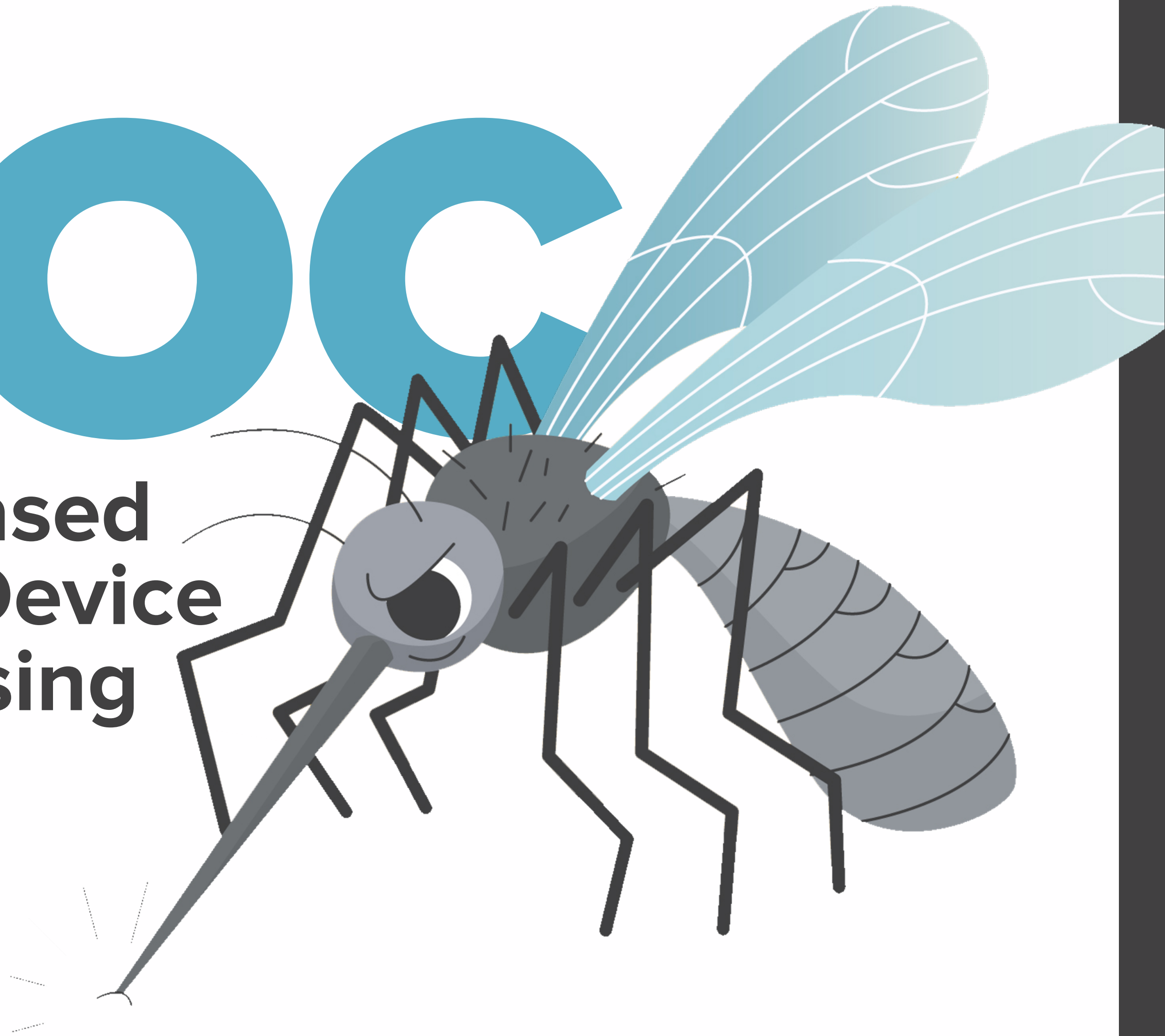
LAMOC

Development of an IoT-Based Acoustic Signal Sensing Device in Mosquito Monitoring using Raspberry Pi



Fianza | Manguan | Ponio

Mosquitoes bring **deadly diseases***

Anopheles sp.

malaria

Aedes aegypti

dengue

Culex sp.

west nile virus

* Tolle, M. A. (2009). Mosquito-borne diseases. Current Problems in Pediatric and Adolescent Health Care, 39(4), 97–140. doi:10.1016/j.cppeds.2009.01.001
Images taken from http://medent.usyd.edu.au/arbovirus/mosquit/photos/mosquitophotos.htm

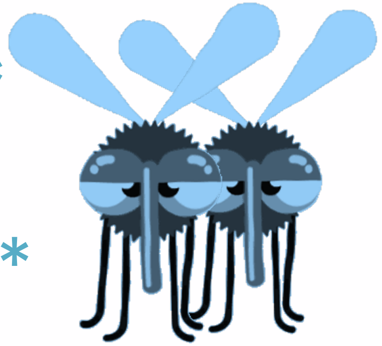
Existing methods are **not enough***

	Human landing catch	**Bioacoustics**
Contact	**close-contact**	**none**
Specialized knowledge	**species identification**	**none, automated**
Results obtained	**after several days**	**real-time**
Cost	**$**	**$$$**

* Dia, I., Diallo, D., Duchemin, J., Ba, Y., Konate, L., Costantini, C., & Diallo, M. (2005). Comparisons of Human-Landing Catches and Odor-Baited Entry Traps for Sampling Malaria Vectors in Senegal. Journal of Medical Entomology, 42(2), 104–109. https://doi.org/10.1093/jmedent/42.2.104

Mosquitoes are uniquely identified by their wingbeat frequencies*

Ae. aegypti (male)	900-1000 Hz**
Ae. aegypti (female)	550-600 Hz**
Anopheles sp.	320-480 Hz***
Culex sp.	500-650 Hz**

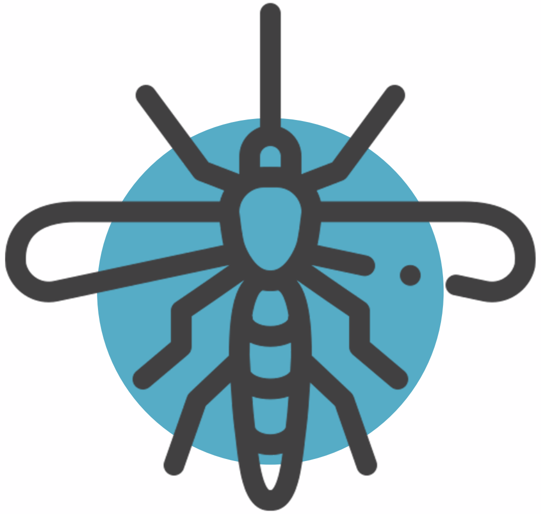


* Arthur, B. J., Emr, K. S., Wyttenbach, R. A., & Hoy, R. R. (2014). Mosquito (Aedes aegypti) flight tones: Frequency, harmonicity, spherical spreading, and phase relationships. *The Journal of the Acoustical Society of America, 135*(2), 933–941. doi:10.1121/1.4861233

** Vasconcelos, D., Nunes, N., Ribeiro, M., Prandi, C., & Rogers, A. (2019). LOCOMOBIS: a low-cost acoustic-based sensing system to monitor and classify mosquitoes. 2019 16th IEEE Annual Consumer Communications & Networking Conference (CCNC), 1–6. https://doi.org/10.1109/CCNC.2019.8651767

*** Caprio MA, Huang JX, Faver MK, & Moore A. (2001). Characterization of male and female wingbeat frequencies in the Anopheles quadrimaculatus complex in Mississippi. Journal of the American Mosquito Control Association, 17(3), 186–189.

What we need is a device that can



detect the presence of mosquitoes

identify the species of the mosquitoes

inform interested individuals

LAMOC

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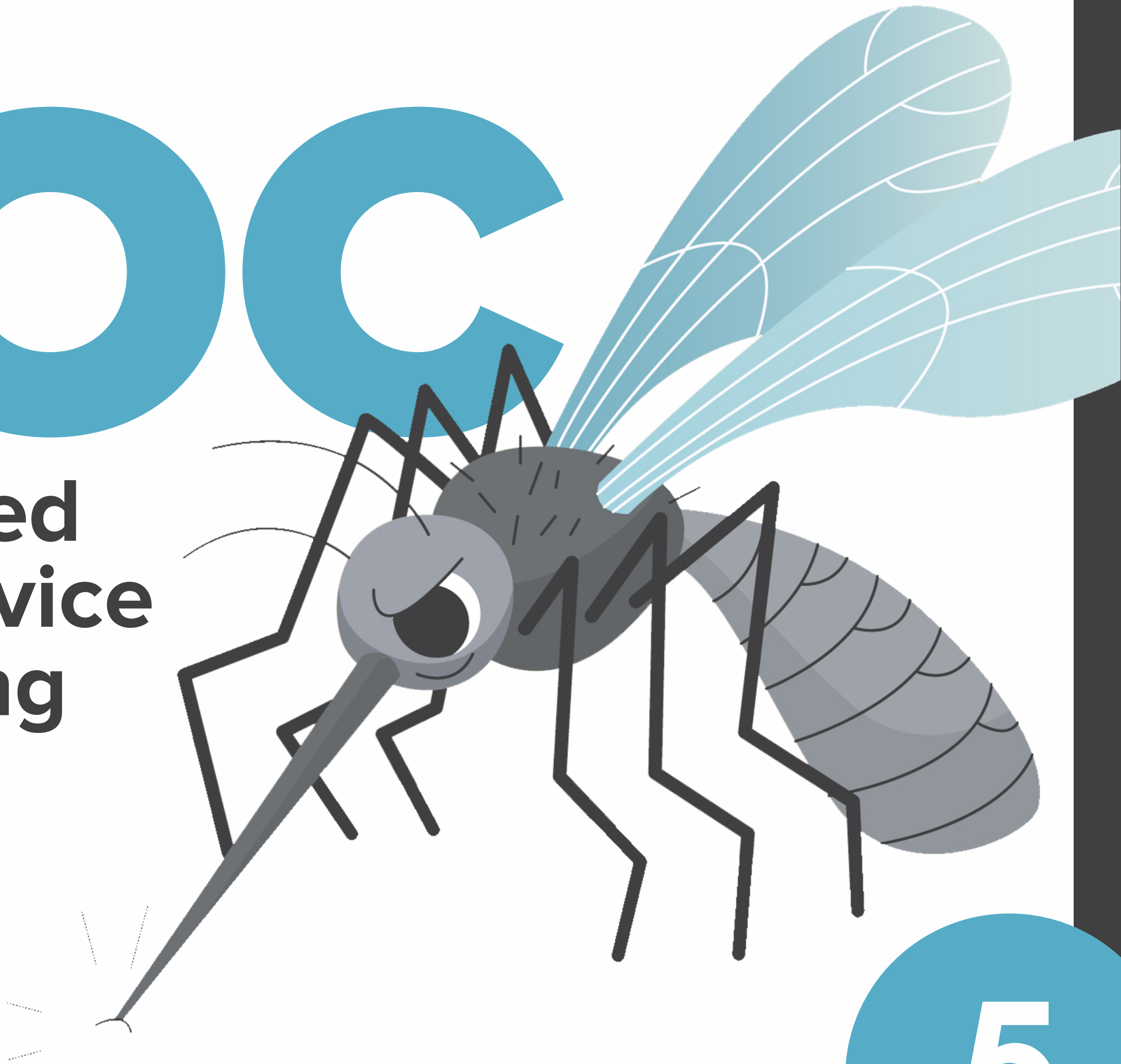
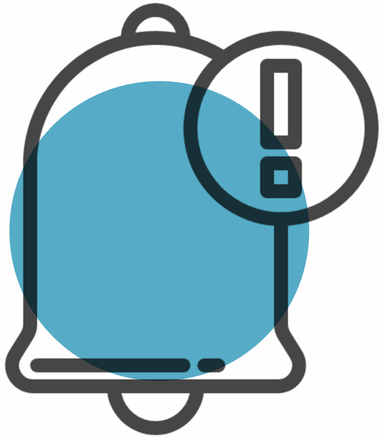


Significance

provides safer, more sustainable, and efficient mosquito monitoring



informs health centers in identifying the trend of mosquito population

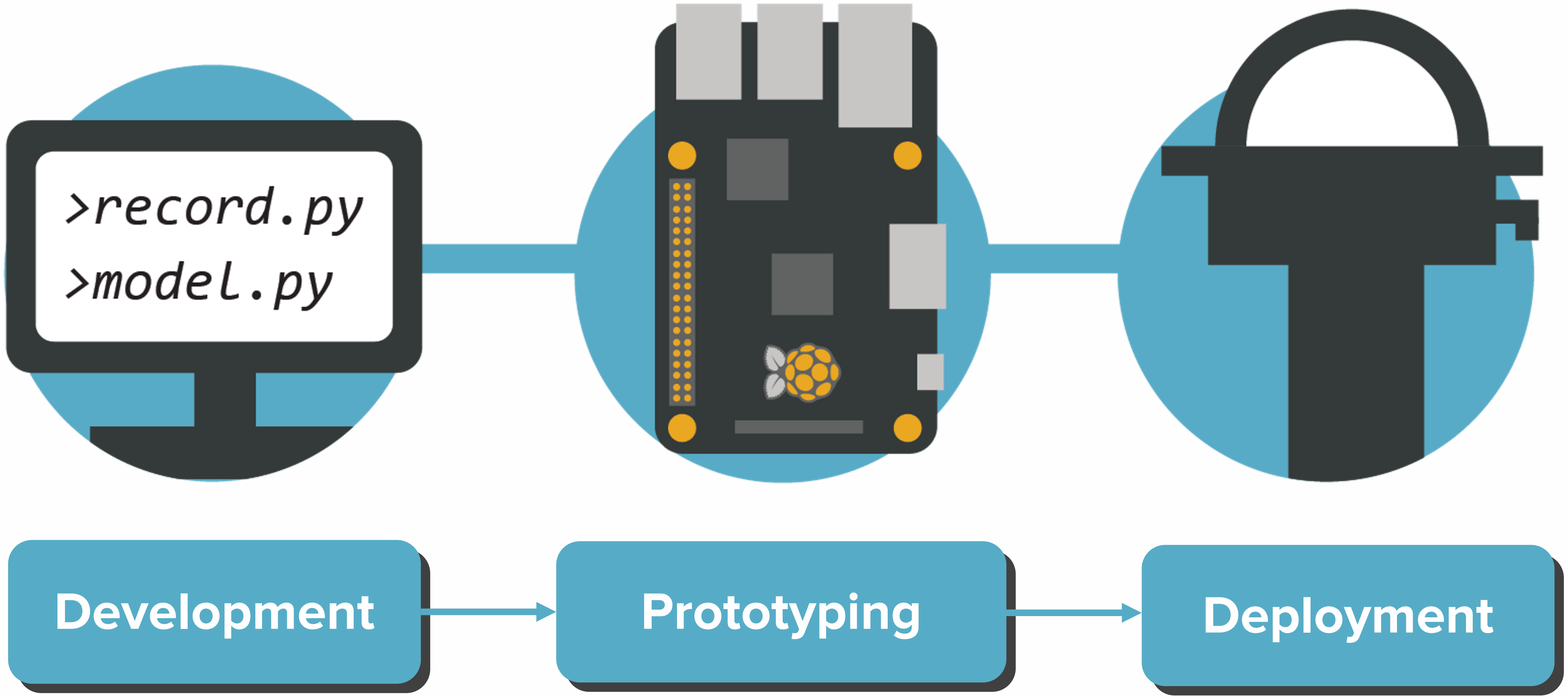
allows LGUs to formulate countermeasures for a possible outbreak

Scope and Limitations

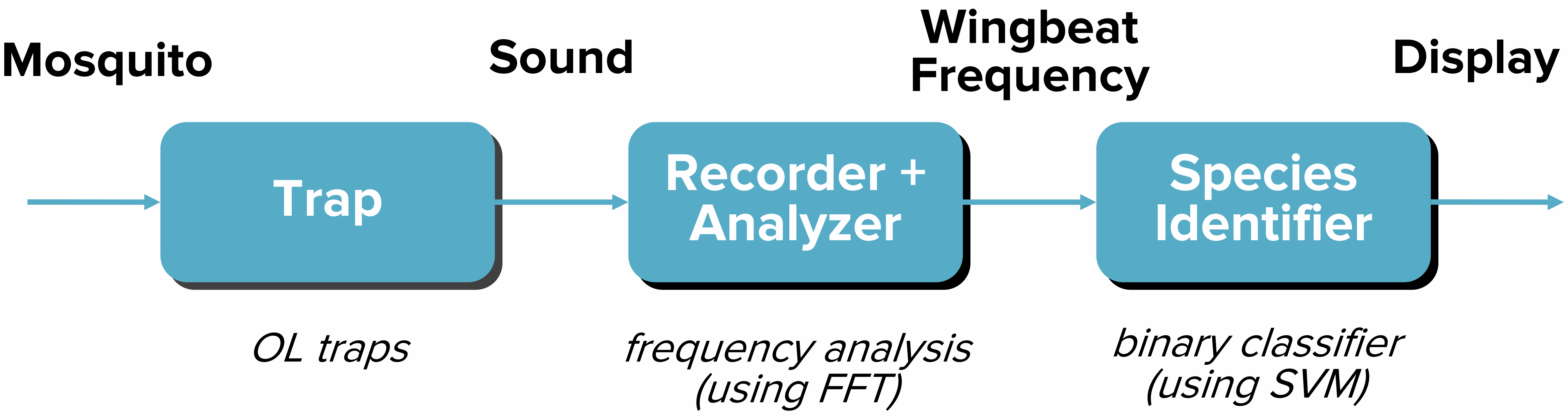
- create a single device
- use audio samples from other researchers
  - *Culex sp.* *
  - *Anopheles sp.* **
  - *Aedes aegypti* ***
- detect three mosquito species
- identify using wing beat frequencies

* Li, Y., Zilli, D., Chan, H., Kiskin, I., Sinka, M., Roberts, S., & Willis, K. (2017). Mosquito detection with low-cost smartphones: data acquisition for malaria research. NIPS Workshop on Machine Learning for the Developing World (ML4D), 1–5.
** Mukundarajan, H., Hol, F. J. H., Castillo, E. A., Newby, C., & Prakash, M. (2017). Using mobile phones as acoustic sensors for high-throughput mosquito surveillance. ELife, 6. https://doi.org/10.7554/eLife.27854
*** Homer, M., Champneys, A., Aldersley, A., & Robert, D. (2015). Lone & Pair Mosquito Auditory Interaction. Engineering and Physical Sciences Research Council.

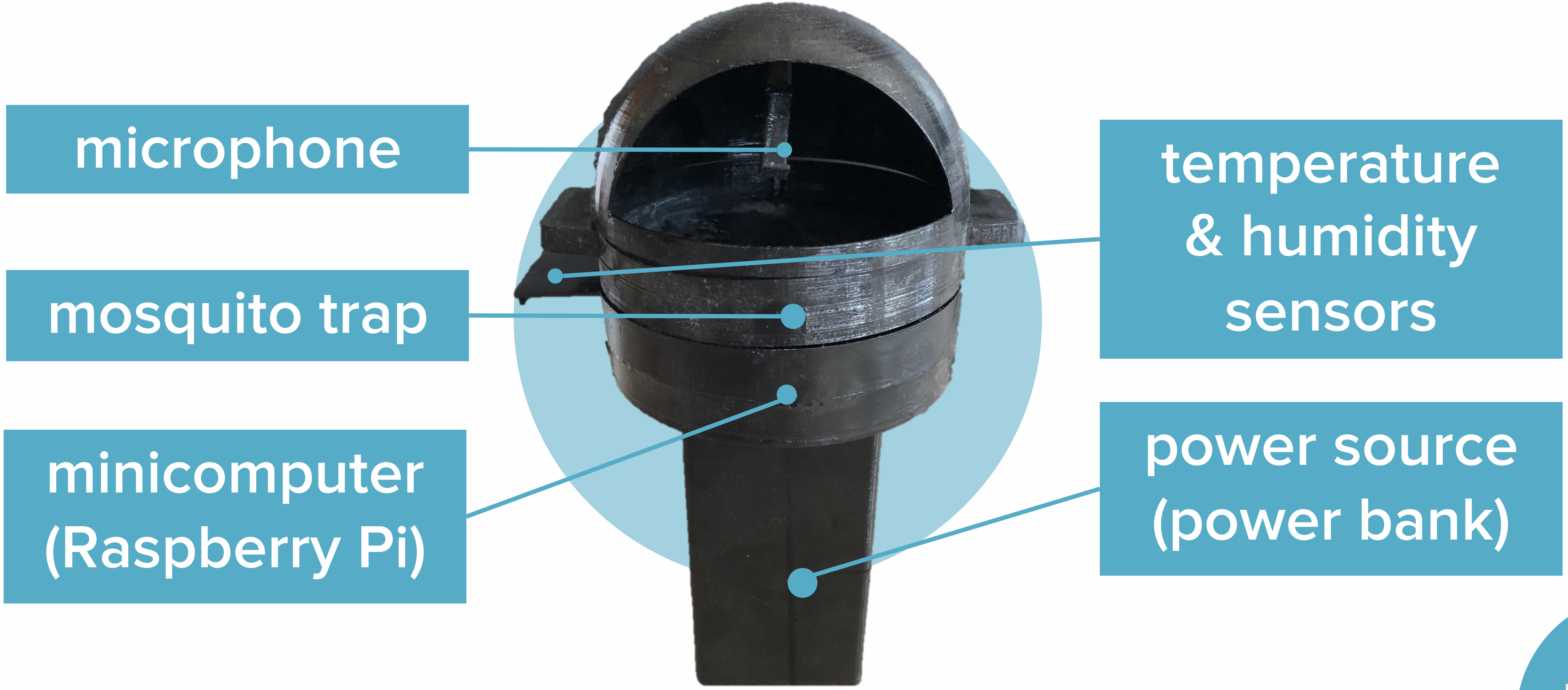
Methodology



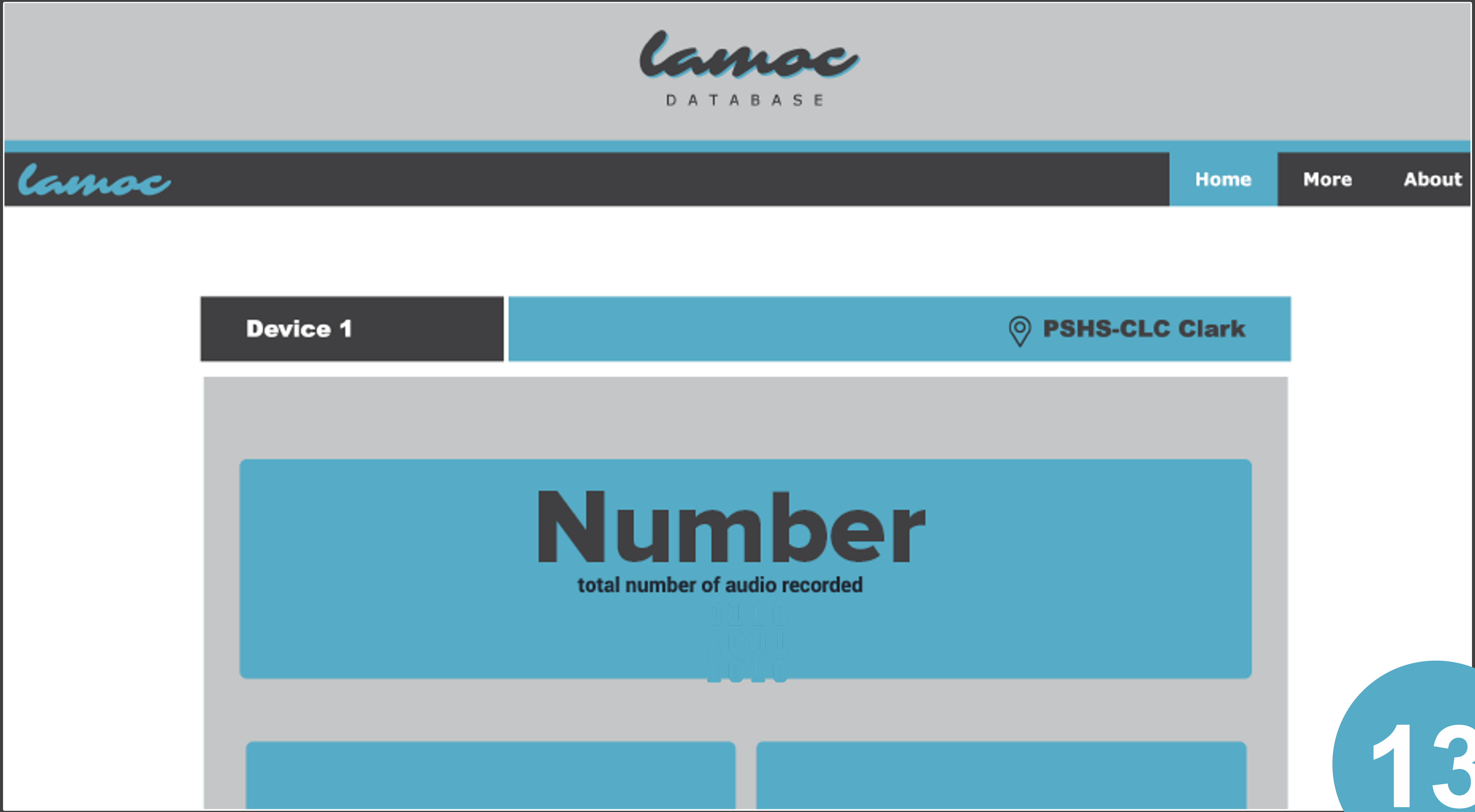
How the device works



LAMOC Components

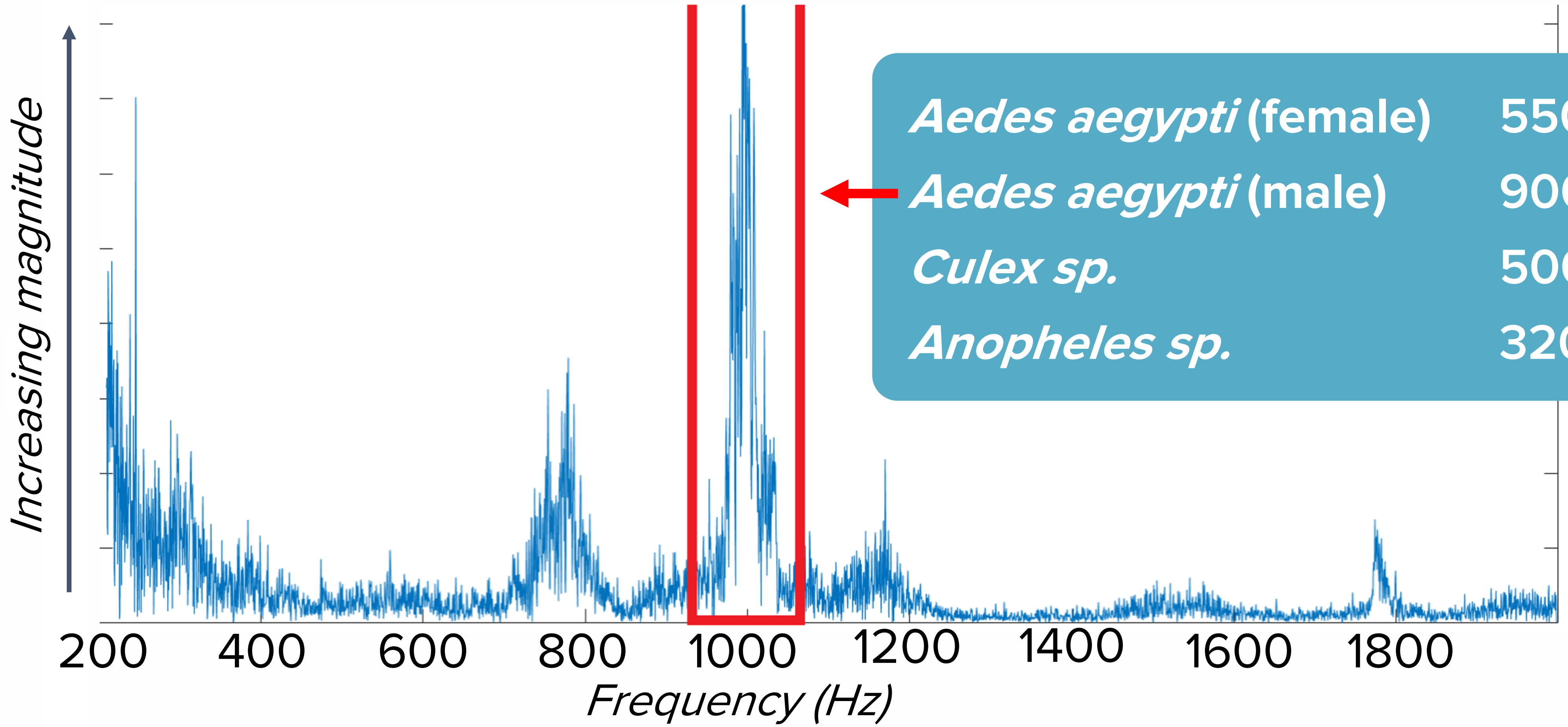



identify species
record temperature & humidity
send to server
0110
1001
1010
0110
1001
1010
12


lamoc
DATABASE
lamoc
Home
More
About
Device 1
PSHS-CLC Clark
Number
total number of audio recorded

13

LAMOC **detects** mosquitoes



Aedes aegypti (female)	550-600 Hz*
Aedes aegypti (male)	900-1000 Hz*
Culex sp.	500-650 Hz*
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* Vasconcelos, D., Nunes, N., Ribeiro, M., Prandi, C., & Rogers, A. (2019). LOCOMOBIS: a low-cost acoustic-based sensing system to monitor and classify mosquitoes. 2019 16th IEEE Annual Consumer Communications & Networking Conference (CCNC), 1–6. https://doi.org/10.1109/CCNC.2019.8651767

**Caprio MA, Huang JX, Faver MK, & Moore A. (2001). Characterization of male and female wingbeat frequencies in the Anopheles quadrimaculatus complex in Mississippi. Journal of the American Mosquito Control Association, 17(3), 186–189.

LAMOC detects mosquitoes

Table 1. **Confusion matrix for mosquito detection**

n = 5500		Predicted	
		Positive	**Negative**
Actual	**Positive**	**TP: 4200**	**FN: 200**
	Negative	**FP: 105**	**TN: 995**

Precision	TP / (TP+FP)	**97.56%**
Recall	TP / (TP+FN)	**95.45%**
Accuracy	(TP+TN) / n	**94.45%**

LAMOC identifies mosquito species

Table 2. **Accuracy rates for the five classes using cross-validation**

	Aedes aegypti (male)	*Aedes aegypti* (female)	*Anopheles sp.*	*Culex sp.*	**Background noise**
Accuracy	**99.30%**	**96.74%**	**93.72%**	**92.09%**	**90.47%**
n	1100	1100	1100	1100	1100

LAMOC has higher accuracy

Table 3. **Comparison of LAMOC to Li et al. (2017)**

	Smartphone detector (Li et al., 2017)	LAMOC
Species detected	*Ae. aegypti* *Ae. ealbopictus* *An. albimanus* *An. gambiae* *An. quadrimaculatus* *Cu. tarsalis* *Cu. quinquefasciatus*	***Aedes aegypti*** ***Anopheles sp.*** ***Culex sp.***
Samples	372	**5500**
Overall Accuracy	80.25%	**94.45%**

Li, Y., Zilli, D., Chan, H., Kiskin, I., Sinka, M., Roberts, S., & Willis, K. (2017). Mosquito detection with low-cost smartphones: data acquisition for malaria research. NIPS Workshop on Machine Learning for the Developing World (ML4D), 1–5.

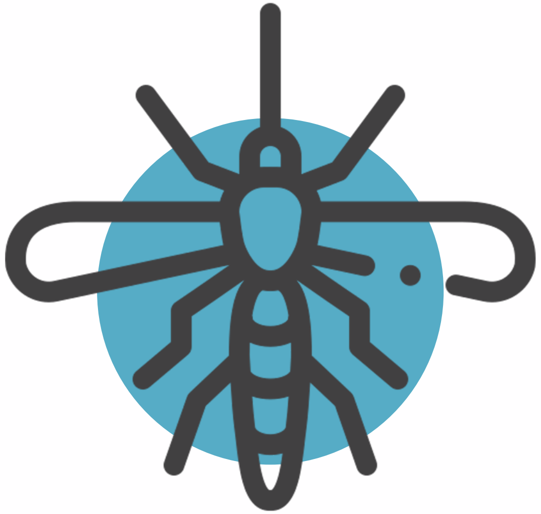
LAMOC Website

lamoc Home More About

ID	Play	Species	Location	Time	Date	Temp (°C)	Humidity (%)
13	▶	*Aedes aegypti (female)*	PSHS-CLC Clark	09:13:53 am	03/03/2020	23	50
12	▶	*Aedes aegypti (female)*	PSHS-CLC Clark	09:13:34 am	03/03/2020	23	50
11	▶	*Aedes aegypti (female)*	PSHS-CLC Clark	10:03:05 pm	03/02/2020	23	50

ID	Play	Species	Location	Time	Date	Temp (°C)	Humidity (%)
13	▶	*Aedes aegypti (female)*	PSHS-CLC Clark	09:13:53 am	03/03/2020	23	50

LAMOC was able to



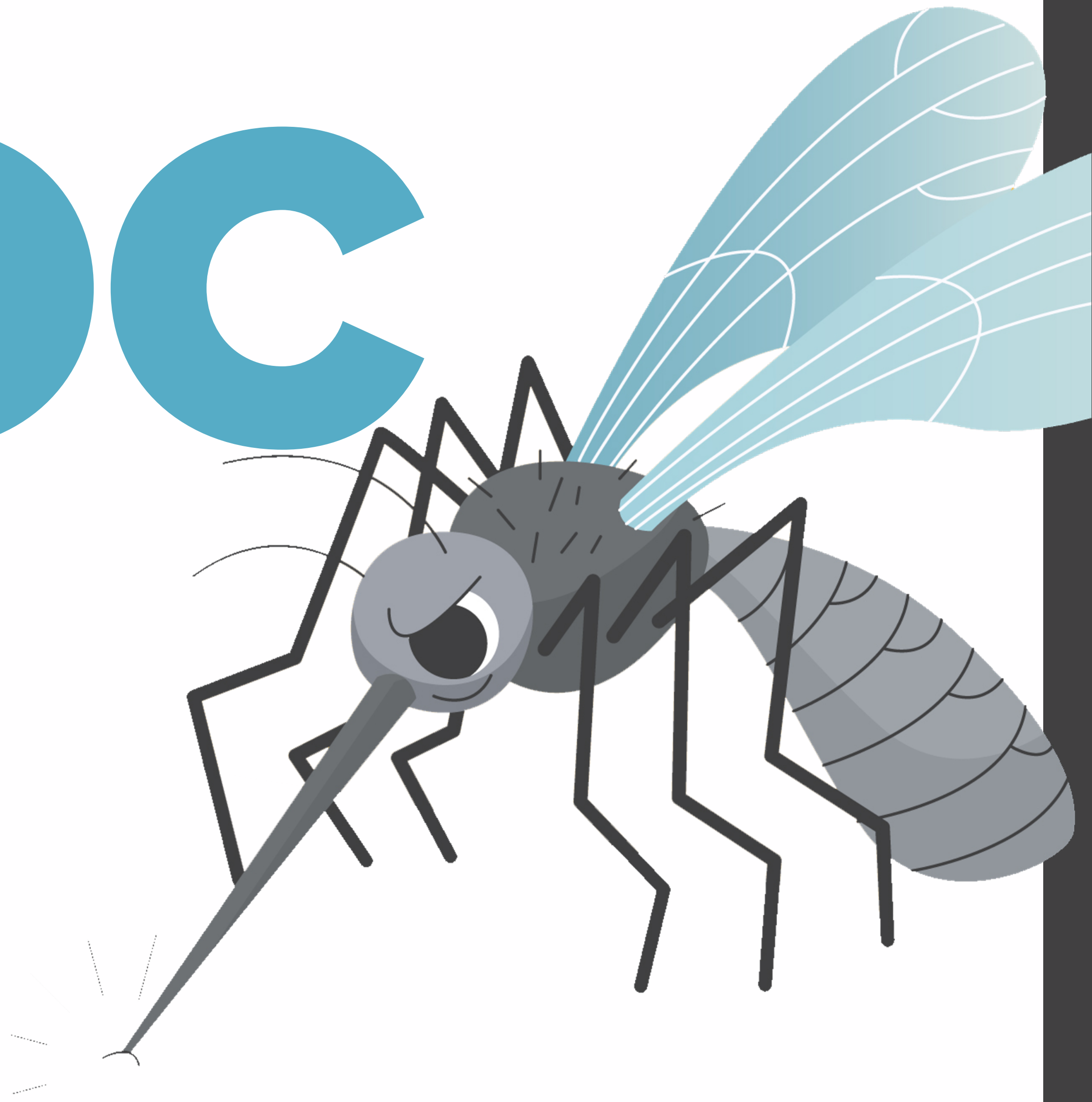
detect the presence of mosquitoes

identify the species of the mosquitoes

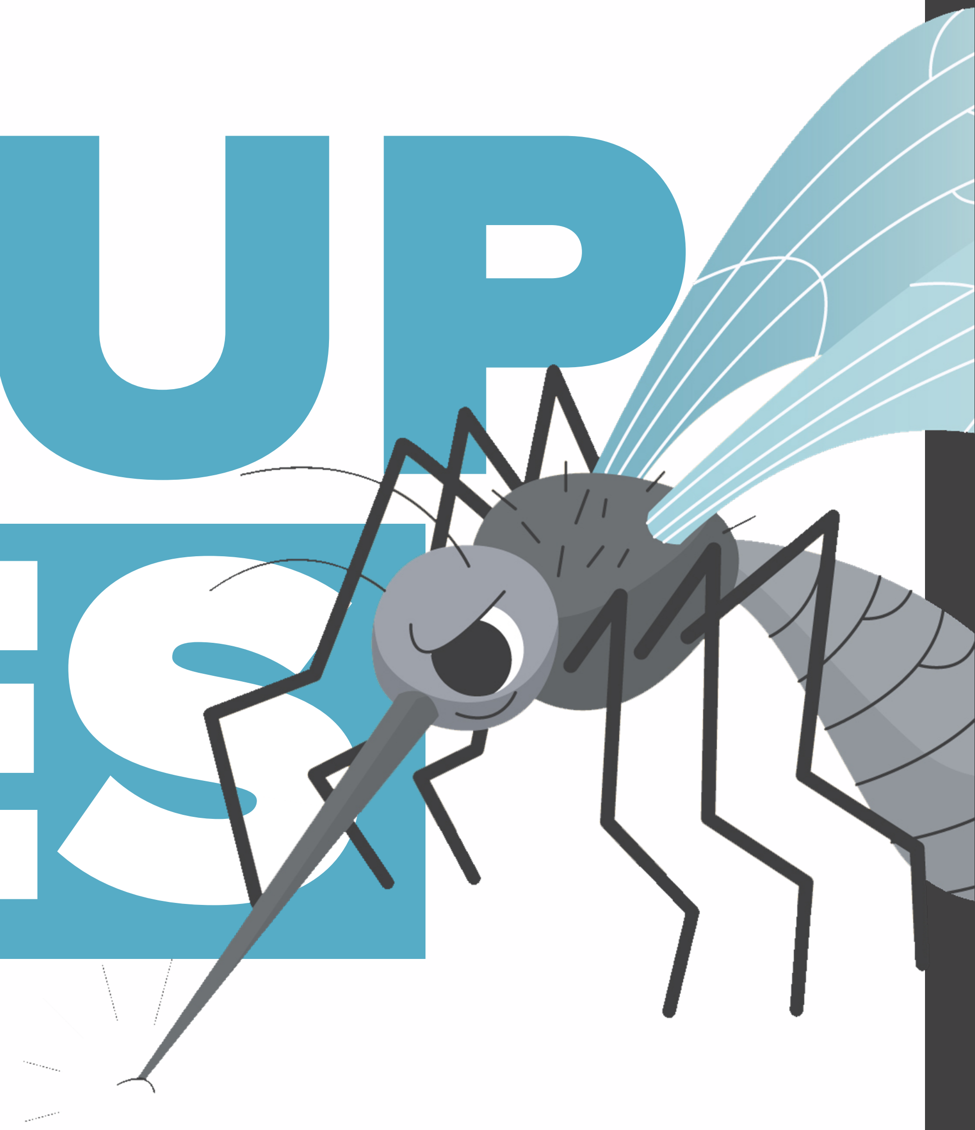
inform interested individuals

LAMOC

IS HERE CAN HEAR



BACKUP SLIDES



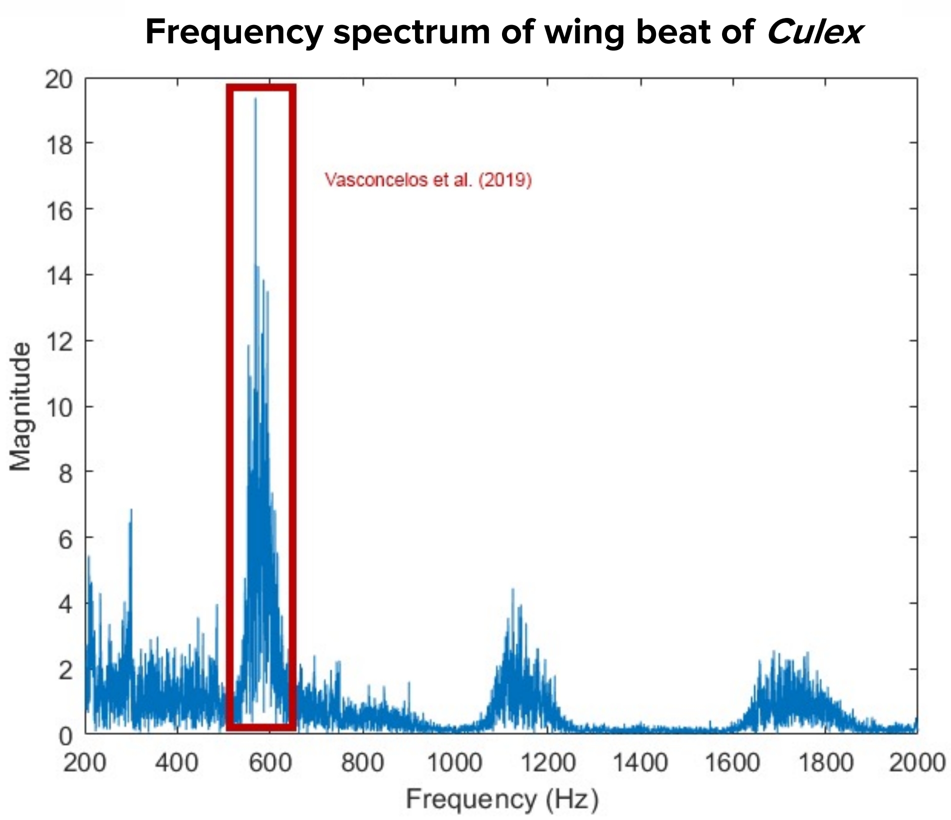
Mosquitoes vs orders of insects

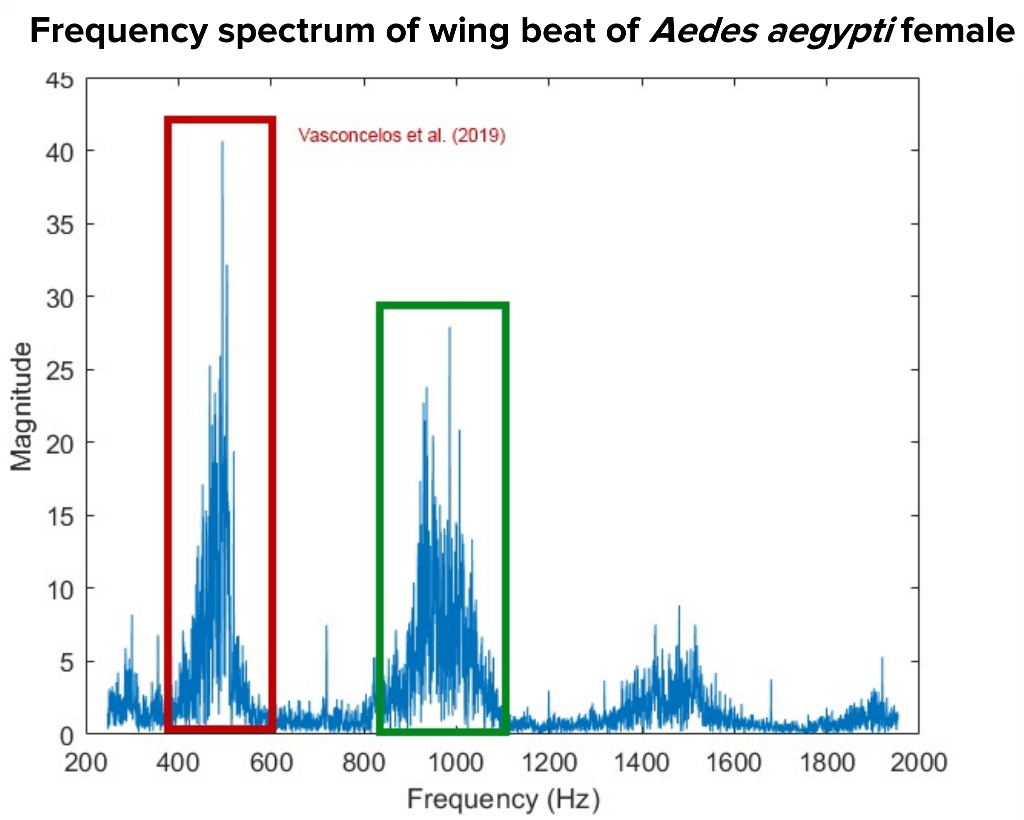
Table 4. **Wingbeat frequencies of different insect orders**

`	Wingbeat frequency (mean Hz)		Bodymass (g)		Wing length (cm)		Wing area (cm^2)		Wing loading (g/cm^2)		Number of specimens
	range	mean	range	mean	range	mean	range	mean	range	mean	
Coleoptera	79 - 123.396	97.512	0.0061 - 0.117	0.0539	0.521 - 1.188	0.898	0.19 - 0.982	0.545	0.0321 - 0.141	0.085	10(10)
Diptera	59.567 - 557.351	208.244	0.0005 - 0.162	0.0268	0.172 - 1.739	0.729	0.022 - 1.17	0.327	0.0119 - 0.168	0.0554	28(28)
Ephemeroptera	n/a	75.0454	n/a	0.0027	n/a	0.634	n/a	0.306	n/a	0.00882	1(1)
Hemiptera	90.222 - 152.247	116.39	0.0011 - 0.14	0.0226	0.345 - 1.185	0.624	0.112 - 1.186	0.445	0.009 - 0.118	0.034	11(11)
Hymenoptera	87.129 - 230.987	163.89	0.0024 - 0.223	0.103	0.356 - 1.48	1.006	0.038 - 1.234	0.64	0.022 - 0.245	0.136	24(15)
Lepidoptera	12.468 - 64.566	39.606	0.0044 - 2.24	0.203	0.646 - 5.214	1.792	0.318 - 23.362	5.031	0.004 - 0.096	0.025	22(22)
Mecoptera	n/a	48.885	n/a	0.0398	n/a	1.387	n/a	1.492	n/a	0.027	1(1)
Neuroptera	25-923 - 94.413	52.801	0.0003 - 0.0065	0.0035	0.352 - 1.393	0.757	0.106 - 1.972	0.701	0.003 - 0.007	0.005	6(6)
Odonata	17.847 - 40.665	32.331	0.0278 - 1.23	0.27	1.795 - 5.158	3.002	1.964 - 22.784	8.768	0.0112 - 0.054	0.022	8(6)
Trichoptera	n/a	27.515	n/a	0.159	n/a	2.267	n/a	4.738	n/a	0.0336	1(1)

Tercel, M.P.T.G., Veronesi, F., & Pope, T.W. (2018). Phylogenetic clustering of wingbeat frequency and flight-associated morphometrics across insect orders. *Physiological Entomology.* https://doi.org/10.1111/phen.12240

Fundamental Frequencies





Culex sp. **500-650 Hz***

Aedes aegypti **(female) 550-600 Hz***

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Cross validation

ANALYSIS OF DATA

Table 2. **Day 1 (February 26, 2020)**

Accuracy 86.91%		n 657	Predicted	
			Positive	**Negative**
Actual	**Positive**		**0**	**0**
	Negative		**86**	**571**

ANALYSIS OF DATA

Table 3. Day 2 (February 27, 2020)

Accuracy 99.34%	n 4989	Predicted	
		Positive	**Negative**
Actual	**Positive**	**0**	**0**
	Negative	**33**	**4956**

ANALYSIS OF DATA

Table 4. **Day 3 (February 28, 2020)**

Accuracy 98.04%	n 4896	Predicted	
		Positive	**Negative**
Actual	**Positive**	**13**	**3**
	Negative	**93**	**4787**

LAMOC DATABASE

Figure 1. Website Ratings