AMCARF Project Final Report

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Project Title: ARCHIVe - Automated Real-time Collection and High-Fidelity Identification of Vectors

AMCARF project number: 2019-002

Project Cost: $45,223.00

Project Leader: Nathan Burkett-Cadena

Collaborators: TrakITNow, LLC: Terry DeBriere (20%), Satish Cherukumalli; Salt Lake City Mosquito Abatement District; Indian River mosquito control district; and USDA ARS Gainesville

Project Objectives:

- Aim 1. Construct a wave file library for 30 mosquito species of vector and nuisance significance.
- Aim 2. Determine the sensitivity and specificity of the ARCHIVe system under semi-field conditions.
- Aim 3. Field deployment and validation of the ARCHIVe system in Florida and Utah.

Total Project Progress:

Key Research Accomplishments:

Aim 1. We have successfully collected and established wingbeat profiles of thirty mosquito species from 11 genera **(Table 1)**. These included a majority of the dominant vector and nuisance species of the eastern and western US. These included species of *Culex*, *Aedes*, *Anopheles*, *Wyeomyia*, *Psorophora*, *Sabethes*, *Deinocerites*, *Mansonia*, *Uranotaenia*, *Toxorhynchites*, and *Culiseta*. The numbers of female wingbeat profiles varied among species. In total, 41,739 wingbeat files were measured for building

Table 1: *Total number of mosquito wingbeat files by species, composed of sensor array and association hardware/software.*

Species	Files (n)	Species	Files (n)
Culex quinquefasciatus	3,992	*Aedes triseriatus*	3,201
Culex nigripalpus	1,074	*Aedes japonicus*	3,170
Culex coronator	1,021	*Anopheles albimanus*	2,164
Culex tarsalis	3,158	*Ano. quadrimaculatus*	1,843
Culex pipiens	2,843	*Anopheles crucians*	536
Culex iolambdis	1,759	*Wyeomyia smithii*	234
Culex interrogator	232	*Wyeomyia vanduzeei*	1,200
Culex restuans	984	*Wyeomyia mitchellii*	1,113
Aedes aegypti	2,549	*Psor. columbiae*	1,167
Aedes albopictus	2,959	*Sabethes cyaneus*	23
Aedes dorsalis	425	*Deinocerites cancer*	394
Aedes sierrensis	442	*Mansonia titillans*	20
Aedes taeniorhynchus	1,676	*Uranotaenia lowii*	269
Aedes vexans	1,888	*Toxorhynchites rutilus*	156
Aedes infirmatus	168	*Culiseta incidens*	1,079

the wave file library and confusion matrix **(Table 1)**. Especially, the wingbeat files from species that medically important (*Culex quinquefasciatus, Aedes aegypti, Aedes albopictus,* and *Anopheles albimanus*) were collected with a minimum of 3,000 individual females **(Table 1)**.

We collaborated with Salt Lake City Mosquito Abatement District (SLCMAD), Indian River Mosquito Control District (IRMCD), and USDA ARS Gainesville, Florida to obtain targeting or additional mosquito species for wingbeat profiles that were accessible or in colony at those locations. Since non-target insects were captured during field deployment (Aim 3), we collected additional wingbeat profiles of 4 orders (i.e., Diptera, Coleoptera, Lepidoptera, and Hymenoptera) belong species to enhance and optimize the sensitivity of the ARCHIVe system (Aim 2) **(Supplementary Table 1).**

In order to determine whether the mosquito wingbeat variation was consistent within an individual and a population in a species, an individual mosquito wave files in each species consisting of the most common nuisance and vector species consisting of *Culex quinquefasciatus, Aedes taeniorhynchus, Aedes aegypti, Aedes albopictus,* and *Anopheles albimanus* were collected **(Supplementary Table 2)**. We introduced an individual mosquito into a flight tube with ARCHIVe sensor array in succession and experiment was replicated ten times in each species. This wingbeat library is critical to the development and evaluation of the ARCHIVe system and other platforms that utilize mosquito wingbeat frequency for automated identification.

Aim 2. To determine the sensitivity and specificity of the ARCHIVe system, we tested light traps, BG-Sentinel traps, and gravid traps equipped with ARCHIVe system under semi-field and field (Aim 3) conditions. To optimize the ARCHIVe system for the efficient sampling, the ARCHIVe baited light traps were compared in updraft and downdraft configurations under field settings. Trapping was replicated over 12 trap nights using dry ice and UV-LED array bulbs that are commonly used in mosquito traps. In total, 3,899 adult mosquitoes were collected by the combined sampling methods **(Supplementary Table 3)**. Results demonstrate that updraft configuration of the ARCHIVe trap collected 2.1 & 1.6 times more *Cx. nigripalpus* and *Ae. taeniorhynchus* females, respectively than the downdraft trap **(Figure 1)**. Combined, these traps collected 12 mosquito species belonging to 8 genera (**Supplementary Table 3)**.

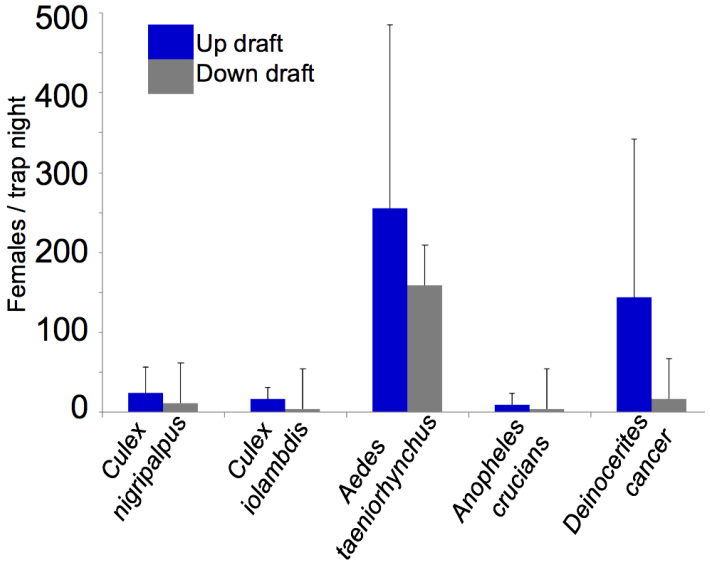


Figure 1: Average of capture rate of ARCHIVe up draft and down draft carbon dioxide baited light traps for the most common nuisance and vector species in

We also conducted evaluation of the ARCHIVe equipped BG-Sentinel traps in screened cages with single (*Cx. quinquefasciatus*, *Ae. albopictus* or *Ae. aegypti*) or mixed (*Cx.*

quinquefasciatus, *Ae. albopictus* and *Ae. aegypti*) species in semi-field settings. In single species trials, each of female species (N=25) were released into screened cages with ARCHIVe equipped BG traps. Result showed capture rate was the highest for *Ae. aegypti* (100.0%) and *Ae. albopictus* (82.0%), compared to *Cx. quinquefasciatus* (46.0%) **(Figure 2a)**. In the mixed species settings, females (each species N=50, total=150) were released and capture rate was compared between ARCHIVe and commercially available (unaltered) BG traps. Total capture rate was higher with the ARCHIVe BG trap (56.5%) than with commercially available BG-sentinel trap (53.0%) **(Figure 2b)**. The ARCHIVe equipped BG trap collected 1.7 and 1.4 times more *Culex quinquefasciatus* and *Ae. albopictus* females than commercial BG-sentinel trap. However, *Ae. aegypti* was higher in capture rate from BG-sentinel trap (97.0%) than ARCHIVe trap (74.0%) **(Figure 3)**.

The ARCHIVe gravid trap was compared to the commercially available CDC gravid trap with *Cx. quinquefasciatus* in semi-field settings. Gravid females (N=25) were released into screened cages with either ARCHIVe or CDC gravid traps to compare capture rate of the two traps. Capture rate was higher with the CDC gravid traps (76.8%) than with ARCHIVe trap (52.8%) **(Figure 3)**. However, ARCHIVe gravid trap efficacy was significantly enhanced from 14.0% to 52.8% comparing to the previous preliminary evaluation (described in Midterm report) after critical trap and assay modifications.

Aim 3. Field deployment and validation of the ARCHIVe system in Florida and Utah were conducted. Three mosquito traps consisted of ARCHIVe light trap baited with dry ice and UV-LED array bulbs, ARCHIVe BG-sentinel trap baited with dry ice and BG lure and ARCHIVe gravid trap baited with 1.5 litter of an infusion in which oak leaf (*Quercus spp.*) had fermented for forty-eight hours. The traps were set at each of three sites representing urban, suburban, and rural locations in both Florida and Utah. The study period began

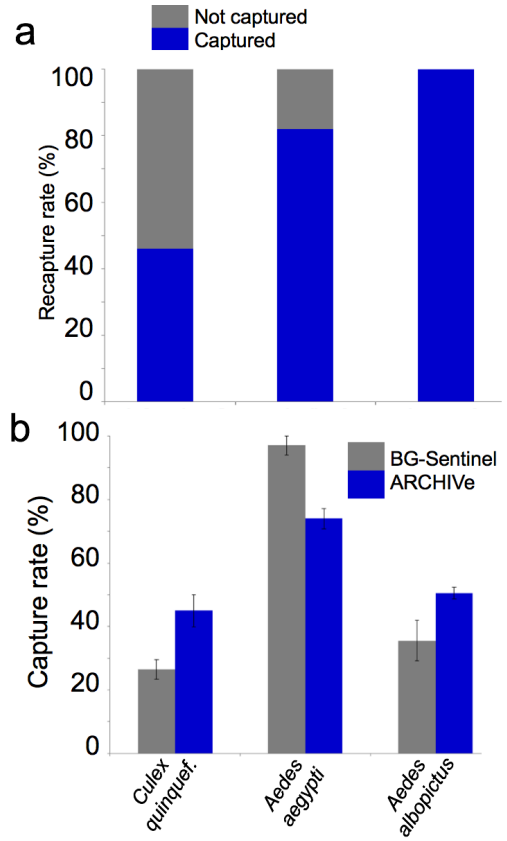


Figure 2. Recapture rate of BG-Sentinel traps equipped with ARCHIVe system for three nuisance and vector species (N=50) in a screened enclosure.

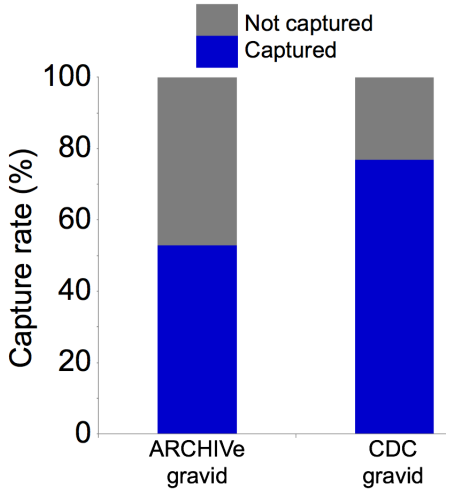


Figure 3. Recapture rate of gravid traps with ARCHIVe system for Cx. quinquefasciatus (screened enclosure).

September 24 or 25 and terminated November 14, 2019 in Indian River County, FL and July 19 and terminated August 23, 2019 in Salt Lake County, UT, USA. The traps were operated for 15 hours including dusk and dawn and sampled four times weekly in Indian River County and once weekly in Salt Lake County. The collected adult mosquitoes in the capture chamber were freeze-killed and identified under the dissecting microscope according to standard keys (Darsie).

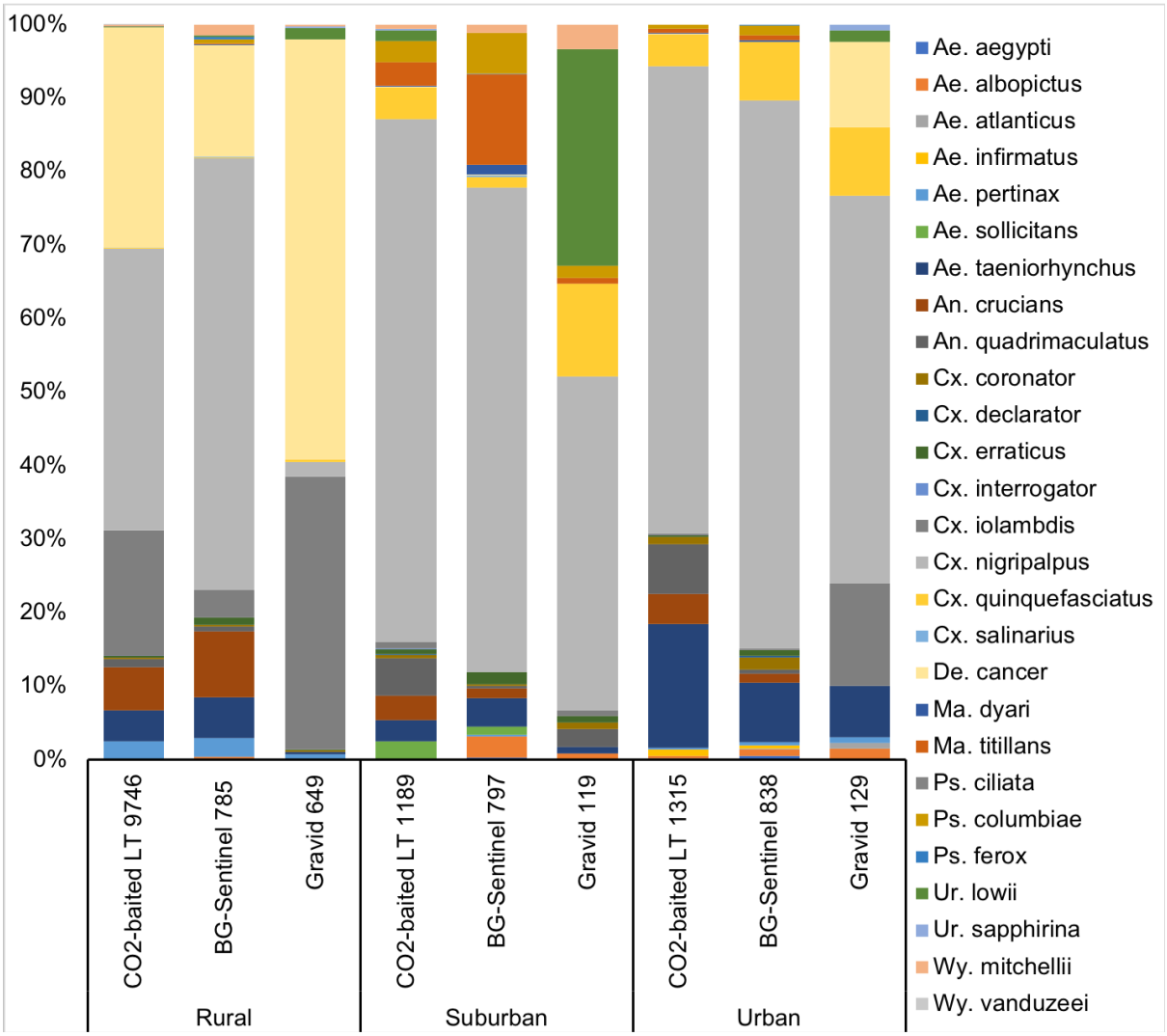


Figure 4. Mosquitoes captured during field deployment of ARCHIVe traps (light traps, BG-Sentinel traps, gravid traps) at rural, suburban and urban sites in Indian River Co. FL, 2019.

In Indian River County, the combined trapping methods resulted in a diverse mosquito community, consisting of 8 genera and 27 species (**Figure 4**). In total, 15,567 adult mosquitoes were collected by the combined sampling methods and sites during field deployment and validation of the ARCHIVe system. Of the mosquitoes collected, 98.9% (N= 15,390) were female and 1.1% (N=177) were male. Chi-square test of independence comparing efficacy of the different traps for capturing mosquitoes, revealed signicant differences (X^2=388.471; df=2; P<0.001) in the distributions of overall mosquitoes numbers **(Supplementary Table 4)** among the three sites.

ARCHIVe light trap collections constituted 77.69% of total mosquitoes collected, but 15.55% and 6.76% were from BG-sentinel trap and gravid trap, respectively.

The relative numbers of female mosquitoes varied among trap types and sites. Collections of ARCHIVe light trap, ARCHIVe BG-sentinel trap, and ARCHIVe gravid trap in FMEL (Florida Medical Entomology Laboratory) representing rural area were dominated by genera of *Culex and Deinocerites* **(Supplementary Table 5)**. Collections of ARCHIVe light trap and ARCHIVe BG-sentinel trap in FS (Fire Station) representing urban area were dominated by genera of *Culex and Aedes*, while collections from ARCHIVe gravid trap were dominated by *Culex* and *Deinocerites* **(Supplementary Table 6)**. Collections from ARCHIVe light trap, ARCHIVe BG-sentinel trap, and ARCHIVe gravid trap in IRMCD (Indian River Mosquito Control District) representing suburban area were primarily dominated by genera of *Culex*, while secondary dominated genera were *Anopheles*, *Mansonia*, and *Uranotaenia*, respectively **(Supplementary Table 7)**. Substantial differences were observed in mosquito communities in overall collections among the three sites. *Culex nigripalpus* and *Deinocerites cancer*, for example, dominated overall collections from FMEL, constituting more than two quarters (37.67 and 30.54%) of total mosquito collections. However, *Cx. nigripalpus* was the most commonly collected species in both FS and IRMCD, constituting 66.91 and 67.70% of each overall collection, secondary dominated species were *Aedes taeniorhynchus* (13.06%) and *Mansonia titillans* (6.51%).

Culex nigripalpus and *Culex iolambdis* were the most common *Culex spp.* from traps in rural, while *Culex quinquefasciatus and Cx. nigripalpus* were the most common species at suburban and urban sites. *Aedes taeniorhynchus* was the most common *Aedes* species collected in among all sites. The secondary dominated in *Aedes spp.* was *Aedes infirmatus* in rural, *Aedes albopictus* in urban, and *Aedes pertinax* in suburban sites. *Anopheles quadrimaculatus* was the most commonly collected *Anopheles* species in urban and suburban sites, while *Anopheles crucians* in rural sites 5.6 times more common

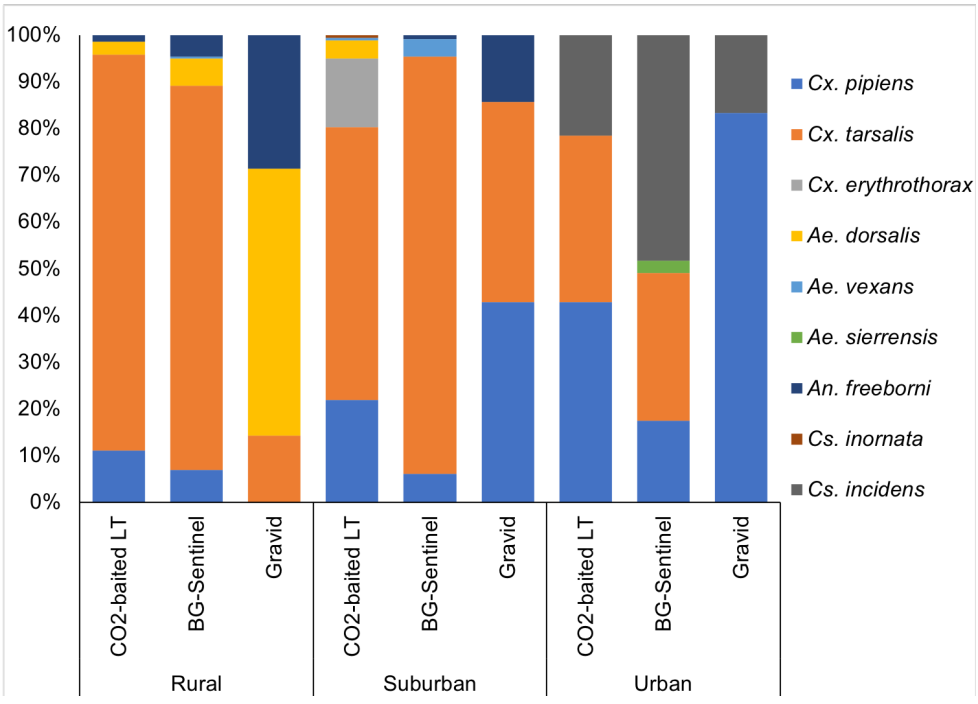


Figure 5. Mosquitoes captured during field deployment of ARCHIVe traps (light traps, BG-Sentinel traps, gravid traps) at rural, suburban and urban sites in Salt Lake City, UT, 2019.

than *Anopheles quadrimaculatus*. Species of *Culex* (*Culex decorator*, *Culex interrogator*, and *Culex salinarius*), *Aedes* (*Aedes aegypti, Aedes infirmatus,* and *Aedes atlanticus*), *Psorophora* (*Psorophora ferox* and *Psorophora ciliate*), *Mansonia* (*Mansonia dyari*), *Wyeomyia* (*Wyeomyia mitchellii* and *Wyeomyia vanduzeei*), and *Uranotaenia* (*Uranotaenia sapphirina*) were relatively minor in trap collections in among all sites (less than 1.0%).

In Salt Lake City, the combined trapping methods, ARCHIVe light trap, ARCHIVe BG-sentinel trap and ARCHIVe gravid trap resulted in a diverse mosquito community, consisting of 4 genera and 9 species. In total, 1,407 adult mosquitoes were collected by the combined sampling methods and sites and no male adult mosquitoes were recorded. Chi-square test of independence comparing efficacy of the different traps for capturing mosquitoes, found no signicant differences (X^2=37.251; df=2; P<0.909) in the distributions of overall mosquitoes numbers due to low collection rate **(Table 12)** among the three sites. ARCHIVe BG-sentinel trap collections constituted 54.02% of total mosquitoes collected, but 44.14% and 1.85% were from light and gravid trap, respectively.

The relative numbers of female mosquitoes varied among trap types and sites. Collections of ARCHIVe light trap and ARCHIVe BG-sentinel trap in Site “Rudy” representing rural area were dominated by genera of *Culex* and *Aedes*, while collections from ARCHIVe gravid trap were dominated by *Aedes* and *Anopheles* **(Supplementary Table 8)**. Collections from ARCHIVe light trap and ARCHIVe BG-sentinel trap in Site “ATV representing suburban area were primarily dominated by genera of *Culex* and *Aedes*, while collections from ARCHIVe gravid trap were dominated by *Culex* and *Anopheles* **(Supplementary Table 9).** Collections of all types of traps in Site “Downingtown” representing urban area were dominated by genera of *Culex and Culiseta* **(Supplementary Table 10)**. *Culex tarsalis* and *Culex pipiens*, for example, dominated overall collections from Rudy, constituting more than three quarters (70.70 and 15.92%) of total mosquito collections. However, *Culex tarsalis* was 29.29%. *Culex tarsalis* and *Culex pipiens* dominated in ATV, constituting more than three quarters (82.79 and 8.81%) of total mosquito collections. *Culiseta incidens* was the most commonly collected species in Downingtown constituting 42.86% across all trap types. Species of *Aedes* (*Aedes vexans* and *Aedes sierrensis*) and *Culiseta* (*Culiseta inornata*) were relatively minor components of trap collections in among all sites (less than 1.0%). Results for all Salt Lake City sites are summarized in **Supplementary Table 11.**

To test the ability of the ARCHIVe system to identify mosquito species, wingbeat files from traps during semifield and field evaluations of ARCHIVe systems were processed using four analytic pyAudio Analysis frameworks: Logistic Regression Confusion Matrix, Decision Jungle Confusion Matrix, Decision Forest Confusion Matrix, Neural Network Confusion Matrix. The

Table 2: Comparison of overall accuracy of different AI algorithms for classifying mosquito species using pyAudio Analysis with and without activity time of mosquitoes.

Algorithms	pyAudio Analysis	pyAudioAnalysis + Activity Time
Multiclass Neural Networks	37%	63.2%
Multiclass Logistic Regression	36%	42%
Multiclass Decision Forest	59%	75.8%
Multiclass Decision Jungle	34%	55.8%

results of these analyses were compared in two ways. First, validation studies were performed by assigning wingbeat files to training and test data sets, using variables time of activity (circadian) and other variables to inform models. Second, a blind test was performed using five common mosquito species in a flight tube with the ARCHIVe sensors and detection hardware/software.

The results demonstrate the including activity time in analyses results in significant increase in the predictive capabilities of pyAudio Analysis for determining mosquito species (**Table 2**). Confusion matrices showing the results of logistic regression (left) and decision forest (right) show how far improved results can be obtained, based upon which analysis is used, and which variables are taken into account.

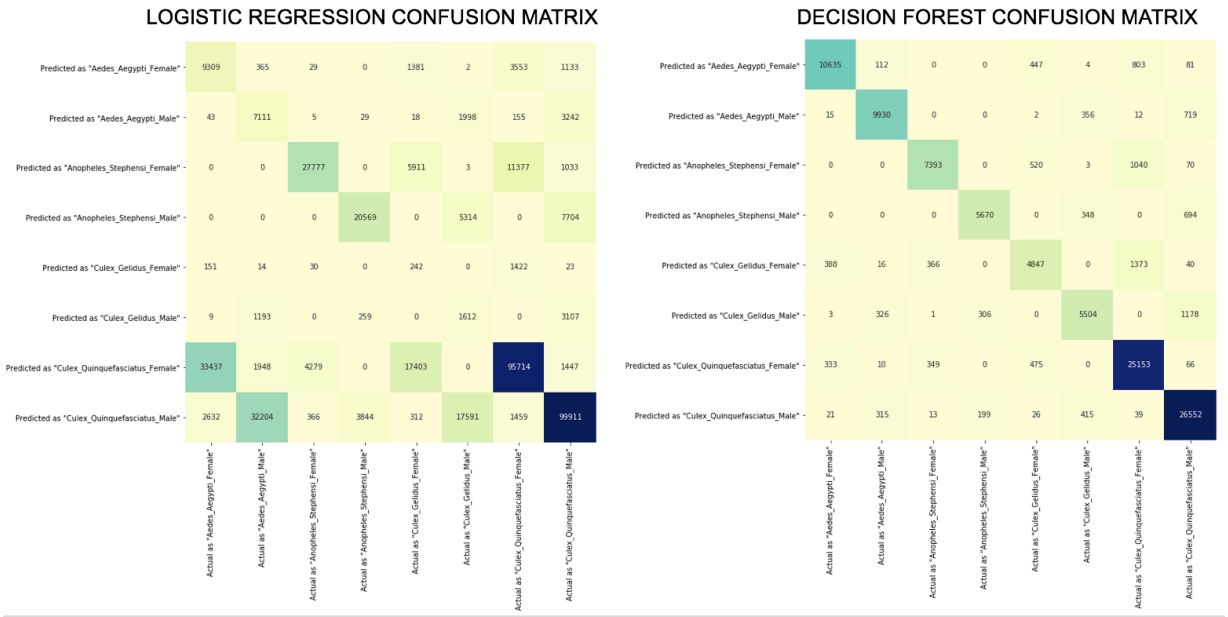


Figure 6. Confusion matrices showing the results of logistic regression (left) and decision forest (right) for pyAudio analysis of mosquito wingbeat files.

Reportable Outcomes:

No papers, inventions filed, or patents issued to date.

Our project has advanced the field of mosquito control scientifically by providing copious data on wingbeat frequency of nuisance and vector species and testing the ability of remote systems to detect and identify mosquitoes. When developed into commercially available products, this technology will enable mosquito control districts and researchers to access more data from more locations in their efforts to better understand and quantify the mosquito community.

Progress Assessment:

- Aim 1. We successfully collected wingbeat frequency data and constructed a wave file library for 11 genera 30 mosquito species of vector and nuisance significance. To complete our metric for success, we substituted other mosquito species unavailable or

difficult to collect in Florida and Utah. We utilized wild types of non-target insects (9 species) captured during field deployment and collected wingbeat files to optimize accurate identification of vector species for ARCHIVe system. Mosquito wingbeat for an individual and a population variation was measured with multiple species.

- Aim 2. The sensitivity (number) and specificity (species) of the ARCHIVe system under semi-field conditions were determined. We developed and modified ARCHIVe traps and utilized numerous assays to compare the ARCHIVe traps for the efficient sampling and adapting commercially available traps. We completed the efficacy of ARCHIVe traps comparing to commercially available traps (e.g., BG-sentinel trap, and CDC gravid trap). The ability of the sensors and AI to determine the specificity of the system for assigning a species designation to captured single or mixtures of mosquito species was validated.

- Aim 3. Field deployment and validation of the ARCHIVe system were conducted in Florida and Utah. We collaborated with Salt Lake City Mosquito Abatement District and Indian River Mosquito Control District accompany for field trials. We successfully trapped mosquitoes using newly developed traps or adapting commercially available traps (i.e., BG-sentinel) with ARCHIVe system under field conditions. In total, 15,567 and 1,407 adult mosquitoes were collected by the combined methods and sites during the sampling period in Indian River County, FL and Salt Lake County, Utah. A diverse mosquito community, consisting of 8 genera and 27 species in FL and 4 genera and 9 species in UT was identified, respectively. More analysis of wingbeat files is needed.

  Green = successfully completed, Amber = slight delay but will meet all deliverables 6 months late

Plans for the following year: Collaborators continue to refine analysis of wingbeat files for automated identification of mosquitoes. Substantial improvements are expected prior to the Annual AMCA meeting.

Conclusion: AMCARF project number: 2019-002 “ARCHIVe - Automated Real-time Collection and High-Fidelity Identification of Vectors” represents efforts towards the development of an autonomous system for mosquito capture and identification. We completed to collect wingbeat profiles of thirty mosquito species from 11 genera (Aim 1), and sensitivity (number) and specificity (species) of the ARCHIVe system under semi-field conditions was determined (Aim 2). Field deployment and validation of the ARCHIVe system were conducted in Florida and Utah (Aim 3). We also found testable predictions about how specific abiotic (e.g., temperature) and biotic (e.g., age) factors influence wingbeat variation amenable to testing in the lab and applicable in a field setting for future study. Finally, the potential to integrate experiment approaches with medically important vectors and computational system, ARCHIVE make this possible to provide a more efficient tool for mosquito surveillance that lead to suppressing pathogen transmission.

Supporting Data AMCARF project number: 2019-002

Supplementary Table 1. Total number of non-target insect wingbeat files by species collected from ARCHIVe, composed of sensor array and association hardware/software

Order	Species	Common name	# of wingbeat files
Diptera	*Plecia spp.*	Lovebug	88
Diptera	*Drosophila spp.*	Fruit fly	8
Diptera	*Musca spp.*	Housefly	57
Diptera	*Chironomus spp.*	Non-biting midges	540
Diptera	*Culicoides spp.*	Biting midges	105
Coleoptera	*Phyllophaga spp.*	June Beetle	1
Lepidoptera	*Caenurgina Spp.*	Forage looper moth	311
Hymenoptera	*Apis spp.*	Honey bee	87
Hymenoptera	*Lasioglossum spp.*	Sweat bee	15

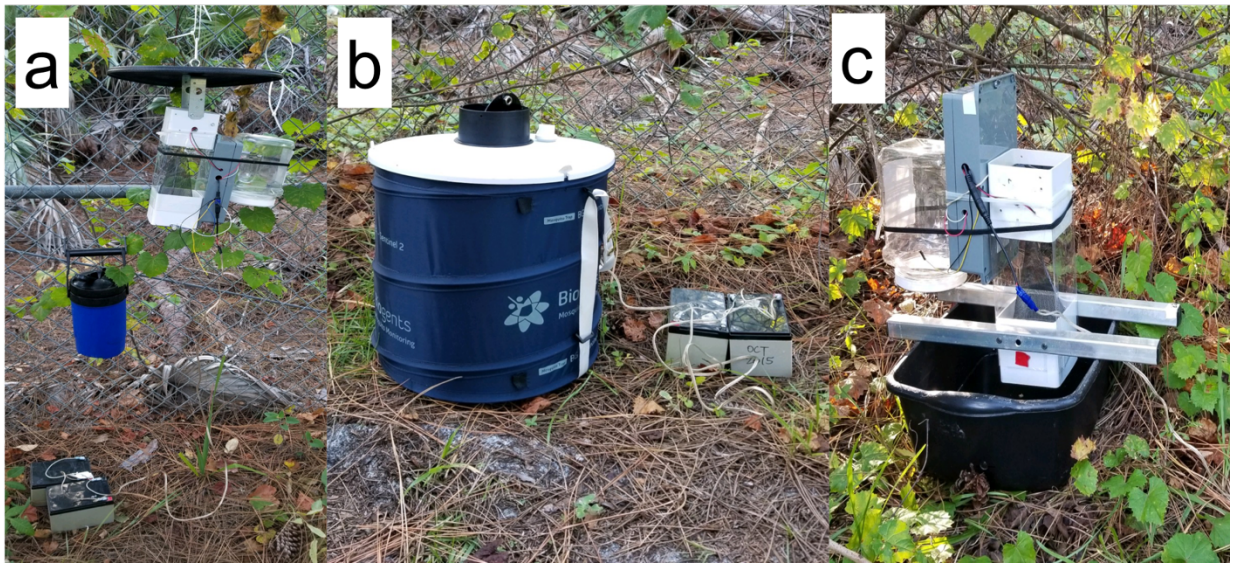
Supplementary Table 2. Total number of individual wingbeat by five species consisting of *Culex quinquefasciatus, Aedes taeniorhynchus, Aedes aegypti, Aedes albopictus,* and *Anopheles albimanus* collected from ARCHIVe, composed of sensor array and association hardware/software

Mosquito species	# of wingbeat files
Cx. quinquefasciatus	798
Ae. taeniorhynchus	1,550
Ae. aegypti	675
Ae. albopictus	1,122
An. Albimanus	427

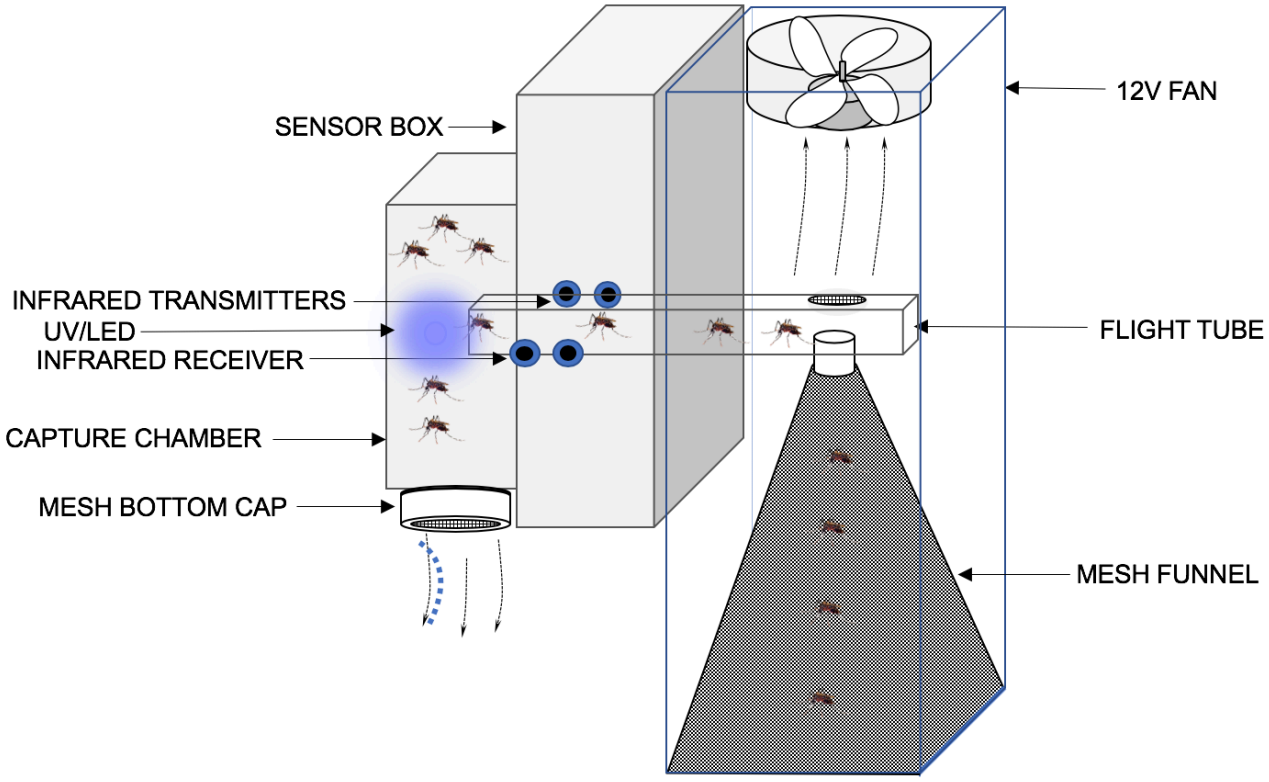
Supplementary Table 3. Total number of mosquitoes collected by ARCHIVe updraft and downdraft carbon dioxide baited light traps in Indian River County, Florida (2019).

Mosquito species	Collecting method			
	Updraft light trap		Downdraft light trap	
	Total (N)	Mean (fem / trap night)	Total (N)	Mean (fem / trap night)
Cx. nigripalpus	142	23.7	69	11.5
Cx. iolambdis	97	16.2	23	3.8
Ae. taeniorhynchus	1,535	255.8	956	159.3
Ae. albopictus	13	2.2	0	0.0
Ae. infirmatus	1	0.2	0	0.0
An. crucians	55	9.2	24	4.0
An. atropos	1	0.2	0	0.0
De. cancer	863	143.8	101	16.8
Ps. ferox	4	0.7	0	0.0
Ma. titillans	2	0.3	0	0.0
Wy. vanduzeei	11	1.8	1	0.2
Ur. lowii	0	0.0	1	0.2
Total	2,724	454	1,175	196
Total species found	11		7	

Supplementary Figure 1. ARCHIVe traps in Indian River County, Florida, 2019



Supplementary Figure 2. ARCHIVe traps structure



Supplementary Table 4. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at urban, suburban and rural sites (combined) in Indian River County, Florida, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. quinquefasciatus	116	80	29	22.118	0.453
Cx. nigripalpus	5384	1610	169	239.531	< 0.0001*
Cx. iolambdis	1657	31	270	83.908	0.303
Cx. coronator	32	18	2	20.435	0.009*
Cx. erraticus	31	28	2	20.969	0.021*
Cx. decorator	8	1	0	6.099	0.412
Cx. interrogator	4	0	0	8.122	0.017*
Cx. salinarius	1	2	0	2.023	0.364
Ae. taeniorhynchus	664	143	15	97.919	< 0.0001*
Ae. aegypti	4	7	0	6.885	0.142
Ae. albopictus	3	33	3	33.461	< 0.0001*
Ae. infirmatus	15	3	0	10.383	0.109
Ae. pertinax	245	26	6	34.280	0.128
Ae. sollicitans	30	9	0	12.876	0.378
Ae. atlanticus	0	1	1	1.008	0.604
An. crucians	654	90	11	131.314	< 0.0001*
An. quadrimaculatus	259	13	3	105.883	< 0.0001*
De. cancer	2830	120	482	101.872	0.148
Ps. ferox	2	4	0	4.053	0.399
Ps. columbiae	45	59	2	29.715	0.040*
Ps. ciliata	0	1	0	2.008	0.367
Ma. dyari	6	14	0	13.128	0.041*
Ma. titillans	47	105	1	50.107	< 0.0001*
Wy. mitchellii	29	21	6	15.020	0.059
Wy. vanduzeei	0	0	1	2.008	0.367
Ur. lowii	26	1	47	30.169	0.007*
Ur. sapphirina	2	0	3	2.853	0.240
Total	12,094	2,420	1,053	388.471	< 0.0001*
Total species found	24	24	18		

Asterisks denote significant differences for trap effectiveness as determined by Chi^2

Supplementary Table 5. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at a rural site (FMEL) in Indian River County, Florida, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-Sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. quinquefasciatus	8	1	2	5.769	0.217
Cx. nigripalpus	3,737	461	13	126.857	0.006*
Cx. iolambdis	1,654	29	241	106.097	0.013*
Cx. coronator	13	2	1	6.519	0.368
Cx. erraticus	21	8	1	20.886	0.008*
Cx. decorator	7	0	0	6.207	0.400
Cx. interrogator	1	0	0	2.022	0.364
Cx. salinarius	1	1	0	1.023	0.600
Ae. taeniorhynchus	412	44	2	70.676	0.001*
Ae. aegypti	1	1	0	1.023	0.600
Ae. albopictus	0	2	0	4.091	0.129
Ae. infirmatus	3	0	0	6.207	0.045*
Ae. pertinax	242	20	5	37.944	0.061
Ae. sollicitans	0	0	0	-	-
Ae. atlanticus	0	0	0	-	-
An. crucians	571	70	0	131.961	< 0.0001*
An. quadrimaculatus	110	5	0	49.789	0.001*
De. cancer	2,924	119	371	113.333	0.036*
Ps. ferox	2	3	0	4.093	0.394
Ps. columbiae	3	4	0	4.028	0.134
Ps. ciliata	0	0	0	-	-
Ma. dyari	2	1	0	2.069	0.355
Ma. titillans	2	1	0	2.069	0.355
Wy. mitchellii	22	12	2	19.206	0.014*
Wy. vanduzeei	1	0	0	2.022	0.364
Ur. lowii	8	1	10	10.780	0.095
Ur. sapphirina	1	0	1	1.023	0.600
Total	9,746	785	649		
Total species found	23	19	11		

Asterisks denote significant differences for trap effectiveness as determined by Chi^2

Supplementary Table 6. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at an urban site (FS) in Indian River County, Florida, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. quinquefasciatus	57	67	12	26.267	0.157
Cx. nigripalpus	835	624	68	88.418	0.156
Cx. iolambdis	3	2	18	6.024	0.421
Cx. coronator	13	14	0	12.250	0.057
Cx. erraticus	3	7	0	5.093	0.532
Cx. decorator	0	1	0	2.022	0.364
Cx. interrogator	1	0	0	2.022	0.364
Cx. salinarius	0	0	0	-	-
Ae. taeniorhynchus	221	68	9	32.444	0.257
Ae. aegypti	3	4	0	5.014	0.286
Ae. albopictus	3	8	2	5.574	0.062
Ae. infirmatus	12	3	0	7.463	0.280
Ae. pertinax	3	4	1	1.571	0.814
Ae. sollicitans	0	0	0	-	-
Ae. atlanticus	0	1	1	1.023	0.600
An. crucians	55	10	0	30.35	0.003*
An. quadrimaculatus	88	5	0	38.731	0.003*
De. cancer	1	0	15	4.023	0.403
Ps. ferox	0	1	0	2.022	0.364
Ps. columbiae	8	11	0	16.683	0.082
Ps. ciliata	0	0	0	-	-
Ma. dyari	2	2	0	2.093	0.351
Ma. titillans	7	6	0	7.519	0.276
Wy. mitchellii	0	0	0	-	-
Wy. vanduzeei	0	0	0	-	-
Ur. lowii	0	0	2	4.091	0.129
Ur. sapphirina	0	0	1	2.022	0.364
Total	1,315	838	129		
Total species found	17	18	10		

Asterisks denote significant differences for trap effectiveness as determined by Chi^2

Supplementary Table 7. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at a suburban (IRMCD) in Indian River County, Florida, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. quinquefasciatus	51	12	15	9.478	0.488
Cx. nigripalpus	846	525	54	107.333	0.004*
Cx. iolambdis	10	0	1	7.317	0.120
Cx. coronator	6	2	1	5.205	0.074
Cx. erraticus	7	13	1	9.680	0.139
Cx. decorator	1	0	0	2.023	0.364
Cx. interrogator	2	0	0	4.094	0.129
Cx. salinarius	0	1	0	2.023	0.364
Ae. taeniorhynchus	34	31	1	25.701	0.012*
Ae. aegypti	0	2	0	4.094	0.129
Ae. albopictus	0	23	1	27.501	0.0001*
Ae. infirmatus	0	0	0	-	-
Ae. pertinax	0	2	0	4.094	0.129
Ae. sollicitans	30	9	0	13.78	0.315
Ae. atlanticus	0	0	0	-	-
An. crucians	39	10	0	21.982	0.038*
An. quadrimaculatus	61	3	3	22.339	0.133
De. cancer	1	1	0	1.024	0.599
Ps. ferox	0	0	0	-	-
Ps. columbiae	34	44	2	22.948	0.115
Ps. ciliata	0	1	0	2.023	0.364
Ma. dyari	2	11	0	12.351	0.055
Ma. titillans	38	98	1	60.567	< 0.0001*
Wy. mitchellii	7	9	4	3.083	0.544
Wy. vanduzeei	0	0	0	-	-
Ur. lowii	18	0	35	21.567	0.088
Ur. sapphirina	2	0	0	4.094	0.129
Total	1,189	797	119		
Total species found	18	18	12		

Asterisks denote significant differences for trap effectiveness as determined by Chi^2

Supplementary Table 8. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at a rural site (Rudy) in Salt lake County, Utah, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. pipiens	48	36	0	5.833	0.442
Cx. tarsalis	363	425	1	16.000	0.313
Cx. erythrothorax	0	0	0	-	-
Ae. dorsalis	12	30	4	13.667	0.323
Ae. vexans	0	2	0	1.143	0.565
Ae. sierrensis	0	0	0	-	-
An. freeborni	6	24	2	16.000	0.1000
Cs. inornata	0	0	0	-	-
Cs. incidens	0	0	0	-	-
Total	429	517	7		
Total species found	4	5	3		

Supplementary Table 9. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at a Suburban site (ATV) in Salt lake County, Utah, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. pipiens	39	8	3	10.444	0.577
Cx. tarsalis	104	115	3	16.500	0.419
Cx. erythrothorax	26	0	0	4.286	0.369
Ae. dorsalis	7	0	0	2.500	0.645
Ae. vexans	1	5	0	3.905	0.419
Ae. sierrensis	0	0	0	-	-
An. freeborni	0	1	1	2.708	0.258
Cs. inornata	1	0	0	1.111	0.574
Cs. incidens	0	0	0	-	-
Total	178	129	7		
Total species found	6	4	3		

Supplementary Table 10. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system at an urban site (Downingtown) in Salt lake County, Utah, 2019

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. pipiens	6	20	10	8.000	0.238
Cx. tarsalis	5	36	0	8.000	0.238
Cx. erythrothorax	0	0	0	-	-
Ae. dorsalis	0	0	0	-	-
Ae. vexans	0	0	0	-	-
Ae. sierrensis	0	3	0	4.000	0.135
An. freeborni	0	0	0	-	-
Cs. inornata	0	0	0	-	-
Cs. incidens	3	55	2	8.000	0.238
Total	14	114	12		
Total species found	3	4	2		

Supplementary Table 11. Total number of female mosquitoes collected by light trap, BG-sentinel trap, and gravid trap equipped with ARCHIVe system in Salt lake County, Utah, 2019 (all sites combined).

Mosquito species	Collecting method			Statistical outcomes	
	Light trap (N)	BG-sentinel trap (N)	Gravid trap (N)	X^2	*P*
Cx. pipiens	93	64	13	20.075	0.578
Cx. tarsalis	472	576	4	33.733	0.481
Cx. erythrothorax	26	0	0	4.168	0.384
Ae. dorsalis	19	30	4	14.654	0.402
Ae. vexans	1	7	0	4.583	0.598
Ae. sierrensis	0	3	0	1.833	0.400
An. freeborni	6	25	3	16.893	0.154
Cs. inornata	1	0	0	1.257	0.533
Cs. incidens	3	55	2	7.526	0.275
Total	621	760	26	37.251	0.909
Total species found	8	7	5		