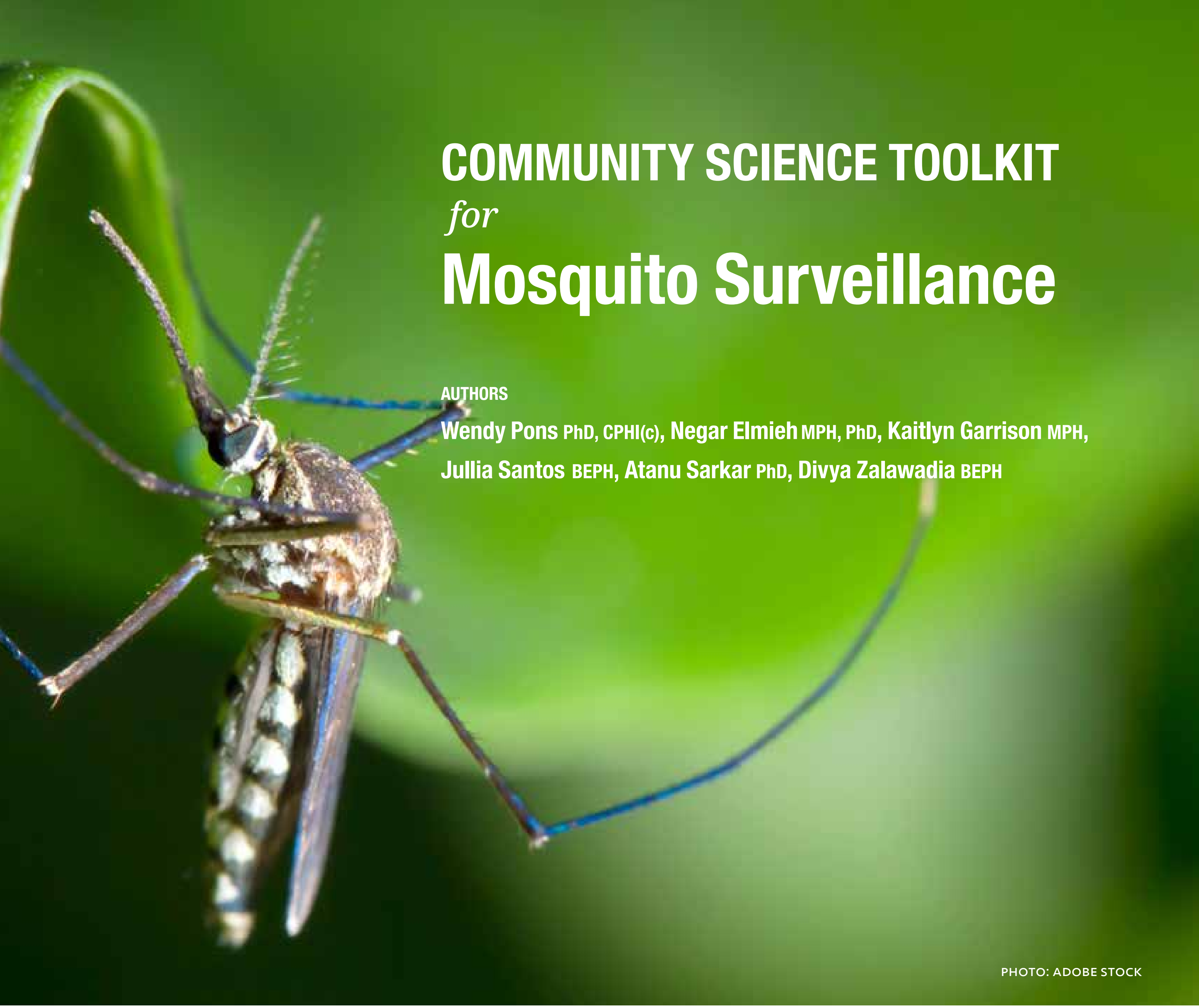

COMMUNITY SCIENCE TOOLKIT *for* Mosquito Surveillance

AUTHORS

Wendy Pons PhD, CPHI(C), Negar Elmieh MPH, PhD, Kaitlyn Garrison MPH, Jullia Santos BEPH, Atanu Sarkar PhD, Divya Zalawadia BEPH

PHOTO: ADOBE STOCK

IN COLLABORATION WITH

National Collaborating Centre for Environmental Health

Centre de collaboration nationale en santé environnementale

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Land Acknowledgement

We acknowledge that the land on which this work has been conducted, across the land known as Canada, is the traditional territory of many Indigenous peoples, including the First Nations, Métis, and Inuit peoples. We recognize and honour the enduring relationship that Indigenous peoples have with this land and the stewardship they have shown for generations.

As we engage in community science for mosquito surveillance, we recognize the importance of collaboration and partnership with Indigenous communities. We are committed to working respectfully and inclusively, recognizing Indigenous knowledge and perspectives in our efforts to protect public health and the environment.

COMMUNITY SCIENCE TOOLKIT *for* Mosquito Surveillance

Authors:

Wendy Pons[*] PhD, CPHI(c), Negar Elmieh[+] MPH, PhD, Kaitlyn Garrison[‡] MPH, Jullia Santos[*] BEPH, Atanu Sarkar[‡] PhD, Divya Zalawadia[*] BEPH

Affiliations

[*]School of Health and Life Sciences, Conestoga College, Ontario, Canada
[+]National Collaborating Centre for Environmental Health, British Columbia, Canada
[‡]Population Health and Applied Health Sciences, Memorial University, Newfoundland and Labrador, Canada

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Heather Coatsworth, *Chief Research Scientist, National Microbiology Laboratory, Public Health Agency of Canada*

Jade Savage, *Professor, Bishops University*

Juliette Martin,*Programming and Research Planning Officer, Directorate of Infectious Disease Prevention and Control, Ministry of Health and Social Services, Quebec Government*

Tegan Padgett, *Senior Ecosystems Biologist, British Columbia Ministry of Water, Land and Resource Stewardship*

Margaret Haworth-Brockman, *Senior Program Manager, National Collaborating Centre for Infectious Diseases*

Mark Nelder, *Senior Program Specialist, Public Health Ontario*

Muhammad Morshed, *Clinical Microbiologist, British Columbia Centre for Disease Control*

Nariman Shahhosseini, *Head of Centre for Vector-Borne Diseases, Canadian Food Inspection Agency*

Shaun Dergousoff, *Research Scientist, Agrifood Canada*

Stefan Iwasawa, *Project Co-ordinator, British Columbia Centre for Disease Control*

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PHOTOS: GETTY IMAGES

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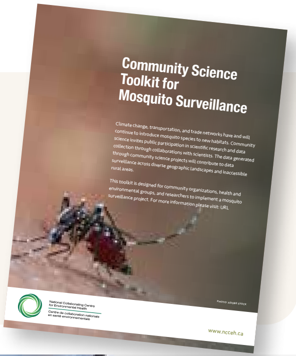
Glossary

Advisory Group	A group of specialists who provide guidance, expertise, and recommendations on specific topics or projects.
BOLD	The Barcode of Life Data System, a database of DNA barcodes used for species identification.
Community Science (Citizen Science)	A collaborative process where members of the public participate in scientific research, contributing to data collection, analysis, and project implementation.
Dashboards	A visual display of key data metrics, often used for monitoring and analyzing data in real-time.
Data Standardization	Aligning different data formats and protocols to integrate community-collected data into existing surveillance systems.
Data Validation	A process that ensures data collected is accurate and free from errors.
Extrinsic Motivation	External incentives offered to people, such as monetary rewards, recognition, or physical rewards, to encourage participation.
GenBank	A genetic sequence database that provides a collection of all publicly available DNA sequences.
Geographical Information Systems (GIS)	Tools used to map and analyze the geographic distribution of data collection sites.
Gravid Traps	A type of mosquito trap designed to capture egg-carrying female mosquitoes by attracting them with water and/or organic material.
Intrinsic Motivation	The internal drive that encourages people to participate in projects, often due to personal interest or a desire to contribute to their community.
L3 (Third Instar Larva) and L4 (Fourth Instar Larva)	The specific developmental stages in the life cycle of mosquito larvae. Larvae are larger and easier to identify at this stage. L4 is the final stage of the larvae before it molts to become an adult mosquito.
Larviciding	Application of insecticides to water to kill mosquito larvae, or stop development before they can mature into adults.
Mosquito Development Site	Specific locations where mosquitoes lay their eggs and the immature stages (larvae and pupae) develop until they emerge as adults. These sites involve water and can include natural bodies like ponds and marshes, as well as artificial containers like birdbaths and discarded tires.

Mosquito Habitat	The environment where adult mosquitoes live, feed, and rest. Habitats include areas that provide shelter, moisture, and access to blood meals, such as forests, grasslands, wetlands, urban gardens, and human-made structures.
Mosquito Sitings	Instances where mosquitoes are observed in an area.
Mosquito Surveillance	Monitoring and tracking mosquito populations to understand their distribution, abundance, and potential health impacts.
Organization	A group or entity with a structured framework, working together toward common goals. In the context of this toolkit, organizations can include researchers, community groups, public health departments, environmental groups, and other stakeholders who collaborate to achieve a project's objective.
PCR (Polymerase Chain Reaction)	A laboratory technique used to amplify DNA sequences. In the context of mosquitoes, PCR is often utilized to identify and analyze specific genetic markers, pathogens, or genetic modifications within mosquito populations.
Pooter	A small, handheld device used to safely collect small insects, such as mosquitoes, without harming them. It typically includes a container with two tubes: one for sucking in the insect and another to exhale air, with a fine mesh preventing the insect from being inhaled.
Sampling Strategy	A plan for how data will be collected across different regions, often involving quotas or targets to ensure even data collection.
Source Reduction	Eliminating mosquito breeding sites, such as standing water, to control mosquito populations.
Systematic Review	A comprehensive review of existing research and literature on a specific topic, aimed at summarizing and synthesizing research findings.
Quality Control Measures	Procedures implemented to ensure the accuracy and reliability of data collected by community scientists.
Vector	An organism that transmits a pathogen from one host to another. In reference to mosquitoes, vectors are mosquitoes that carry and spread diseases such as malaria, dengue fever, Zika virus, and West Nile virus.

DID YOU KNOW?



A companion publication to this toolkit is available here **https://ncceh.ca/resources/videos-tools/quick-guide-community-science-toolkit-mosquito-surveillance**. This summary document is a great starting point for community organizations who may wish to start a surveillance project.

PHOTO: ADOBE STOCK

Life Cycle of the Mosquito

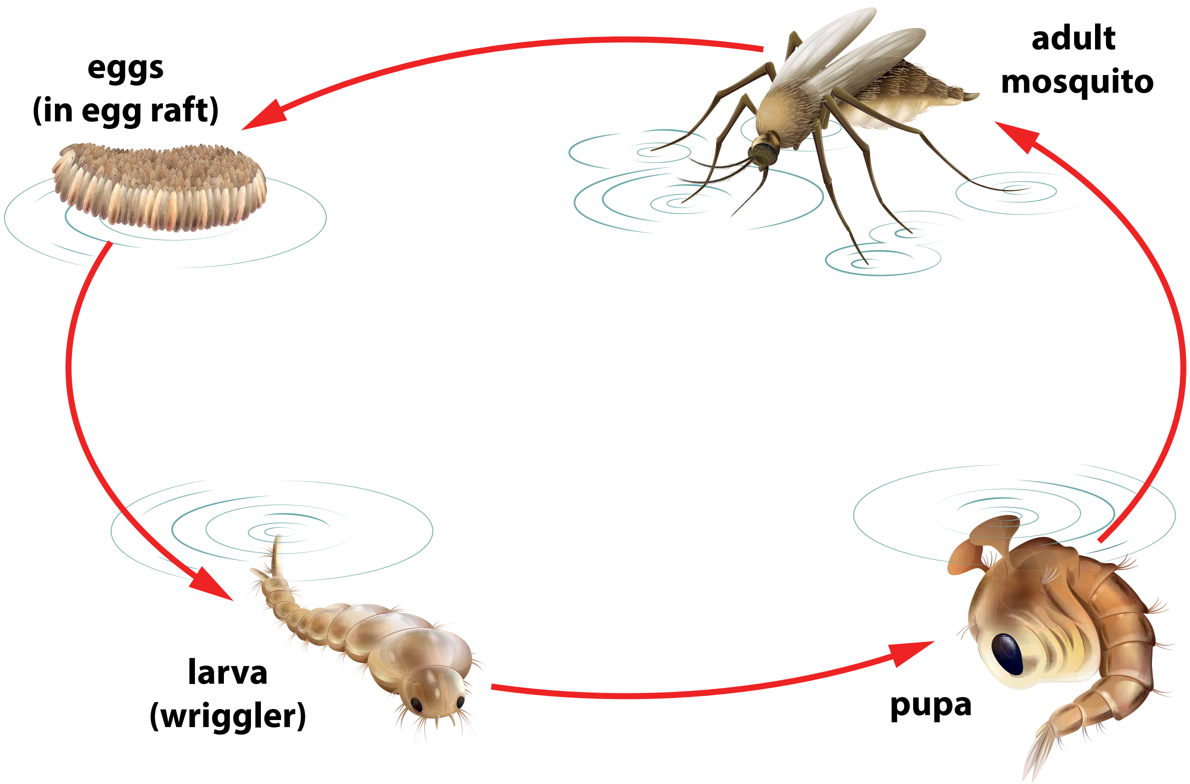


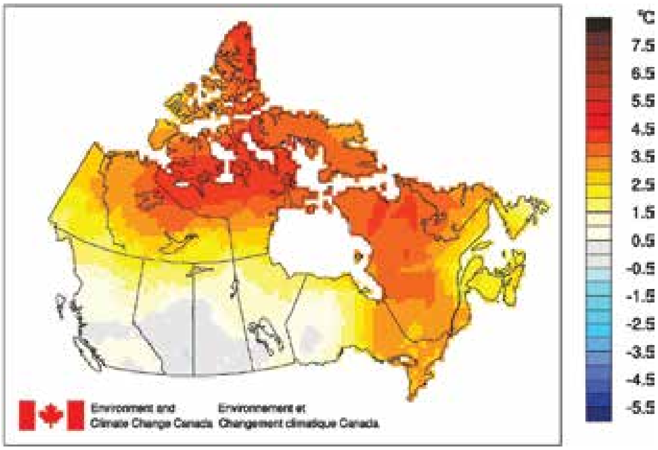
ILLUSTRATION: GETTY IMAGES

PHOTO: TIMO-CS STUDY

INTRODUCTION

1.1 Background

Climate change and the expansion of international trade routes and transportation networks are driving the introduction of native and non-native mosquito species into new areas of Canada [1]. Conventional approaches for monitoring mosquitoes in Canada face challenges due to the vast geography and lack of accessibility in rural and remote locations. Community science programs could enhance surveillance efforts and help to address some of the challenges in monitoring mosquitoes.



Temperature Departures from the 1961-1990 Average SPRING 2024

1.2 Community Science in Mosquito Surveillance

Community science, also known as citizen science, involves public participation in various aspects of the scientific process [2]. Community science participants assist with data collection and analysis. Some participants are involved in active, ongoing programs; others may be casual participants who respond to seasonal campaigns or those who occasionally report observations through apps or dashboards. Many community science projects are active in Canada across different domains, such as **eTick** and **iNaturalist**, to raise awareness of and bring attention to the distribution of vectors, such as ticks and mosquitoes.

There are many approaches to community science projects. This toolkit provides guidance on how to establish an approach and implement a community science project, understand the costs and logistics involved, and identify the aspects of community science programs that can enrich formal mosquito surveillance programs. It also provides supplementary information and insights from professionals in the field. The toolkit presents several resources, training materials, and templates.

1.3 Who is this Toolkit for?

Establishing a successful community science project requires effective collaboration. Whether you represent a health department, environmental group, research team, or community organization, this guide offers valuable strategies for mapping out the steps and navigating the process.

If you are a health department or researcher:

It may not be easy to engage with participants if you do not have established relationships. You can directly reach out to community members or partners through existing organizations (such as schools, youth organizations, environmental programs, or other community science groups). These networks provide access to engaged community members who may want to participate in your project.

If you are a community organization:

To conduct a mosquito surveillance project, you will need to find partners with mosquito expertise and equipment. You can contact organizations like the local health department, city, municipality, researchers, or conservation authority to inquire about a partnership. Some organizations may even have equipment loan programs to support your mosquito surveillance initiative.

Before you get started, consider the following:

- Community science projects that involve multiple groups tend to be more successful [3,4].
- Every participant in these partnerships brings valuable contributions to the team, allowing for diverse perspectives [4,5].
- Meeting face-to-face, especially at the start, can be crucial for a successful collaboration [4,5].

1.4 How was this Toolkit Created?

This toolkit was developed through the combined insight from a systematic review of relevant scientific literature and consultation with an expert advisory group. The systematic review focused on gaining insight into evidence-based techniques and a broader understanding of community science globally. The expert advisory group was comprised of subject-area experts in mosquito surveillance, community science, and epidemiology. Insights from the group provided priorities on the types of information to include in the toolkit and the possible challenges and considerations for implementing various projects.

The Future...

FUTURE OF MOSQUITO SURVEILLANCE

National mosquito surveillance requires establishing a standardized data format and portal that can easily be accessed to upload data. This would allow community science observations and health or government mosquito surveillance data to be combined to provide a more comprehensive view of mosquito activity.

DID YOU KNOW?

Collaborations are critical in community science initiatives. In 2024, a partnership between Let's Talk Science, the Public Health Agency of Canada, Public Health Ontario and the Windsor-Essex County Health Unit, started a citizen science project in Windsor, Ontario, called the **TIMO-CS study**. The goal of the project was to help identify the presence of the tiger mosquito in areas without mosquito traps. The project involved school-age children (particularly grades 6 and 7 students) and teachers, in May and June and summer camps in July and August. The program brought the expertise and skills of each of the partners to ensure its success.

PHOTO: TIMO-CS STUDY

PHOTO: STEFAN IWASAWA

DESIGNING A COMMUNITY SCIENCE PROJECT

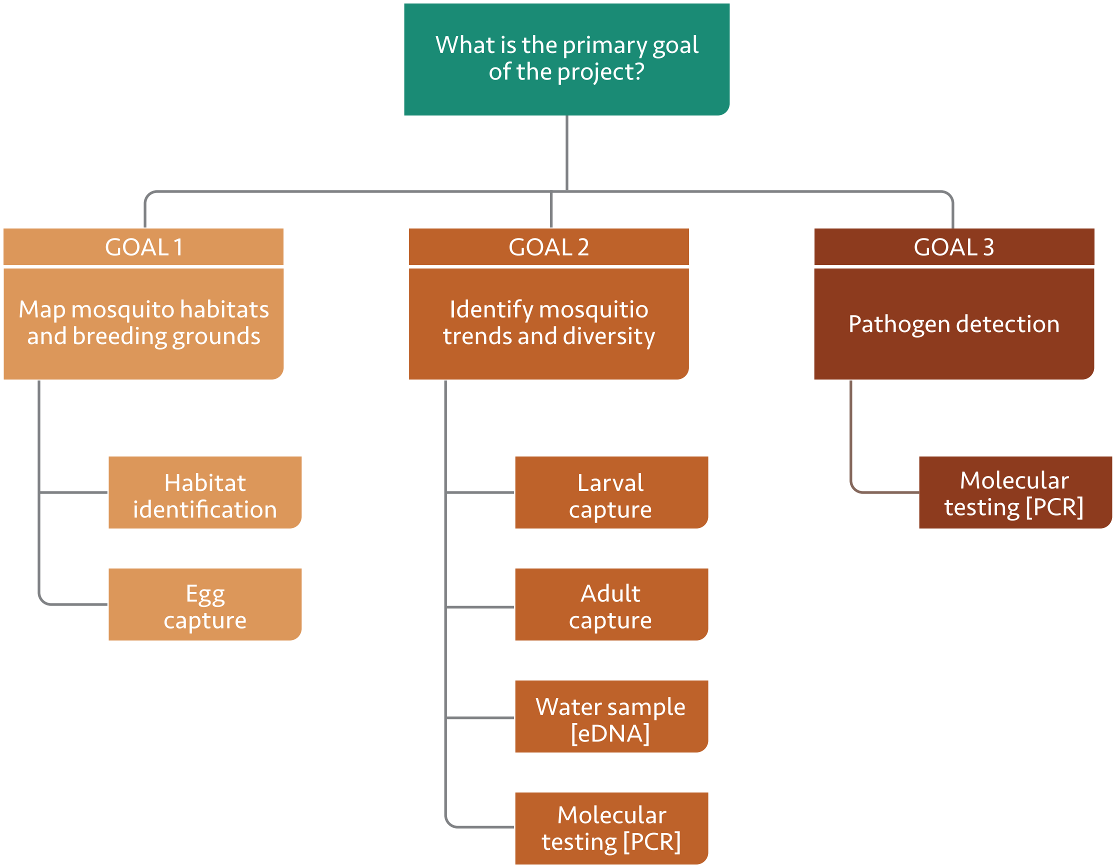
Developing and implementing successful community science projects requires careful planning, time, and resources. Projects should align with an organization's objectives, values, and mission. This section will outline how to select a project goal, how to identify the appropriate sampling method(s), and how to collect data. There are also two visuals to support the decision-making process.

2.1 Goal(s) of the Project

Identifying the project goal(s) will provide a foundation for aligning the project with community science activities, skills, and resources. There are 3 main goals of a mosquito surveillance community science project (outlined in *Figure 1*). These goals will be discussed in the context of what they contribute and in what circumstances they would be most appropriate. Once the goal(s) of the community science project have been identified, specific approaches to data collection can be planned.

Table 2, on pages 12-15, provides detailed activities, benefits, costs, limitations, and equipment related to each approach. The costs will vary depending on your group's ability to repurpose materials and secure donated services. Establishing partnerships with organizations that can contribute materials or expertise can significantly reduce expenses and help to improve the quality of data collected. Additionally, costs can vary widely across the country depending on the specific approach taken and different circumstances.

FIGURE 1
Identifying the project goal(s)



GOAL 1: Map Mosquito Habitats and Development Sites

Objective

To obtain information on mosquito habitats in a specific location and provide potential solutions for reducing the number of mosquitoes.

Best for

The initial phases of building a mosquito species database in a specific location, where ongoing surveillance activities have resource constraints and/or cannot deliver comprehensive monitoring of mosquito development sites.

PHOTO: GETTY IMAGES

Activities and considerations

- Participants are encouraged to identify mosquito development sites and habitats, with or without larvae.
- Mosquito larvae are usually found in stagnant water, freshwater, brackish water, potholes, or even on moist surfaces instead of water, including items like buckets, old tires, and eavestroughs.
- Once larvae locations have been identified, control efforts can be implemented to reduce these habitats.
- In past projects, participants have been asked to report mosquito sitings, [6] mosquito development sites [7], and environmental information regarding the area the mosquito or development site was located [8].
- Such projects are simple for participants to engage with and require minimal training. It allows for broad participation without having an overwhelming number of sample submissions that need identification.

DID YOU KNOW?

Source reduction, or removing mosquito habitat, has been shown to have a measurable positive impact on mosquito-borne disease transmission. **TopaDengue**, a community science project in Paraguay, encouraged community members to take tours of their neighbourhood and identify mosquito development sites for the presence of mosquito larvae. The identified development sites were shared with the research team using a web and mobile platform called Dengue Chat. Families were then encouraged to remove the development site from their homes, reducing mosquito breeding habitats. The initiative was found to reduce the larval levels in the area compared to neighbouring areas not participating in the project [9].

PHOTOS: GETTY IMAGES

GOAL 2: Identify Mosquito Trends and Diversity

Objective

To map mosquito species by tracking the presence of mosquitoes in an area.

Best for

- Areas with ongoing routine surveillance that cannot cover all regions within their jurisdiction.
- Areas where the mosquito species are not uniformly distributed or consistently found in an area.
- Areas where conventional surveillance and trapping are believed not to be capturing the true representation of the mosquito population.

Activities and considerations

- Having participants trap mosquitoes is the most common type of community science project involving mosquitoes, with participants setting up traps, monitoring them, and reporting basic information on quantity of mosquitoes observed over different time periods [2,9–11].
- Participants can participate in one or a combination of adult and larval capture techniques, such as visual characteristic observation and/or using eDNA and PCR testing to identify mosquito species rapidly.
- Individuals can be trained to identify mosquitoes visually. However, this is a challenging skill to develop due to the similarity between species, leading to potential misidentification. The project team should develop a mosquito identification tool specific to their project goals to help participants with this task.
- Careful and timely handling of different sample types is needed to maintain quality of submitted samples, as samples degrade over time. See *Box 1* for details on sample submission.
- Samples of mosquitoes can be submitted to the project team for identification, either through physical submission or by submitting images. Good-quality images are crucial; *Table 3*, includes suggestions for improving mosquito photographs.
- Some species may require molecular techniques such as PCR testing for accurate identification. DNA sequencing of the PCR products and comparison to sequences in genetic databases, such as **GenBank** and **BOLD**, can be used to confirm the identity of individual mosquitoes.
- Additional training and support may be needed for the participants involved in trapping and shipping or identification activities, compared with activities related to Goal 1. Support from mosquito experts is also required to verify participant results.

TABLE 1
Mosquito Storage Techniques and Sample Submission

SAMPLE	STEPS FOR SAMPLE SUBMISSION
Larvae	Larvae can be kept in a container of water until they reach L3-L4, as it is easier to identify at this stage. ▪ Using a pipette, the larvae should be put in hot water (60°C) and then transferred to a 70-80% alcohol solution. If hot water is not available, put samples directly into alcohol. ▪ Place in fridge or freezer until ready to identify or photograph.
Adult identification	▪ Put live mosquitoes in a container in the freezer for 2 hours. ▪ Specimens can be removed from the freezer and manipulated using tweezers for pictures or identification purposes. ▪ If mailing specimens, put in a tube or other container with a small piece of paper towel or cotton ball to minimize damage to the specimen. Keep tube in the freezer until shipping. Sample can be left in the freezer for days or weeks.
Adult PCR analysis	▪ Put live mosquitoes in the freezer for 2 hours. Transfer into a container or envelope for shipping. Keep the container in the freezer until shipping. ▪ Ship mosquitoes for testing as soon as possible and if possible, ship in a cooler with ice or dry ice to keep cool.
eDNA water sample	▪ Water samples should be run through membrane filters, adding a preservative to the filter right away. Filters need to be sent to the lab for analysis. ▪ Filters in preservatives can be kept at room temperature for up to a week. Filters without preservatives should be kept below 4°C until analysis.

Goal 3: Pathogen Detection

Objective

- To identify disease-causing pathogens within mosquito populations.

Best for

- Communities experiencing a higher incidence of mosquito-borne disease and in areas concerned with emerging diseases.

Activities

- Participants can assist in mosquito trapping to detect viruses through PCR testing in regions that may be difficult to travel to regularly, such as remote or rural areas, or on the participants' private property where traps are not usually located.
- A laboratory or university testing centre needs to be included as a partner for these types of projects. Confirmation of a specific pathogen can be made using PCR testing, through laboratory services.
- By providing locations of mosquito presence, government organizations can implement targeted interventions such as larviciding to reduce mosquito populations and control the spread of disease.
- Participants will require training and support on how to use traps and how to package and ship samples shortly after collection to a laboratory for testing.
- Some projects have also had success with asking participants to freeze captured mosquitos before mailing them for analysis [13,14]. While effective, this option poses challenges for remote participants or large groups due to the necessity of providing mosquito traps and dry ice, as well as the timely shipment of samples.

Once project goal(s) are specified, it is important to note that education and engagement with the community are central and should be overarching goals of any community science project. Practical initiatives that communities find personally or collectively significant can motivate individuals to adopt preventative behaviours to protect themselves and others from mosquito-borne diseases [15].

TABLE 2
Approaches to Data Collection

GOAL 1: Map Mosquito Habitats and Development Sites

APPROACH	ACTIVITY	PURPOSE	BENEFITS	LIMITATIONS	RESOURCES	COST
Habitat identification	Observe and report potential mosquito habitats	Look for potential mosquito habitats and report if they observe larvae	Simple to create and manage	Being able to interpret and integrate this data into existing data sets	Participants do not require any additional resources to participate	$
		Participants are asked to eliminate the mosquito habitat	Can be used as a first step in mosquito surveillance leading to larval surveillance	Data quality and the ability to validate results	Staff time for education, outreach and interpretation of data	
Egg capture	Ovitraps/Gravid Traps	To attract egg laying females (More specifically Aedes)	Simple to make and use and is low maintenance	Need to be checked on in 3 day intervals as traps may dry out if not cared for	Can use household materials to construct a trap	$
			Allows capture of multiple life stages of mosquitoes and morphological identification based on egg characteristics	Does not represent abundance of mosquitoes in the area		
			Can be used to confirm if a species is laying eggs in the area			
			Requires only submission of photos for identification			
	Netting/Dipping	To collect all mosquito species for surveillance and identification	Quick collection	Bycatch can be large and sampling a large water body can be time consuming	Dipper/Net	$
		To determine abundance of mosquitoes in a certain area.	Easy, little to no training and limited equipment needed	Identification of larvae is time consuming	Sample collection container	
				PCR analysis, if done, will increase costs	Lab technician for identification of specimens	
				Safety concerns for participants working near open water		
	Aspirating	To collect all types of mosquito species for identification	Appropriate for small water bodies	Limited applications and tedious process	Aspirator	$
				PCR analysis, if done, will increase costs	Lab technician for identification of specimens	
				Safety concerns for participants working near open water		

TABLE 2
Approaches to Data Collection

GOAL 2: Identify Mosquito Trends and Diversity

APPROACH	ACTIVITY	PURPOSE	BENEFITS	LIMITATIONS	RESOURCES	COST
Larval Mosquito collection	Rearing larvae into adult mosquitoes	To collect all types of mosquito species for identification	Enhanced educational component of the project as citizens learn about the life stages of the mosquito	Volunteers will require training and guidance on mosquito identification of common species	Training materials (field guide or identification key) for citizens to be able to identify species	$
		To identify mosquito species more easily	Some species look very similar as larvae but very different as adults so identification can be easier		Participants will need a magnifying glass or microscope cell phone attachment for identification	
Adult Mosquito collection	Adult mosquito traps	Capturing all types of adult mosquitos for identification which could lead to pathogen surveillance (See PCR)	Good for working with specific communities (school groups, workplaces)	Requires training for proper setup and requires daily attention by the citizen	Need to provide participants with traps	$$
			Fairly easy to set up and maintain	Getting samples and equipment returned	Lab technician needed to identify specimens	
				Sample damage is common		
	BG sentinal	Especially good for capturing *Aedes spp.* mosquitoes	Designed to mimic human body odour and heat, making it highly attractive to mosquitoes	Requires multiple components like power source/CO2/ lure	BG Sentenniel- lure, CO2 and a power source needed	$$
			Can be used in a variety of weather conditions			
	CO2 baited traps	To attract many species of adult mosquitoes including *Aedes spp., Culex spp.* and *Coquillettidia spp.*	Effective for attracting adult mosquitoes but not other insects	Traps can be influenced by weather conditions such as temperature, humidity, and wind speed.	Dry ice and power source needed	$$
	Light traps	Attracts many adult mosquito species	Effective for attracting adult mosquitoes	Captures more insects than just mosquitoes	Requires a power source	$$
	Aspirator (pooter approach)	Capturing all adult mosquitos for identification which may lead to pathogen surveillance (See PCR)	Good for capturing only mosquitoes.	Small samples	Lab technician to identify specimens	$
			Low technology	Time and labour intensive	Aspirators	
				Risk of becoming infected /ethical concerns		

TABLE 2
Approaches to Data Collection

GOAL 2: Identify Mosquito Trends and Diversity

APPROACH	ACTIVITY	PURPOSE	BENEFITS	LIMITATIONS	RESOURCES	COST
eDNA	Water sampling of mosquito habitat	To identify new/emerging species that may be difficult to detect using other methods	Detecting species that are difficult to trap or collect using other methods.	Expensive	Access to a laboratory that can do eDNA testing	$$$
			Precise determination of mosquito species	Degradation of DNA over time, and degradation happens quicker in higher temperatures	Sample containers, filters, preservatives, disposable gloves, dippers/disposable pipettes	
			Quick and feasible compared to trapping.	Cannot do viral testing	DNA sequencing facilities (many pay-for-service sequencing providers available)	
			Identification of species without specimen collection	Prone to environmental contamination.	Refer to a genetic database for comparison of DNA sequences (e.g., BOLD, GenBank)	
			Easy and requires little training.			
PCR	Adult/larval sample analysis	To detect genetic material in order to identify mosquito species	Quick	Expensive	Laboratory facilities with the capability of PCR testing for to determine DNA sequencing of mosqutio species and/or the presence of pathogens (many pay-for-service sequencing providers available)	$$$
			Samples can be damaged and still be tested	Limited by the representativeness of the samples collected		
			Reliable results and high accuracy	Samples must be kept cold	Refer to a genetic database for comparison of DNA sequences (e.g., BOLD, GenBank)	

TABLE 2
Approaches to Data Collection

GOAL 3: Pathogen Detection

APPROACH	ACTIVITY	PURPOSE	BENEFITS	LIMITATIONS	RESOURCES	COST
PCR	Adult/larval sample analysis	To identify the presence of pathogens in mosquitoes.	Quick	Expensive	Laboratory facilities with the capability of PCR testing for to determine DNA sequencing of mosqutio species and/or the presence of pathogens (many pay-for-service sequencing providers available)	$$$
			Samples can be damaged and still be tested	Limited by the representativeness of the samples collected		
			Reliable results and high accuracy	Samples must be kept cold	Refer to a genetic database for comparison of DNA sequences (e.g., BOLD, GenBank)	
			Detection and confirmation of virus in mosquitoes			

Notes

$$$ - High Cost I $$ - Moderate Cost I $ - Low Cost
Cost can vary greatly depending on a project's ability to reuse and repurpose household items, donations from partners, and size of the project.

Sample submissions can include a variety of approaches including pictures, preserved samples through drop-off or mail submissions

Safety concerns exist for volunteers during certain activities and have been discussed further in *Section 3.2.2 Volunteer Safety*

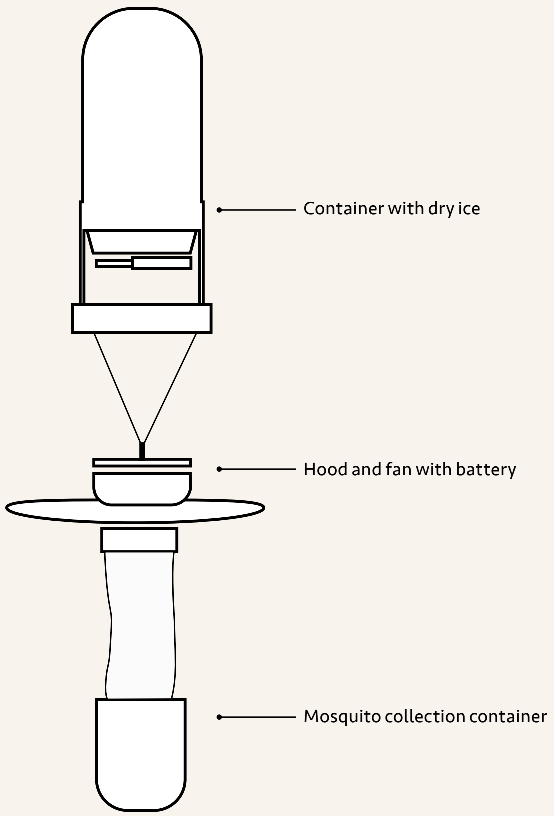
→ **Download an easy to display printout of this table here:**
https://ncceh.ca/sites/default/files/2025-01/TABLE_2_Approaches_to_data_collection_EN.pdf

DID YOU KNOW?

Community science is especially useful for monitoring mosquitoes as it can help build a database of existing species and their distribution [12]. Mozzie Monitors is an adult mosquito surveillance project in Australia where participants use mosquito traps to collect adult mosquitoes and take pictures of the captured species. The photographs are emailed to the research team for identification. The results are shared through a website where residents can learn about mosquito species and abundance in their area. Over 1000 mosquitoes were collected and photographed in the first year of the program.

2.2 Data Collection

Community science projects can lead to the creation of large data sets. The usefulness of the data depends on the type and quality of data collected. Without foresight, it can be difficult to interpret and understand the data. This section contains suggestions on what data should be collected, how to verify, analyze, and interpret the data, the importance of sharing data, and how to integrate collected data into existing frameworks.



Mosquito CDC light trap

2.2.1 Mosquito development sites and trap locations

Generally, mosquitoes lay eggs in still water with organic matter. To design effective, species-specific surveillance, target participant activities specifically to the mosquito species being monitored [16]:

- ***Aedes*** prefer artificial containers around homes with shade, such as flowerpots.
- ***Culex*** prefer still water in the shade with a high content of organic material such as leaves and debris. Such environments can often be found in catch basins and old tires.
- ***Anopheles*** prefer shallow waterbodies containing grasses and direct sunlight, such as ditches.
- ***Coquillettidia*** can be found in freshwater marshes containing cattails.

When setting up the mosquito trap, consider:

- Setting traps as close as possible to mosquito sources and ensure they are placed in shaded areas.

- Placing traps only on participants' private property or public lands. If participants are not sure who owns the land, then mosquito traps should not be placed there.

- Ensuring traps are placed out of the way so that people walking on a trail will not see them. Traps placed on public lands are often vandalized.

2.2.2 Analyzing and interpreting data

The intent of community science data is not to replace existing mosquito surveillance activities but rather to supplement and enhance these existing systems.

Community science data is not free from bias as it does not provide an equal representation or a random or stratified sample. However, community science data is often appropriate for estimating species' abundance or presence [17,18] and can be useful for indicating that more formal surveillance is needed in certain areas. If large amounts of data are collected, patterns can emerge, and repeated measures can solidify a finding.

2.2.3 Data quality

Ensuring accurate data collection relies on 3 criteria:

1. Clear data collection protocols

Using standardized protocols for data collection ensures consistency across participants who might collect data in numerous different ways [19–21]. For instance, participants may be asked to collect samples using gravid traps. To ensure standardization, establish a standard protocol for setting up traps, collecting samples, and reporting results. Consistent data collection can be ensured through templates and clear expectations for taking photographs (see 2.2.5).

2. Simple and tested data forms

For improved accuracy, use validated tools when possible [21–23]. Data collection tools can be simple (e.g., paper forms) and increase in complexity to emails, SMS submissions, or app-based platforms [7,15,23].

3. Support for participants

Training and education are at the core of community science projects [19–21]. Section 3 further discusses the role of participant training.

2.2.4 Errors

Errors in data collection can easily occur in mosquito surveillance and should be considered during project setup. Mosquito identification is especially challenging due to the ease of confusing similar species, the delicate nature of mosquitoes, their susceptibility to damage, and the rapid degradation of specimens.

Strategies to minimize errors include: giving clear instructions, using simple data entry tools, and providing real-time support[11,24,25]. The organization leading the project should set parameters to identify errors through expert review or automated data validation tools [1,20,26]. For example, if a participant reports the presence of a mosquito species that has never or rarely been recorded in that region, the observation should undergo additional verification before being incorporated into the dataset.

PHOTO: TIMO-CS STUDY

PHOTO: GETTY IMAGES

Artificial Intelligence (AI) may also play an important role in identifying data errors in community science data sets. Images captured by participants can be used to train and test AI algorithms to identify mosquito species. AI would employ a human-in-the-loop approach for validation, ensuring accuracy and efficiency in mosquito species identification [27]. Eventually, all community science submissions could be validated and checked for errors using AI.

2.2.5 Photographic data submissions

Using photograph submissions of mosquitoes simplifies sample submissions for participants leading to increased data collection. Previous programs have used photographs for submissions [10,28]. However, this approach has limitations, including the potential for misidentification due to varying photographic skills and the quality of the image. Some species may be easily identified through pictures, like *Aedes albopictus* (a.k.a. tiger mosquito), which has clear distinguishing features. Other mosquito species are not easily distinguishable from photos, which may affect the reliability of the data.

If you choose to use pictures, *Table 3* includes tips to improve participant mosquito picture submissions.

DID YOU KNOW?

The iNaturalist program reduces errors in data by requiring identification agreement by two-thirds or more of community members at the species level, and at least two identifications from separate observers. In the case of disagreements, the agreement with the most specific shared classification is used. For instance, if one person identifies a sample as Aedes albopictus and another as Aedes aegypti, the observation will stay as Aedes until others weigh in and a two-thirds agreement is reached [12].

2.2.6 Sharing of data

An important component of community science is sharing data with participants and the broader community. Communities are curious about their results, the impact on their community, and the results of the entire project. The more participants interact with the data, the greater the educational value of the project.

Dashboards and data visualization software can allow participants to manipulate or explore the data, increasing participant engagement with the data and the overall project [29]. Many programs have used mobile applications to support submissions [2,6,12,25]. However, if there are resource or technology constraints, even simple, timely follow-ups with participants via email or phone can be effective at communicating results and keeping participants engaged in the project [7,15,23].

Participants also appreciate learning the final and ongoing results of the project. Such information can be communicated in numerous ways, including: a final report, a website, and/or social media sites where updates on the project are shared.

2.2.7 Integrating data into an existing mosquito surveillance system

Organizations that complete their own mosquito surveillance program may want to integrate data from a community science project into their existing data set. This can create a more comprehensive and richer data source, a broader geographical coverage, enhanced mosquito screening, cost efficiency, and higher operational effectiveness. Data captured by community scientists can be integrated into existing data platforms when there is:

- a uniform data format
- standardized data collection
- a process for eliminating data errors

DID YOU KNOW?

Inconsistent standards for collecting and analyzing data leads to many obstacles in merging and analyzing datasets. The steps outlined in this toolkit will help remove some of those barriers, allowing for data sets to be used in a broader context, supplementing conventional surveillance efforts.

TABLE 3
Tips for Taking Photographs of Mosquitoes [49]

STABILIZE THE CAMERA OR-PHONE	▪ Use a tripod or rest your phone on a stable surface.
LIGHTING	▪ Ensure good lighting by photographing in natural daylight or using a strong artificial light source. ▪ Be mindful of shadows and reflections that can obscure the mosquito.
ZOOM AND FOCUS	▪ Use the phone's camera to zoom in but avoid using digital zoom as it can reduce image quality. ▪ Physically move closer to the mosquito and tap the screen to focus.
MACRO LENS ATTACHMENT	▪ Consider using a clip-on macro lens attachment for the phone. These lenses allow for extreme close-up shots, capturing fine details and cost about $20.
BACKGROUND AND CONTRAST	▪ Place the mosquito against a plain, light-coloured background (e.g., white piece of paper).
USE BURST MODE	▪ By holding down the shutter button you can take multiple shots in quick succession. This increases the chance of getting at least one sharp and well-composed image.
THE LENS	▪ Ensure the camera lens is clean to avoid blurry or smudged images. Use a microfiber cloth to gently clean the lens before taking photos. ▪ Take the case off your phone, which can obscure the camera.
PATIENCE AND MULTIPLE ATTEMPTS	▪ Be patient and take multiple shots from different angles. ▪ Capture the mosquito from a side view showing the body shape, leg placement, and wing structure. ▪ Get a close-up shot of the mosquito's head and thorax, including the antennae, proboscis, and the patterns on the thorax. ▪ Multiple attempts can help you capture the best possible images.

TABLE 4
Parts of a Mosquito

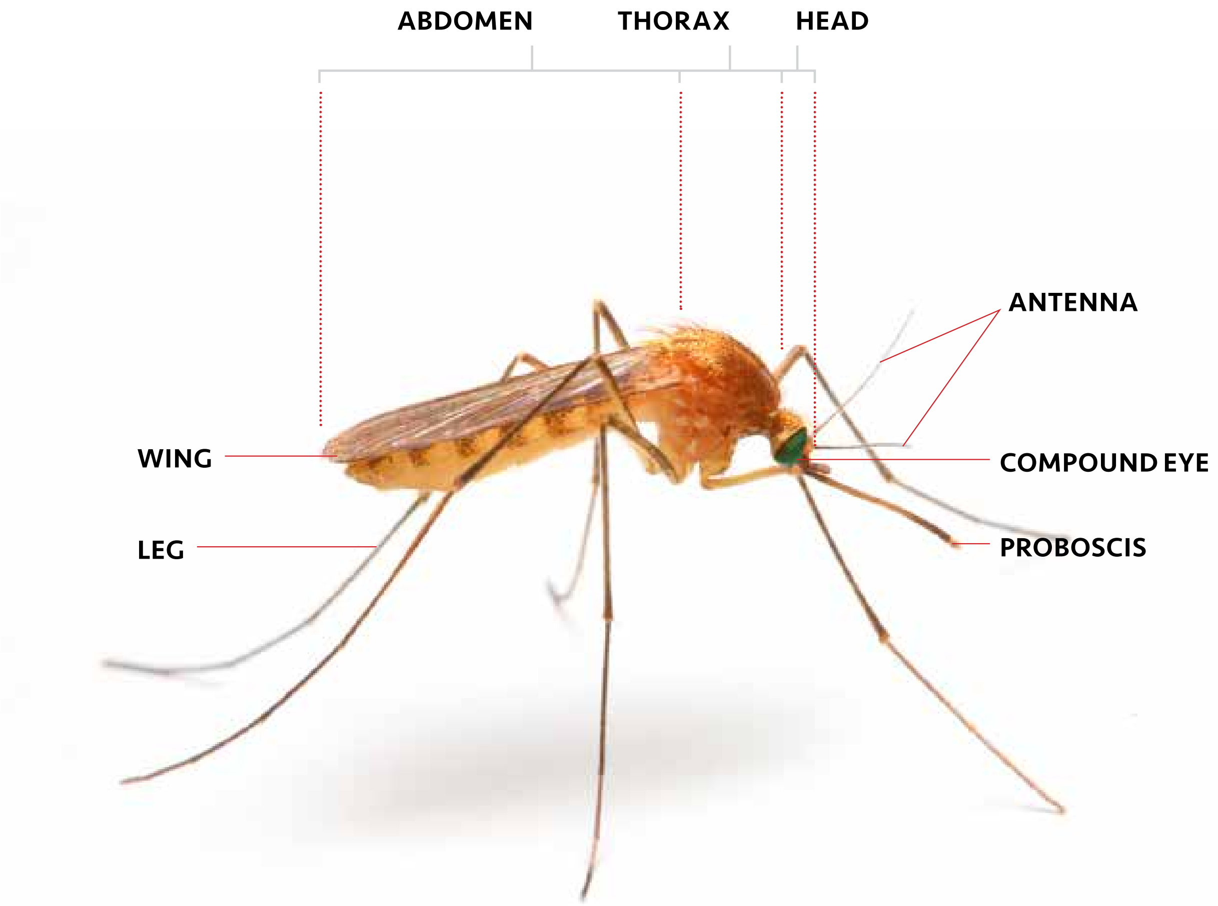


PHOTO: GETTY IMAGES

3.0

COMMUNITY INVOLVEMENT AND OUTREACH

PHOTO: ADOBE STOCK

COMMUNITY INVOLVEMENT AND OUTREACH

Successful community engagement takes careful planning. It is important to connect with local Indigenous communities and Councils to acknowledge the traditional lands where you may be collecting mosquitoes. Make sure to learn about Indigenous ways of knowing related to mosquitoes and explore whether there is interest from the local Indigenous people in being part of the project.

3.1 Recruitment Methods

Participant recruitment plays a crucial role in the success of any community science project. Be sure to receive any applicable approvals before beginning outreach with participants. Consider the following methods to engage participants effectively.

3.1.1 Local outreach

Utilize various channels to increase project awareness and educate the intended audience. Outreach helps to understand how your audience consumes and interacts with information. Consider the following outreach methods [30].

- **Social Media**: Leverage platforms like Facebook, X, formerly known as Twitter, and Instagram to share information about your project, its goals, and volunteer opportunities.
- **Community Bulletin Boards**: Post project details on local bulletin boards to reach interested individuals.
- **Local Newspapers and Letters**: Use print media to inform the community.
- **Neighbourhood Mailing Lists**: Reach out directly to residents through mailing lists.
- **Radio**: Announce your project on local radio stations.

PHOTO: TIMO-CS STUDY

3.1.2 In-person engagement

Host information sessions and recruitment events to connect with community members. People participate in local initiatives to connect with and contribute to their community. Choose welcoming venues like libraries, coffee shops, community centres, and parks.

These events allow organizers to:

- explain the significance of mosquito surveillance.
- describe how participants can collect and analyze data.
- highlight the positive impact on public health.
- provide a chance for potential participants to meet organizers and sign up.

3.1.3 Strategic targeting

Focus on involving people from areas where conventional mosquito surveillance may be lacking. By targeting efforts to specific locations with the biggest data gaps, we can encourage participation with an impact.

Consider the following factors:

- Tailor your approach to fit the community, considering local context and cultures.
- Offer project details in different languages, where appropriate.
- Use platforms familiar to the community.
- Collaborate to build trust and encourage participation with community leaders or organizations.

3.2 Training

Training participants is a crucial part of any community science project. Training modes can differ based on group needs. Training can be offered through online [24,31,32], in-person educational sessions[10,19,22], or interactive workshops [7,33,34]. Training ensures participants feel confident and capable in their role and improves the quality of data collected. Be sure to target your training to the appropriate age of your group.

3.2.1 Training components

Training components should include:

- how to select appropriate locations (sites with high mosquito activity or potential development sites), possibly including field-based training [8,35,36].
- how to collect samples, including storage and shipping [1,20,37].
- how to identify mosquito species, take pictures, and set traps (if applicable).
- participant safety (see section 3.2.2).
- legal and ethical considerations (see section 3.3).
- FAQ's, and how people will be supported (for example, support hotlines and program follow-up [19,21,38].

3.2.2 Participant safety

Safety training is paramount when engaging participants in mosquito surveillance activities. Participants will have potential exposure to insects and environmental hazards.

Consider safety training on the following:

Open water safety

- Be alert to the risk of drowning, particularly in remote areas where help may not be immediately available.

Remote/wilderness safety

- Let someone know where you are going, work with a partner, make sure your phone is working, and have a backup plan in case you lose cell signal.

Personal protective equipment and safety training

- Wear light-coloured, long-sleeved shirts and pants, closed-toe shoes and insect repellent. Consider tick and other insect safety while in high-risk environments by tucking pants into socks, performing tick checks and using insect repellent.
- Be on the lookout for wild animals.
- Remind participants that if they feel unwell at any time to provide their physician with the details of the project they are participating in.

Inclement weather

- Check weather forecasts before heading out and be prepared for sudden changes.
- Carry appropriate gear, such as rain jackets, and know the signs of dangerous weather conditions like thunderstorms, flooding, forest fires, or extreme heat.

3.3 Legal and Ethical Concerns

3.3.1 Human ethics

Most community science projects do not require ethics approval unless the participants are collecting human data. However, it is unethical to ask or encourage participants to collect mosquitoes in areas with a high risk of disease transmission without providing education on how to protect themselves from mosquito bites. If you have concerns about any aspect of your project, you can contact an ethics board at a university or college near you; some institutions have protocols in place to review projects from private companies. Some health units and organizations have their own ethics board committees and can be advantageous partners to involve in your project.

In many cases, working with schools, government departments, and Indigenous communities will require additional approvals.

Have the project reviewed by an ethics committee to ensure there are no ethical concerns.

3.3.2 Community engagement and trust

Be transparent about the project's goals, methods, and outcomes. Being responsive to concerns is essential for building and maintaining public trust.

Develop a plan to be responsive to participant's requests in a timely and respectful manner.

Be Sure To...

Conduct a field test with a diverse sample of volunteers before launching the project. This helps to identify any problems, make improvements, and ensure that procedures are accessible for volunteers. By involving volunteers in practice runs or mock situations, you can get their input and fix any issues before the project's launch.

3.3.3 Privacy and data protection

Collecting data, especially if it involves specific locations, can raise privacy concerns for volunteers and has been a barrier in other projects [10,19].

Develop a plan to collect personal data that follows local, provincial or federal privacy laws.

It is important to ask for informed consent if you are collecting personal information, and complete an ethics review to ensure the study is conducted ethically and responsibly. Participants need to be fully aware of what data is being collected, how it will be used, and who will have access to it. Anonymize data where possible.

Develop clear, accessible consent forms.

3.3.4 Ownership and intellectual property

Clarify ahead of time who owns the data and how it will be used. Also, ensure that the use of the data and any publications respect participants' contributions and provides credit where appropriate.

Inform participants of the purpose of the data collection, what type of data will be collected (personal or non-personal), and how participants can request access to their data.

3.4 Motivating and Maintaining Participant Interest

Engagement and appreciation of participants is crucial to keep participants active in a project. participants can be motivated both intrinsically or extrinsically. Many participants have an intrinsic desire to contribute to projects through community involvement and ownership. Participants genuinely care about the cause or project and have a desire to learn about data collection, public health practices, mosquito lifecycles, disease transmission, and control strategies. This knowledge can be valuable for protecting their own communities against mosquito-borne diseases [30,31].

To encourage involvement, you can provide:

- opportunities for community members to have a say in designing and developing the project [19,34].
- training workshops that enhance their abilities [39].
- mentoring programs to pair experienced participants with newcomers [32].
- leadership opportunities, through the creation of pathways for participants to take on leadership roles, training others, or educating the general public [40].

However, not all people are motivated by these means. Past projects have used monetary incentives [19,39,41], physical incentives, such as giving participants traps and sensors for mosquito control [7,42], and recognition and rewards [3, 6,12,15,43].

To increase volunteer participation, extrinsic motivation can be provided through:

- hosting appreciation events to recognize participants' efforts.
- highlighting success stories.
- seeking support from local businesses that might be willing to donate prizes (e.g., grocery stores, pizza shops).
- creating scoreboards, badges, or checklists of tasks.
- printing certificates for participants to show their contribution and recognition.

Participants spend time and effort collecting data, so it is important to keep them informed about what their work has achieved. Assigning a specific person as a community liaison officer within the project is often helpful. Most participants are eager to see the outcomes of their contributions. It is important to share both their specific results and the overall project goals frequently through regular feedback and communication[31].

DID YOU KNOW?

The **Newfoundland and Labrador Mosquito Surveillance Project** was comprised of investigators from Memorial University, school districts, community members, science camps, Conservation Corps Newfoundland and Labrador, and Inuit and Innu nations.

The project sent mosquito collection packages out to community scientists, with pre-paid postage, so they could collect mosquitoes and mail them back to the university to be identified for species and processed for target viruses. Mosquitoes were collected using a pooter, which was fun and easy for participants to use.

This project provided in-person training sessions in gyms at schools, communicated with participants through email about their individual results, and regularly updated the project's Facebook page. Facebook allowed the project coordinator to provide regular updates on the status of the project, which mosquito species had been found and where, training updates, and fun facts about mosquitoes. This regular communication increased project engagement.

Download a fully customizable Certificate template here:
https://ncceh.ca/sites/default/files/2025-01/Mosquito%20toolkit%20certificate%20EN.pptx

4.0

EVALUATING A COMMUNITY SCIENCE PROJECT

PHOTO: GETTY IMAGES

EVALUATING A COMMUNITY SCIENCE PROJECT

There are numerous ways to define and determine the success of a project. Using performance metrics, the process, feasibility, outcome, and impact of a program can all be evaluated [6,45]. This section will outline evaluation strategies and troubleshooting tips for designing and implementing a community science project.

4.1 How to Determine Success

4.1.1 Participant engagement and retention

The success of community science projects depends on the degree to which participants are interested and engaged [45]. High retention rates and active participation throughout the study period could indicate that the program is well received and engaging. Feedback on the program can support participant engagement. Participant feedback, on their experiences and engagement, can be collected through a survey and could include questions to assess participants' and communities' knowledge about mosquito-borne diseases and prevention methods [12,38]. Asking participants to rate statements on a scale from 1 to 5, such as: "I enjoyed being a part of this program" and "I felt the program was interesting" or "It was motivating to do research in my local community" [32] can help gauge participants' interest and engagement with the project.

4.1.2 Data quality and quantity

Community science projects are primarily designed for surveillance. Evaluating the amount of data collected compared to initial goals can indicate that participants achieved their goals. Other useful forms of data include: identification of novel species, large volumes of data collection, or new data in previously unexplored areas [25].

The accuracy of the data collected is often just as important as the amount of data. This can be assessed by comparing it with established surveillance data or through follow-up verification [44]. Lastly, data collection methods and results should be checked for consistency across different participants and regions.

TABLE 5 Evaluation Measures	
PARTICIPANT KNOWLEDGE	▪ Measure participant's knowledge before and after the program through a survey.
RETENTION RATE	▪ Measure the retention rate by recording the percentage of participants who continue with the program over a specified period.
ENGAGEMENT	▪ Measure engagement in different regions by comparing how many samples/ submissions were received in each region.
ACCURACY OF DATA	▪ Measure the accuracy of the data collected through verification measures. ▪ Determine the number of accurately identified submissions divided by the total number of submissions.
SHARE	▪ Track how many people or different organizations shared and used the data and in which ways. ▪ Track views or shares of on-line or social media data.
COST-BENEFIT ANALYSIS	▪ Identify how funding was used compared to the impact that came from the program.

4.1.3 Impact on mosquito surveillance and public health

While many mosquito control efforts aim to reduce mosquitoes and their associated diseases, this can be difficult to evaluate due to many complex factors, including: seasonal variations, mosquito and human behaviour, and other vector control measures taking place simultaneously [46].

It can still be worthwhile to note any differences in these measures while implementing a new project. This could include identifying areas with high mosquito activity, reporting any actions taken by public health authorities such as targeted spraying or public health warnings, and tracking the incidence of mosquito-borne diseases in the monitored areas [3, 36].

4.1.4 Project effectiveness and sustainability

Identifying which aspects of the project were particularly effective is an important part of an evaluation plan. Consider if there were methods that led to improvements in mosquito surveillance; this might be indicated by:

- a change in the number of mosquitoes caught per trap/night.
- a change in the species being captured.
- whether the project has been sustainable beyond its initial funding period.
- whether surveillance activities are still regularly performed.

A cost-benefit analysis can help assess how efficiently resources were used and the cost differences between various project components [47]. It may be worthwhile to consider the project's outcomes, including:

- the number of scientific publications, reports, or presentations.
- the strength and effectiveness of the partnerships created during the project.
- an assessment of the success of joint initiatives.
- an assessment of the success of sharing data.

DID YOU KNOW?

A project's success can be evaluated through multiple measures. Mosquito Alert, a citizen science project that began in Spain in 2014, measures its impact and success in many ways. In three years, the program provided outreach and training to more than 38,400 members[1]. Since 2014, more than 190,500 mosquito picture submissions from 183 countries have been received. The data is free for the public to use and download[48]. The project has shown that it is contributing to participant knowledge on the distribution of native and invasive mosquito species. Through a cost-effectiveness analysis it demonstrated similar efficiency to mosquito surveillance using traps (e.g., ovitrap), meaning it provided early warning information about tiger mosquito presence equal to traps, but with larger geographical coverage, at a fraction of its cost. The cost of running traps for one month was nearly eight times more than the cost of running the entire Mosquito Alert project for one month[1].

In 2023, the Mosquito Alert project won the International World Summit Award for digital solutions that positively impact society and contribute to the United Nations Sustainable Development Goals [48].

4.2 Potential Challenges and Solutions

Every project comes with its own set of challenges. This section outlines common obstacles encountered in community science projects and provides multiple solutions for each. You should consider the solutions in the context of your specific project and available resources, and choose what works best for your project.

CHALLENGE

Sustaining interest and participation among participants over time.

SOLUTIONS

- Foster a sense of community and purpose among participants by organizing events, workshops, and social media groups where they can interact with peers and experts.
- Incentivize engagement through recognition and rewards by granting badges, certificates or even prizes.
- Consider connecting with media to increase awareness about the project. The more people who hear about a project, the more likely they are to participate.
- Partner with a community organization that is well established with members who might be interested in collecting data for another project.

CHALLENGE

Boosting participation in remote areas where surveillance is needed.

SOLUTIONS

- Identify and train community or local leaders who can advocate for the project and motivate others to participate.
- Conduct training programs in remote areas to build local capacity for data collection and analysis. This also builds trust for the organizations running the project.
- Design a sampling strategy that involves setting quotas or targets for each region that can be shared with participants to encourage them to collect data in underrepresented areas and show areas that are heavily sampled. This could include the use of geographical information systems (GIS) to map existing data collection sites.

CHALLENGE
There are inaccuracies and inconsistencies in the data collected by participants.

SOLUTIONS

- Implement comprehensive training programs and provide resources that are user-friendly, such as field guides, online tutorials, or workshops to ensure participants can accurately identify mosquitoes and collect reliable data.
- Ensure each community group has at least one resource person who has been fully trained and able to answer questions and troubleshoot.
- Establish quality control measures, such as expert validation, to enhance the reliability of community-collected data.
- Determine the level of data needed to achieve your project goals. For example, identifying mosquito genera rather than species might be sufficient and would not only be easier for participants but could also provide more accurate data.
- Establish help desks or support lines where participants can get assistance with technical issues, data collection questions, or other concerns. This could be over the phone, email, or a live chat.

CHALLENGE
Integrating data collected by participants into an existing surveillance system, where there are differences in formats, protocols, and standards.

SOLUTIONS

- Invest in software that can handle different data formats and automate the transformation of community-collected data into standardized formats suitable for the surveillance system.
- Work with surveillance analysts ahead of time to design systems that mitigate this issue.
- If electronic forms are used for data collection, they should include mandatory fields, dropdowns, and data validation checks.
- Develop a data standardization plan to align existing data with desired formats and protocols. This might involve data cleaning, reformatting, and mapping historical data to standardized templates.

CHALLENGE
Constraints in funding, equipment, and human resources needed to support the project.

SOLUTIONS

- Explore opportunities for partnerships that leverage resources from other sectors. Consider collaborating with government agencies, academic institutions, and private organizations.
- Utilize cost-effective methods, such as creating your own mosquito traps with household items, to reduce operational expenses.
- Choose methods that will be most cost-effective while still achieving your project goals. For instance, train participants to identify their own samples so there are no costs associated with shipping and identification.

CHALLENGE
There is a need to change the approach of the project after initiation.

SOLUTIONS

- Use clear communication with all parties explaining why these changes are needed.
- Document the changes that are being made, including the reasons for the change. This will be important for understanding the changes and how the data that was collected before the changes will be used.
- Provide training and support to ensure that all participants and team members are equipped to handle the new approach. This may include workshops, tutorials, and new training.
- Try to keep the new data collection approach as similar as possible to the old approach to facilitate the merging of data.

CHALLENGE

Managing and coordinating community science activities involving a large number of participants across a wide geographic area.

SOLUTIONS

- Assign one lead person as the coordinator of the program that can oversee multiple components and regions at the same time.
- If the project is especially large, appoint regional coordinators (these could be paid or volunteer positions) who can manage and support participants within specific geographic areas. These coordinators act as a point of contact for local issues and can report to a single coordinator who oversees the entire project.
- Use a centralized communication platform like Teams, Slack or WhatsApp to streamline participant communication. This helps in sharing updates and resources.

5.0 CONCLUSION

PHOTO: GETTY IMAGES

CONCLUSION

This toolkit serves as a practical resource to empower communities and organizations in mosquito surveillance and control. By initiating these projects across Canada, there is an opportunity to gain a deeper understanding of mosquito populations and the health risks they may pose, while working to reduce mosquito populations. This initiative also fosters collaboration between community members, public health officials, and other stakeholders to address these challenges together.

With the guidance and resources provided, groups can effectively monitor mosquito activity, contribute to data collection, and identify patterns critical for addressing mosquito-borne diseases. Key strategies, such as engaging diverse groups, leveraging technology, and promoting best practices in data accuracy, are central to successful community science projects.

The future of mosquito surveillance in Canada requires a comprehensive approach, and this toolkit supports the multifaceted efforts needed to achieve it. Organizations are encouraged to adopt the toolkit principles and resources, adapting them as needed, and to share the lessons learned throughout their journey.

For questions or feedback, please contact mosquitotoolkit@conestogac.on.ca

For more resources on mosquitoes, please visit the National Collaborating Centre for Environmental Health

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National Collaborating Centre for Environmental Health
Centre de collaboration nationale en santé environnementale

National Collaborating Centre for Environmental Health

655 W. 12th Avenue
Vancouver, BC V5Z 4R4

www.ncceh.ca