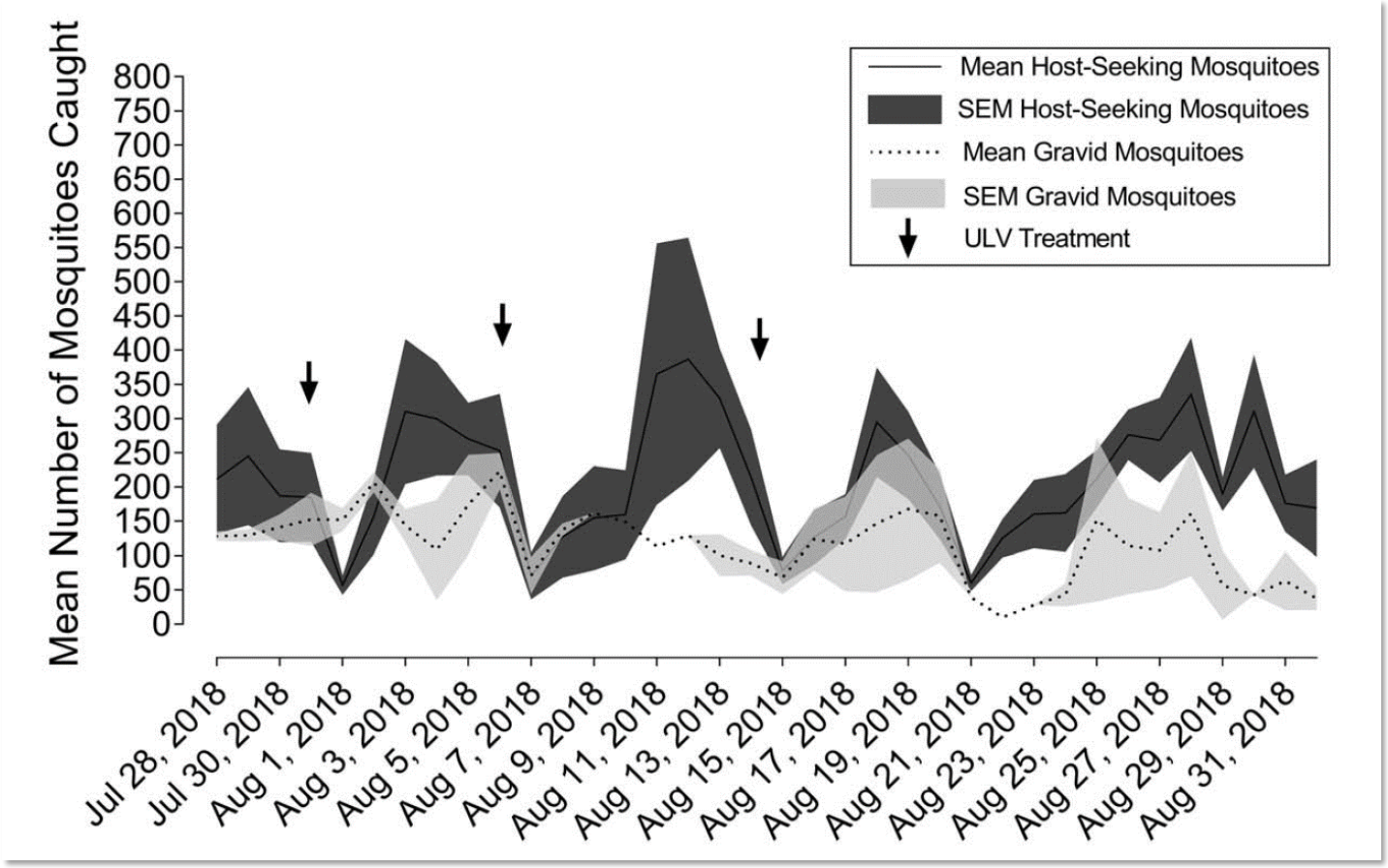
Treatment maps C-18 and C-11



Truck route

- Treatment areas C-11 and C-18 in Skokie, Illinois.
- 4 Treatments occurred on 7/12/2018, 7/31/2018, 8/6/2018, and 8/14/2018.
- Duet™ was applied at 1.25 oz/acre (Near maximum label rate) by Clarke ULV Cougar.
- BG-Counters were monitored continuously from 7/11/2018 through 8/31/2018.

Host-seeking and gravid mosquito abundance in C-18



- ULV treatments produced a decline in host-seeking abundance followed by a rebound.
- The effect on gravid mosquitoes was variable.

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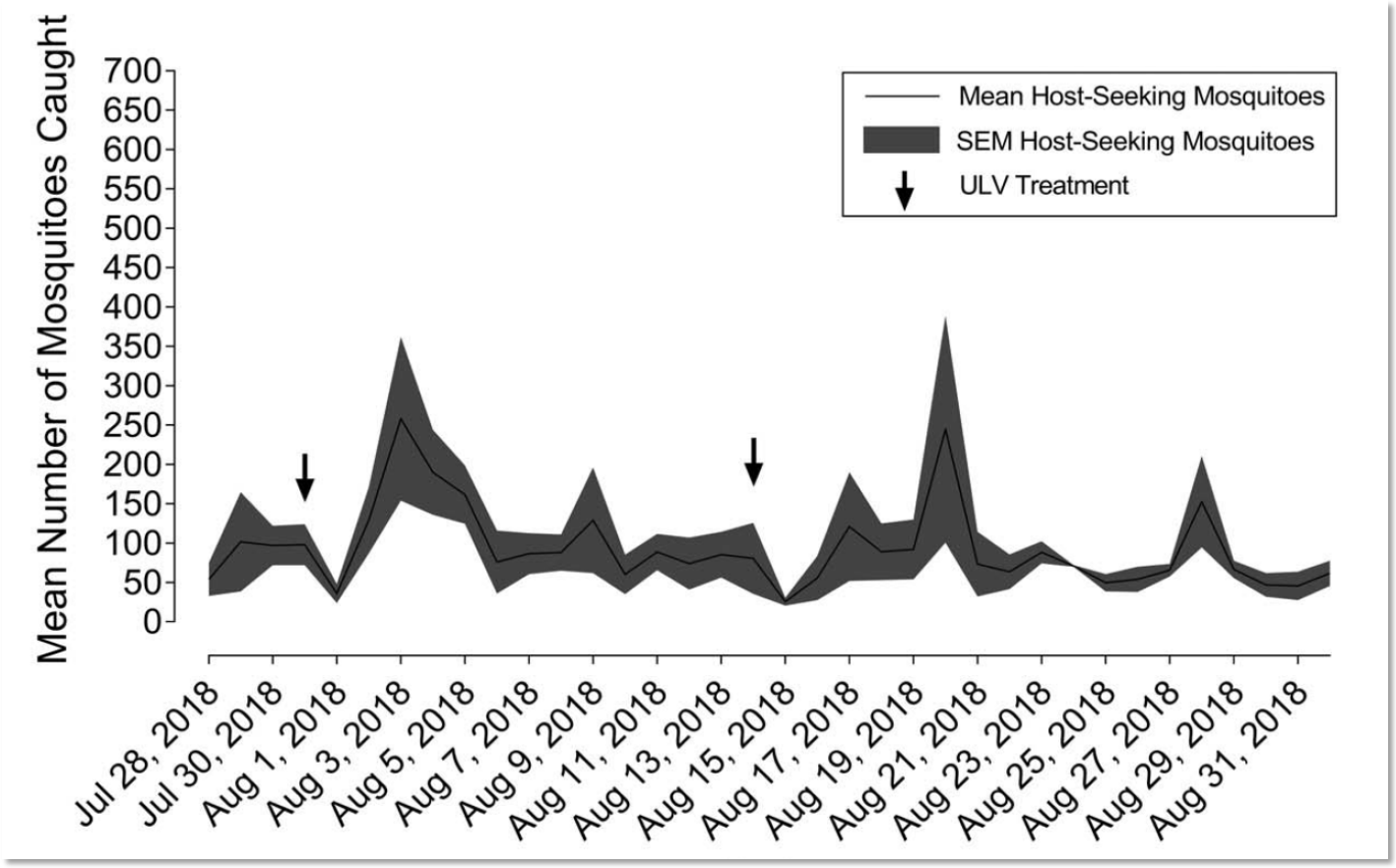
Host-seeking mosquito abundance in C-11



- ULV treatments again produced a decline in host-seeking abundance followed by a rebound

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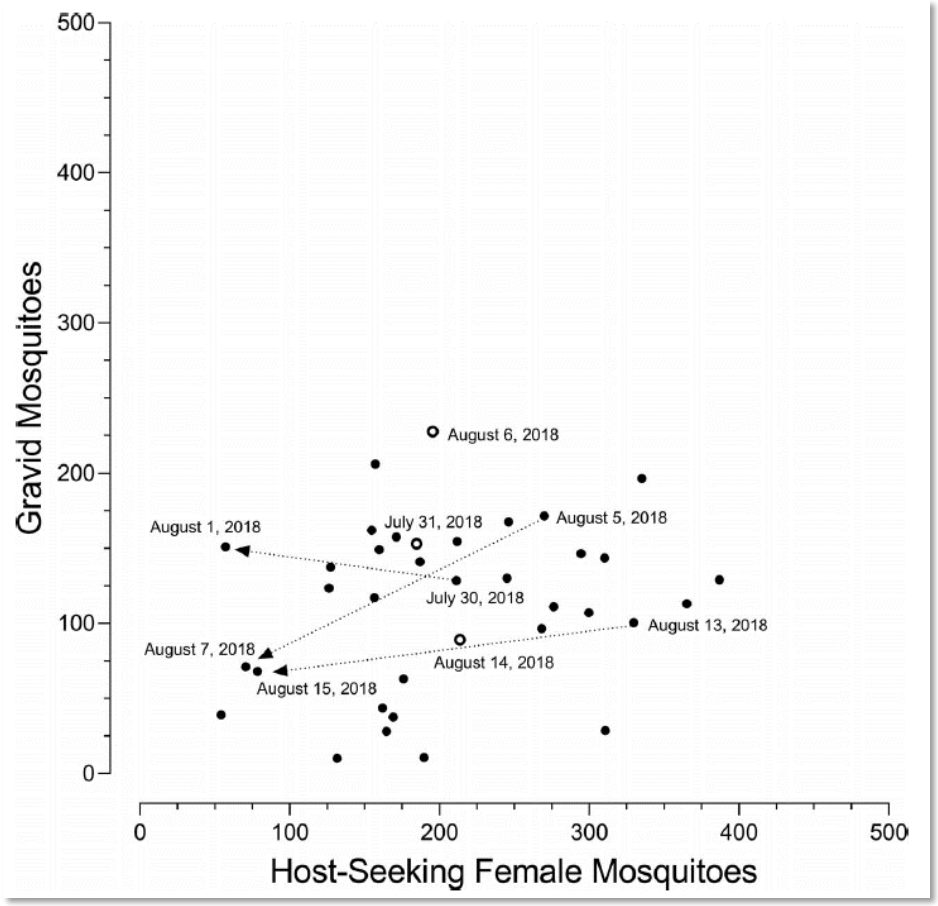
Host-seeking vs. gravid mosquitoes after treatment



- Bivariate plot of host-seeking female mosquitoes and gravid mosquitoes from study site C-18.
- Open circles represent host-seeking and gravid population on day of treatment.
- Arrows connect population of mosquitoes 24h prior to treatment with mosquito population 24h posttreatment to show differential effect of ULV treatments on gravid and host-seeking mosquitoes.

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Summary of results

Table 2. Mean percentage change and standard error of the mean (SEM) in gravid and host-seeking mosquitoes 24 h pretreatment, 24 h posttreatment, and 72 h posttreatment.

		24 h pretreatment		24 h posttreatment			72 h posttreatment		
Study site	Treatment date	Total mosquitoes	No. of traps	Total mosquitoes	No. of traps	% change from 24 h pretreatment	Total mosquitoes	No. of traps	% change from 24 h posttreatment
Host-seeking mosquitoes									
C-11	Jul. 31, 2018	294	3	108	3	−63.3	774	3	616.7
C-18	Jul. 31, 2018	739	4	228	4	−69.1	931	4	308.3
C-18	Aug. 6, 2018	759	3	282	4	−62.8	619	4	119.5
C-11	Aug. 14, 2018	242	3	77	3	−68.2	363	3	371.4
C-18	Aug. 14, 2018	855	4	314	4	−63.3	626	4	99.4
Mean % change ± SEM						−65.3 ± 1.4			303.1 ± 94.4
Gravid mosquitoes									
C-18	Jul. 12, 2018	578	4	584	4	1.0	465	4	−20.4
C-11	Jul. 31, 2018	160	1	97	1	−39.4	57	1	−41.2
C-18	Jul. 31, 2018	305	2	304	2	−0.3	287	2	−5.6
C-18	Aug. 6, 2018	446	2	142	2	−68.2	162	1	14.1
C-11	Aug. 14, 2018	96	1	53	1	−44.8	61	1	15.1
C-18	Aug. 14, 2018	178	2	136	2	−23.6	234	2	72.1
Mean % change ± SEM						−29.2 ± 11.0			5.7 ± 15.9

- Host-seeking *Culex* spp. were only marginally controlled at full label rate (~65% reduction).
- Gravid *Culex* spp. were poorly controlled at max label rate (~29% reduction).
- Host-seeking mosquitoes rebounded by ~300% post treatment.
- Gravid mosquitoes showed a modest and variable rebound (~6%).

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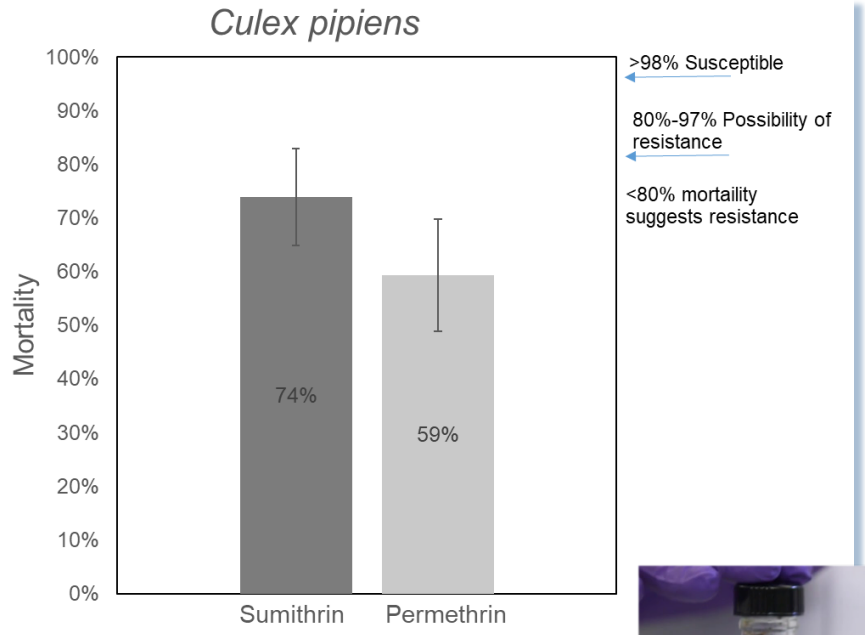
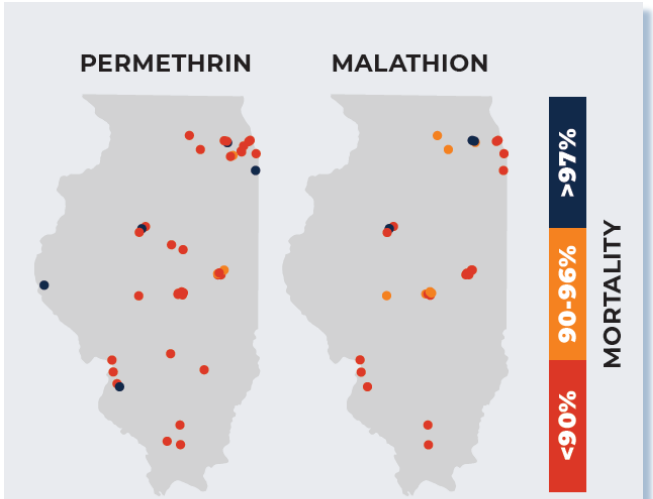
Back to the basics: CDC bottle bioassay



Harbison, J., & Clifton, M.E., Unpublished Data 2018 - 2022



Controlled insecticide-resistance CDC bottle bioassays at the Medical Entomology Lab highlight that resistance to permethrin and malathion is prevalent throughout Illinois in Culex pipiens.

PRI Factsheet INHS Medical Entomology Laboratory (Stone, C. 2021)

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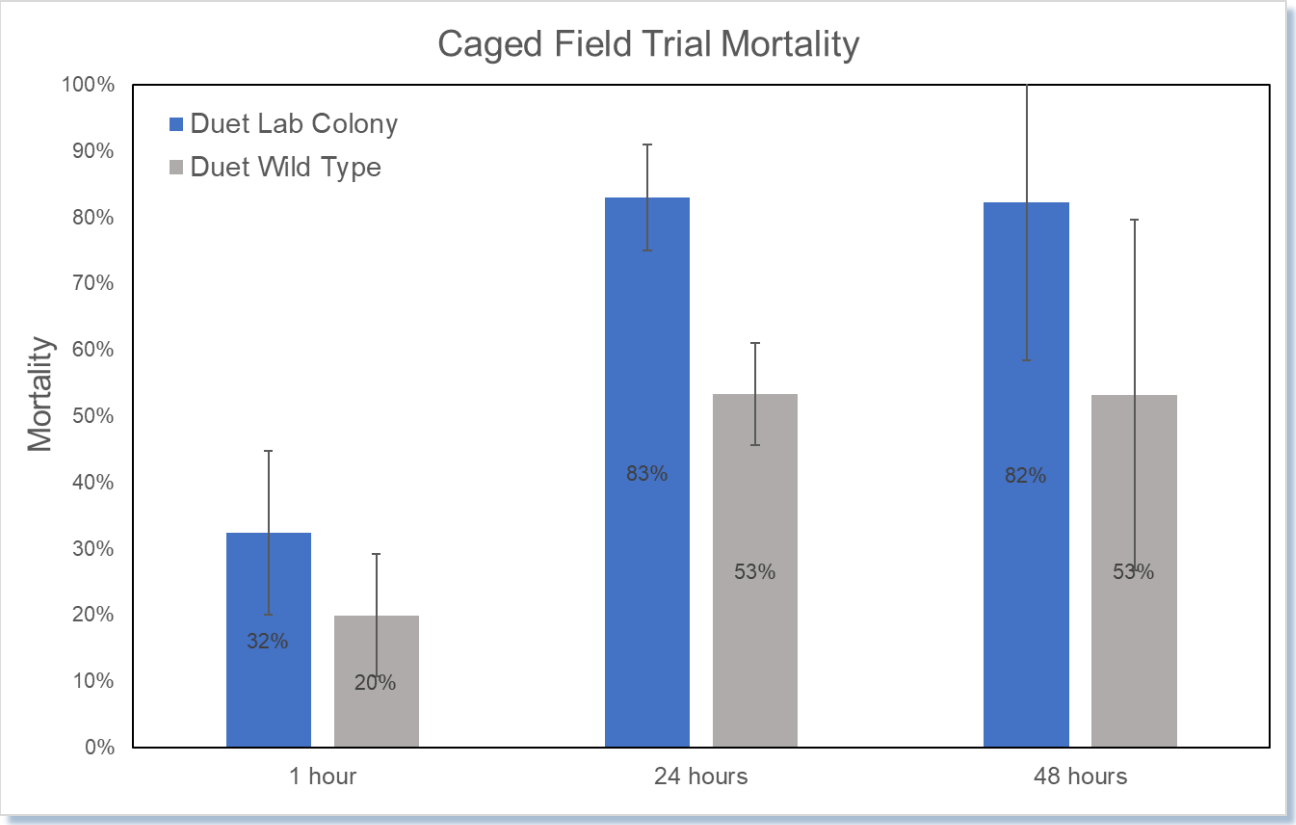
Back to the basics II: Caged field trials



Bottle bioassay vs. caged field trial vs. natural population

	CDC Bottle Bioassay	Caged Field Trial	Natural Population
North Shore Resistant Host-Seeking Mosquito Mortality	74%	53%	65%

Summary of results

Table 2. Mean percentage change and standard error of the mean (SEM) in gravid and host-seeking mosquitoes 24 h pretreatment, 24 h posttreatment, and 72 h posttreatment.

		24 h pretreatment		24 h posttreatment			72 h posttreatment		
Study site	Treatment date	Total mosquitoes	No. of traps	Total mosquitoes	No. of traps	% change from 24 h pretreatment	Total mosquitoes	No. of traps	% change from 24 h posttreatment
Host-seeking mosquitoes									
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Mean % change ± SEM						−29.2 ± 11.0			5.7 ± 15.9

- Why are gravid mosquitoes so poorly controlled?

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Mosquitoes develop a transient resistance post-bloodmeal

Why Does DDT Toxicity Change After a Blood Meal in Adult Female *Culex pipiens*?

TABLE 5

Toxicity of Several Insecticides to Adult Female Culex pipiens

Compound tested	LD_{50} [ng/insect (confidence int	
	Non-blood-fed, Day 6	
DDT	323	(321–326)
Fenvalerate	0.470	(0.392–0.563)
trans-Permethrin	6.21	(5.93–6.50)

Halliday and Feyereisen, Pesticide Biochemistry and Physiology. 28, 172- 181. 1987.

- Nearly two times the amount of material is needed to kill mosquitoes 24-48 hours after a blood meal.

Apparent Influence of the Stage of Blood Meal Digestion on the Efficacy of Ground Applied ULV aerosols for the Control of Urban *Culex* Mosquitoes. II: Laboratory Evidence.

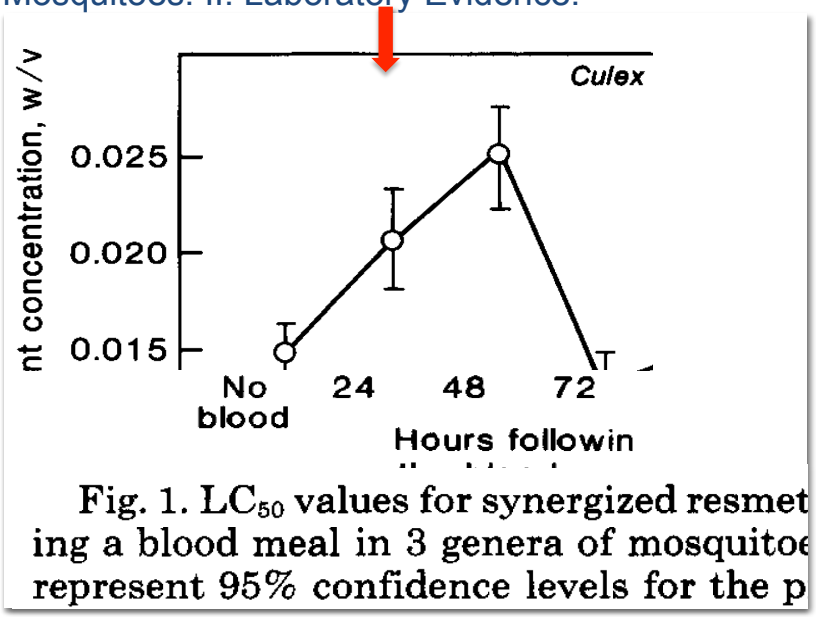
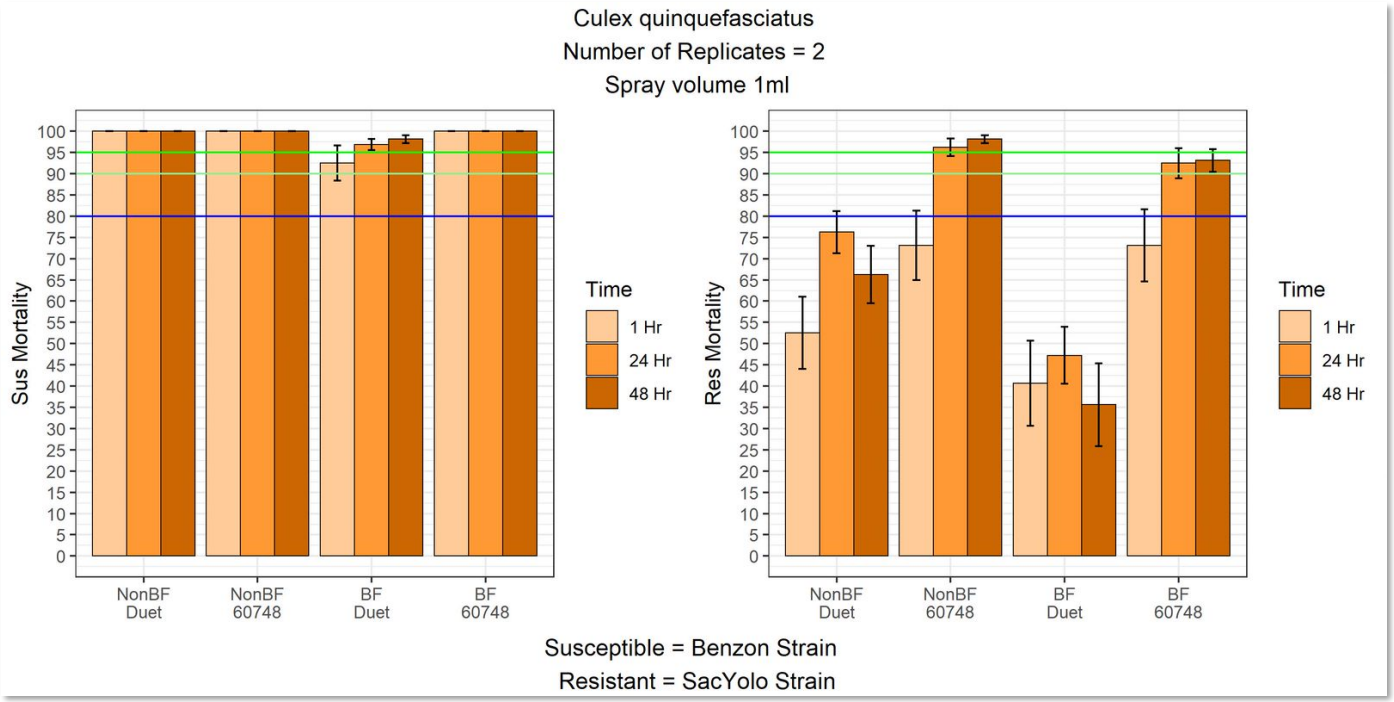


Fig. 1. LC_{50} values for synergized resmet
ing a blood meal in 3 genera of mosquitoe
represent 95% confidence levels for the p

Eliason et al., Journal of the American Mosquito Control Association. 6 (3) 371-376. 1990.

Wind-tunnel assays and post-bloodmeal resistance



Clifton, M.E. & Kesavaraju, B. Unpublished. 2021.

- Blood feeding had minor impacts on susceptible mosquitoes with PBO synergist/formulated product.
- Resistant mosquitoes showed reduced susceptibility to formulated/synergized product.
- 48 hours PBM mortality dropped from ~66% to ~35%.
- VB 60748 remained effective in gravid and resistant mosquitoes.

Post-bloodmeal mosquitoes exhibit half the mortality

	CDC Bottle Bioassay	Caged Field Trial	Wind Tunnel	Natural Population
Resistant Host-Seeking mosquito mortality	74%	53%	66%	65%
Resistant Post-bloodmeal mosquito mortality	-	-	35%	29%

- When resistant mosquitoes are gravid they are half as susceptible to synergized pyrethroid.

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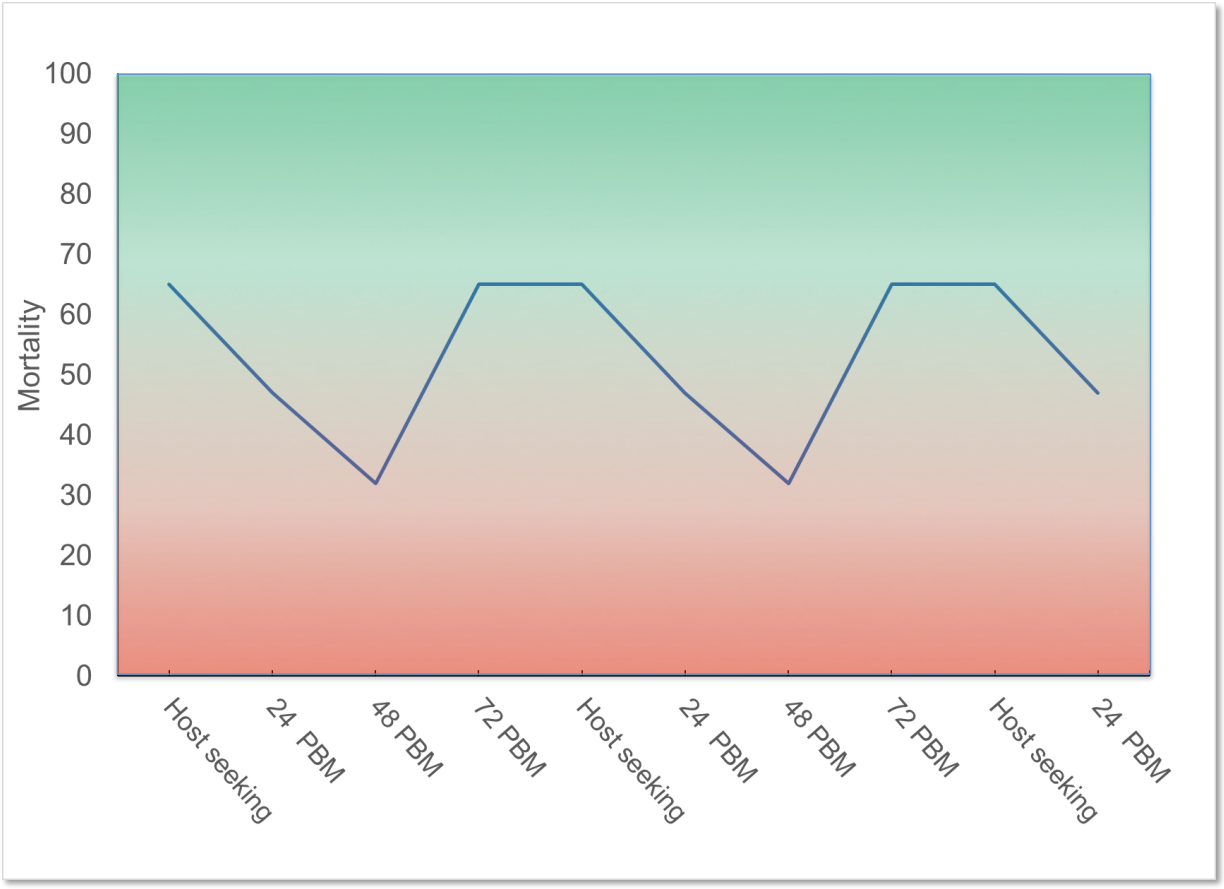
Mosquitoes cycle through various levels of susceptibility



- *Culex spp.* mosquitoes spend about half of each gonotrophic cycle with reduced susceptibility.
- The mosquitoes most likely to be infected with a virus (post-bloodmeal) are the least likely to be controlled.

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Understanding the effect of gravid tolerance with a simple model

	New Mosquitoes	119	92	96	87	85	107	103	90	87	80	94	113	104
Age of Mosquito	**Days in Model**	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Newly Emerged Day 1	119	92	96	87	85	107	103	90	87	80	94	113	104
2	Newly Emerged Day 2		113	87	91	83	81	102	98	86	83	76	89	107
3	Blood Fed 24 hours			102	79	82	75	73	92	88	77	75	69	81
4	Blood fed 48 hours				87	68	71	64	62	79	76	66	64	59
5	Blood fed 72 hours					71	55	57	52	51	64	62	54	52
6	Return to Host-seeking 1						55	43	44	40	39	50	48	42
7	Return to Host-seeking 2							34	31	33	30	29	36	35
8	Blood Fed 24 hours								24	22	23	21	20	25
9	Blood fed 48 hours									16	15	15	14	13
10	Blood fed 72 hours										9	9	9	8
11	Return to Host-seeking 1											5	5	5
12	Return to Host-seeking 2												3	3
13	Blood Fed 24 hours													1
14	Blood fed 48 hours													
15	Blood fed 72 hours													
16	Return to Host-seeking 1													
17	Return to Host-seeking 2													
18	Blood Fed 24 hours													
19	Blood fed 48 hours													
20	Blood fed 72 hours													
	Total mosquitoes	574	565	559	545	529	537	536	530	522	506	507	527	537
	Potentially Infected Mosquitoes	360	360	376	367	362	350	331	342	349	344	337	324	326

ULV Model adapted from: Moore, C. G., et al. "Apparent influence of the stage of blood meal digestion on the efficacy of ground applied ULV aerosols for the control of urban Culex mosquitoes. III. Results of a computer simulation." *Journal of the American Mosquito Control Association* 6.3 (1990): 376-383.

- A random number of mosquitoes between 75 and 125 enters the model each day
- Mosquitoes move diagonally through the model
- Each mosquito has a 95% daily survival probability
- Mosquitoes cycle through gonotrophic states
- A ULV treatment can be simulated by assigned mortality values to each gonotrophic state.

Modeling the effect of ULV on susceptible mosquitoes with 95% efficacy

Stage	Mortality
Host-seeking	95%
Blood fed 24hr	95%
Blood fed 48hr	95%
Blood fed 72hr	95%

ULV Treatment to **susceptible** mosquitoes with a 95% mortality for all stages

	New Mosquitoes	115	118	124	100	94	125	90	103	116	87	120	77	100	94	103	100	118	83	104	111	77	76	103	79	109	101	123	89	122	96
Age of Mosquito	**Days in Model**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Newly Emerged Day 1	115	118	124	100	94	125	90	103	116	87	120	77	100	5	103	100	118	83	104	111	77	76	103	79	109	101	123	89	122	96
2	Newly Emerged Day 2		109	112	118	95	89	119	86	98	110	83	114	73	5	4	98	95	112	79	99	105	73	72	98	75	104	96	117	85	116
3	Blood Fed 24 hours			99	101	106	86	81	107	77	88	99	75	103	3	4	4	88	86	101	71	89	95	66	65	88	68	93	87	105	76
4	Blood fed 48 hours				85	87	91	74	69	92	66	76	85	64	4	3	4	3	76	74	87	61	76	82	57	56	76	58	80	74	90
5	Blood fed 72 hours					69	71	74	60	56	75	54	62	69	3	4	2	3	3	62	60	71	50	62	66	46	46	62	47	65	60
6	Return to Host-seeking 1						53	55	57	46	44	58	42	48	3	2	3	2	2	2	48	46	55	38	48	51	36	35	48	37	50
7	Return to Host-seeking 2							34	40	42	34	32	43	31	2	2	1	2	1	2	2	35	34	40	28	35	38	26	26	35	27
8	Blood Fed 24 hours								24	28	29	24	22	30	1	1	1	1	1	1	1	1	24	24	28	20	25	26	18	18	24
9	Blood fed 48 hours									16	19	20	16	15	1	1	1	1	1	1	1	1	1	16	16	19	13	16	18	12	12
10	Blood fed 72 hours										9	11	12	9	0	1	0	0	1	0	1	0	0	0	10	9	11	8	10	10	7
11	Return to Host-seeking 1											5	6	7	0	0	0	0	0	0	0	0	0	0	0	6	5	6	4	6	6
12	Return to Host-seeking 2												3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	2	3
13	Blood Fed 24 hours													1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	1
14	Blood fed 48 hours														0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
15	Blood fed 72 hours															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Return to Host-seeking 1																0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Return to Host-seeking 2																	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Blood Fed 24 hours																		0	0	0	0	0	0	0	0	0	0	0	0	0
19	Blood fed 48 hours																			0	0	0	0	0	0	0	0	0	0	0	0
20	Blood fed 72 hours																				0	0	0	0	0	0	0	0	0	0	0
	Total mosquitoes	570	587	609	604	591	609	586	582	592	573	587	559	555	27	125	215	315	366	426	480	488	485	505	496	515	524	555	549	575	572
	Potentially Infected Mosquitoes	360	360	372	386	402	395	377	394	378	376	385	368	382	18	18	18	102	171	243	270	305	336	330	319	331	320	336	343	368	360

Modeling the effect of ULV on resistant mosquitoes with variable efficacy

Stage	Mortality
Host-seeking	65%
Blood fed 24hr	47%
Blood fed 48hr	29%
Blood fed 72hr	65%

ULV Treatment to **resistant** mosquitoes with a variable mortality post-bloodmeal

	New Mosquitoes	85	117	114	83	100	98	106	99	98	102	121	119	90	115	75	106	113	120	95	123	95	79	125	113	122	90	76	99	109	106
Age of Mosquito	**Days in Model**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Newly Emerged Day 1	85	117	114	83	100	98	106	99	98	102	121	119	90	40	75	106	113	120	95	123	95	79	125	113	122	90	76	99	109	106
2	Newly Emerged Day 2		81	111	108	79	95	93	101	94	93	97	115	113	30	38	71	101	107	114	90	117	90	75	119	107	116	86	72	94	104
3	Blood Fed 24 hours			73	100	98	71	86	84	91	85	84	87	104	54	27	35	64	91	97	103	81	105	81	68	107	97	105	77	65	85
4	Blood fed 48 hours				62	86	84	61	74	72	78	73	72	75	63	46	23	30	55	78	83	88	70	90	70	58	92	83	90	66	56
5	Blood fed 72 hours					51	70	68	50	60	59	63	59	59	21	51	38	19	24	45	63	68	72	57	74	57	47	75	68	73	54
6	Return to Host-seeking 1						39	54	53	38	46	45	49	46	16	17	40	29	15	19	35	49	52	56	44	57	44	37	58	52	57
7	Return to Host-seeking 2							34	40	39	28	34	33	36	12	12	12	29	21	11	14	26	36	38	41	32	42	32	27	43	38
8	Blood Fed 24 hours								24	28	27	20	24	23	13	8	8	8	20	15	7	10	18	25	27	29	23	29	23	19	30
9	Blood fed 48 hours									16	18	18	13	16	11	9	5	5	6	14	10	5	6	12	17	18	19	15	19	15	12
10	Blood fed 72 hours										9	11	11	8	3	7	5	3	3	3	8	6	3	4	7	10	11	11	9	12	9
11	Return to Host-seeking 1											5	6	6	2	2	4	3	2	2	2	5	3	2	2	4	6	6	6	5	7
12	Return to Host-seeking 2												3	3	1	1	1	2	2	1	1	1	2	1	1	2	3	3	3	3	3
13	Blood Fed 24 hours													1	1	1	0	1	1	1	1	1	1	1	0	1	1	2	2	2	2
14	Blood fed 48 hours														1	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	1
15	Blood fed 72 hours															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Return to Host-seeking 1																0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Return to Host-seeking 2																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Blood Fed 24 hours																		0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Blood fed 48 hours																			0	0	0	0	0	0	0	0	0	0	0	0	0
20	Blood fed 72 hours																				0	0	0	0	0	0	0	0	0	0	0	0
	Total mosquitoes	540	557	572	554	554	552	562	560	556	557	577	595	582	268	294	349	408	468	494	541	551	539	569	583	604	589	559	554	559	563
	Potentially Infected Mosquitoes	360	360	347	363	375	359	363	360	364	362	360	361	379	198	181	172	195	241	285	328	339	370	369	352	374	383	398	382	356	353

Susceptible vs resistant mosquitoes with gravid tolerance

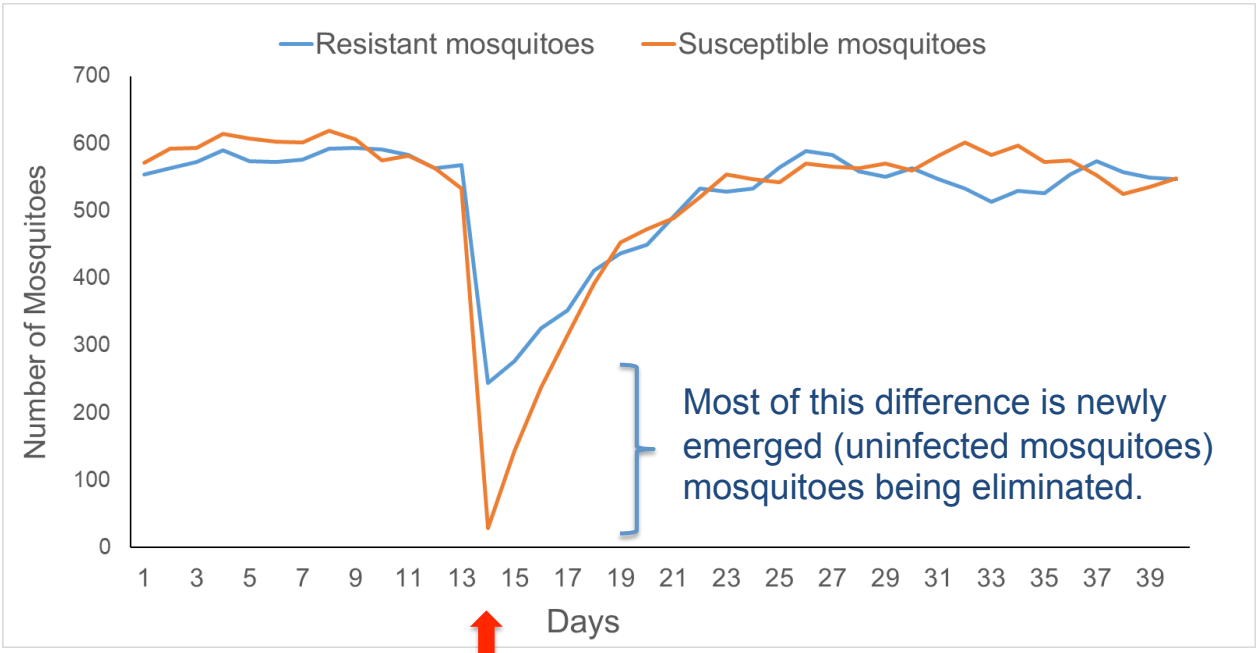
	New Mosquitoes	115	118	124	100	94	125	90	103	116	87	120	77	100	94	103	100	118	83	104	111	77	76	103	79	109	101	123	89	122	96
Age of Mosquito	Days in Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Newly Emerged Day 1	115	118	124	100	94	125	90	103	116	87	120	77	100	5	103	100	118	83	104	111	77	76	103	79	109	101	123	89	122	96
2	Newly Emerged Day 2		109	112	118	95	89	119	86	98	110	83	114	73	5	4	98	95	112	79	99	105	73	72	98	75	104	96	117	85	116
3	Blood Fed 24 hours			99	101	106	86	81	107	77	88	99	75	103	3	4	4	88	86	101	71	89	95	66	65	88	68	93	87	105	76
4	Blood fed 48 hours				85	87	91	74	69	92	66	76	85	64	4	3	4	3	76	74	87	61	76	82	57	56	76	58	80	74	90
5	Blood fed 72 hours					69	71	74	60	56	75	54	62	69	3	4	2	3	3	62	60	71	50	62	66	46	46	62	47	65	60
6	Return to Host-seeking 1						53	55	57	46	44	58	42	48	3	2	3	2	2	2	48	46	55	38	48	51	36	35	48	37	50
7	Return to Host-seeking 2							34	40	42	34	32	43	31	2	2	1	2	1	2	2	35	34	40	28	35	38	26	26	35	27
8	Blood Fed 24 hours								24	28	29	24	22	30	1	1	1	1	1	1	1	1	24	24	28	20	25	26	18	18	24
9	Blood fed 48 hours									16	19	20	16	15	1	1	1	1	1	1	1	1	1	16	16	19	13	16	18	12	12
10	Blood fed 72 hours										9	11	12	9	0	1	0	0	1	0	1	0	0	0	10	9	11	8	10	10	7
11	Return to Host-seeking 1											5	6	7	0	0	0	0	0	0	0	0	0	0	0	6	5	6	4	6	6
12	Return to Host-seeking 2												3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	2	3
13	Blood Fed 24 hours													1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	1	
14	Blood fed 48 hours														0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	
15	Blood fed 72 hours															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	Return to Host-seeking 1																0	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	Return to Host-seeking 2																	0	0	0	0	0	0	0	0	0	0	0	0	0	
18	Blood Fed 24 hours																		0	0	0	0	0	0	0	0	0	0	0	0	
19	Blood fed 48 hours																			0	0	0	0	0	0	0	0	0	0	0	
20	Blood fed 72 hours																				0	0	0	0	0	0	0	0	0	0	
	Total mosquitoes	570	587	609	604	591	609	586	582	592	573	587	559	555	27	125	215	315	366	426	480	488	485	505	496	515	524	555	549	575	572
	Potentially Infected Mosquitoes	360	360	372	386	402	395	377	394	378	376	385	368	382	18	18	18	102	171	243	270	305	336	330	319	331	320	336	343	368	360

	New Mosquitoes	85	117	114	83	100	98	106	99	98	102	121	119	90	115	75	106	113	120	95	123	95	79	125	113	122	90	76	99	109	106
Age of Mosquito	Days in Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Newly Emerged Day 1	85	117	114	83	100	98	106	99	98	102	121	119	90	40	75	106	113	120	95	123	95	79	125	113	122	90	76	99	109	106
2	Newly Emerged Day 2		81	111	108	79	95	93	101	94	93	97	115	113	30	38	71	101	107	114	90	117	90	75	119	107	116	86	72	94	104
3	Blood Fed 24 hours			73	100	98	71	86	84	91	85	84	87	104	54	27	35	64	91	97	103	81	105	81	68	107	97	105	77	65	85
4	Blood fed 48 hours				62	86	84	61	74	72	78	73	72	75	63	46	23	30	55	78	83	88	70	90	70	58	92	83	90	66	56
5	Blood fed 72 hours					51	70	68	50	60	59	63	59	59	21	51	38	19	24	45	63	68	72	57	74	57	47	75	68	73	54
6	Return to Host-seeking 1						39	54	53	38	46	45	49	46	16	17	40	29	15	19	35	49	52	56	44	57	44	37	58	52	57
7	Return to Host-seeking 2							34	40	39	28	34	33	36	12	12	12	29	21	11	14	26	36	38	41	32	42	32	27	43	38
8	Blood Fed 24 hours							24	28	27	20	24	23	13	8	8	8	20	15	7	10	18	25	27	29	23	29	23	19	30	
9	Blood fed 48 hours								16	18	18	13	16	11	9	5	5	6	14	10	5	6	12	17	18	19	15	19	15	12	
10	Blood fed 72 hours									9	11	11	8	3	7	5	3	3	3	8	6	3	4	7	10	11	11	9	12	9	
11	Return to Host-seeking 1										5	6	6	2	2	4	3	2	2	2	5	3	2	2	4	6	6	6	5	7	
12	Return to Host-seeking 2											3	3	1	1	1	2	2	1	1	1	2	2	1	1	2	3	3	3	3	
13	Blood Fed 24 hours												1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	2	2	2	
14	Blood fed 48 hours													1	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	1	
15	Blood fed 72 hours														0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	Return to Host-seeking 1															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	Return to Host-seeking 2																0	0	0	0	0	0	0	0	0	0	0	0	0	0	
18	Blood Fed 24 hours																	0	0	0	0	0	0	0	0	0	0	0	0	0	
19	Blood fed 48 hours																		0	0	0	0	0	0	0	0	0	0	0	0	
20	Blood fed 72 hours																			0	0	0	0	0	0	0	0	0	0	0	
	Total mosquitoes	540	557	572	554	554	552	562	560	556	557	577	595	582	268	294	349	408	468	494	541	551	539	569	583	604	589	559	554	559	563
	Potentially Infected Mosquitoes	360	360	347	363	375	359	363	360	364	362	360	361	379	198	181	172	195	241	285	328	339	370	369	352	374	383	398	382	356	353

- Susceptible mosquitoes with 95% mortality have older cohorts eliminated for up to10 days.
- Resistant mosquitoes with variable gravid susceptibility continue to produce older and infectious cohorts of mosquitoes.

North Shore Mosquito Abatement District

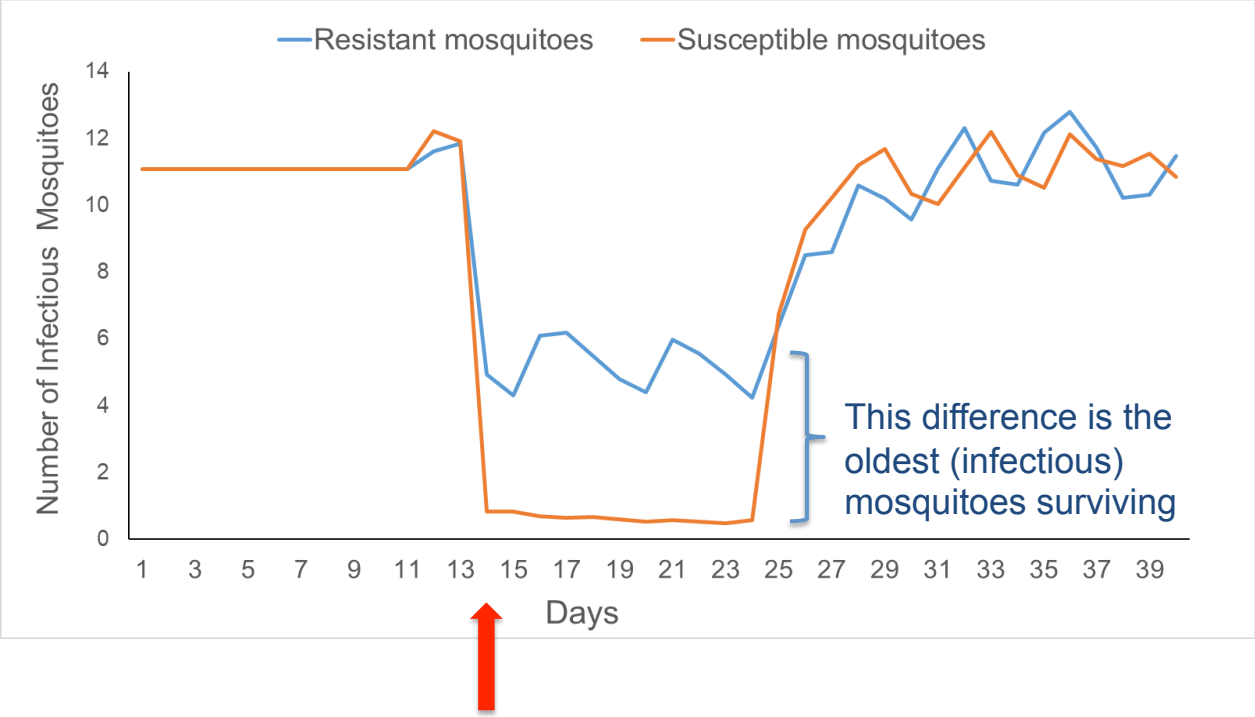
Modeling the effect of ULV on resistant and susceptible mosquitoes- entire population



- Resistant mosquitoes are nearly 9 times more abundant on the day after treatment.
- Most mortality in resistant mosquitoes is in the earliest host-seeking stages and not the older infected mosquitoes.

North Shore Mosquito Abatement District

Modeling the effect of ULV on resistant and susceptible mosquitoes- oldest cohorts(>11 days)



- The oldest cohorts of mosquitoes i.e. those most likely to be infectious are on average, 5 times more common, between days 14 and 24 post treatment.
- Where old and susceptible mosquitoes are nearly eliminated, resistant mosquitoes persist and remain a threat.
- If the probability of daily survival is higher than 95% then the outcome is much worse.

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Conclusions

- Resistance to synergized pyrethroid products is widespread in the NSMAD and Illinois.
- Post-bloodmeal mosquitoes develop a further transient resistance that affects the age structure of the population.
- A reduction in treatment effectiveness due to resistance is only the most superficial effect.
- Age-structure of the population is not important when only considering the treatment effect on total abundance- most mosquitoes eliminated in a population are newly emerged and uninfected.
- Age-structure of a mosquito population is vital when considering the public health impact of a treatment- older, and gravid mosquitoes are most likely to be infectious and least likely to be controlled.
- A modest reduction in control effectiveness due to resistance is more serious because of the failure to impact the age-structure of a population.

North Shore
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District

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