UNIVERSITY HONORS PROGRAM

SENIOR PROJECT - APPROVAL

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PROJECT TITLE: Design Recommendation for an Automated Mosquito Enumerator

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

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Comments (Optional):

Design Recommendation for an Automated Mosquito Enumerator

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Senior Project

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CDC Minature Light Trap Model 512. 2002. Accessed: 15 November 2002. On-line. Available: http://www.qt.com/jwhock/pd_512.htm.

EXECUTIVE SUMMARY

Mosquitoes serve as vectors for a number of diseases including malaria and West Nile virus. Any species that transmits a disease is considered a vector. Integrated vector management, the control of disease carrying insects using minimum amounts of chemical, relies on accurate insect census data to protect human health while minimizing environmental risks associated with insecticide application. Mosquito census data is currently obtained by manually counting the number of mosquitoes caught in traps. Manual counting is labor intensive; therefore, the spatial and temporal resolution of collected census data is limited to the number of traps a labor force can monitor. An automated mosquito trapping system would increase census data accuracy, reduce labor expenses associated with manual monitoring, and potentially improve capabilities for monitoring larger areas. Such a system would detect mosquitoes entering the trap and transmit the census data from a remote location to a public health agency.

Automated mosquito enumerator designs for a standard Center for Disease Control (CDC) mosquito trap were researched. Optical, acoustical, and capacitance based detection systems with either a modem or radio telemetry data transmission system were evaluated. Each design solution was evaluated against four design criteria. These criteria focused the design on the selection of a low-cost, low-power, accurate system that would be easy to implement in CDC mosquito traps. The recommended design for implementation is an acoustical detection system with a modem for data transmission. An acoustical detection system has inexpensive components and has low power requirements. The desired accuracy can be achieved using signal processing. A modem provides virtually unlimited data transmission distances. This system configuration was selected because it best fulfills the requirements of the design criteria.

INTRODUCTION

Mosquitoes transmit many diseases including malaria and West Nile virus. Effective integrated vector management is dependent on accurate insect census data. An automated mosquito trapping system design will be chosen to increase census data accuracy, reduce labor expenses associated with manual monitoring, and potentially increase the size of areas being monitored.

PURPOSE

The goal of this project is to recommend the design of an electronic system to automate the mosquito census data collection process. Mosquito census data is currently obtained by manually counting the number of mosquitoes caught in traps, which is labor intensive. An auto-reporting mosquito trap will improve the spatial and temporal resolution of collected census data and thereby improve management decisions. An automated mosquito enumerator design was selected for use with a standard Center for Disease Control (CDC) mosquito trap. The system will be designed to detect mosquitoes entering the trap and to transmit the census data from a remote location. Possible detection and transmission systems were researched, and a design recommendation for an automated system is made.

SCOPE

Six design solutions were evaluated for this project. Optical, acoustical, and capacitance based detection systems combined with either radio telemetry or modem connections for data transmission were the options analyzed. Design criteria for the automated system were established to focus the evaluation on the development of a low-cost, accurate electronic system that can easily be added to the CDC mosquito trap. Each possible combination of the three detection methods and two data transmission techniques was compared with the alternatives.

LIMITATIONS

The recommended automated system design was selected for use with the CDC mosquito trap. Other methods of automatically monitoring mosquito populations may be more feasible for use with other trapping devices. Due to the lack of previous work on automating mosquito traps, proof of concept for the design alternatives was not established. The evaluation and selection of each method was based on theory, not results from actual implementation.

ASSUMPTIONS

There are two essential assumptions throughout this report. It assumes that controlling disease carrying mosquito populations is necessary to prevent epidemics and that current mosquito monitoring methods limit proper mosquito management. Sparsely populated regions may not be concerned with mosquito monitoring since the risk of an epidemic is low. However, humid urban areas do rely on accurate mosquito census data to prevent the spread of diseases. For this reason, the first assumption is valid. Current monitoring frequency and areas are limited to the labor force available to monitor traps. Proper management depends on accurate, up-to-date data; therefore, the second assumption is also valid.

CRITERIA

Each detection and transmission method was evaluated based on the following four criteria.

1. Combined detection/transmission accuracy must be within ±5% of the actual number of specimens caught in the trap.

2. System cost should be less than the cost of labor for counting specimens in one trap over one season. This value has been estimated at $100.

3. Instrumentation should not inhibit mosquitoes from entering the trap or require extreme trap modifications.

4. Remote reporting system should provide long-range data transmission capabilities.

BACKGROUND

Previous studies on monitoring mosquito populations were researched to establish the need for an automated mosquito enumerator. Automated insect traps were also researched to determine if this work had already been done and to obtain ideas for the automated mosquito enumerator.

IMPORTANCE

Monitoring mosquito populations is important for two main reasons. First, accurate mosquito census data can provide early detection of potential epidemics. Second, mosquito population monitoring can minimize the amount of chemicals applied to control mosquito populations.

Lindblade, Walker, and Wilson (2000) researched methods and procedures for monitoring mosquito populations in the African highlands to provide early warning of malaria epidemics. They correlated the number of mosquitoes per household to the onset of an epidemic. The number of mosquitoes per household was established by fumigating each house. The dead mosquito specimens were caught on sticky paper that was rolled throughout the house. Lindblade, Walker, and Wilson recognized that mosquito census data could aid in the prevention of malaria epidemics; however, the methods used to count mosquitoes were extremely costly and labor intensive and, therefore, limited the accuracy of the data.

Integrated vector management (IVM) is a technique used to minimize the amounts of chemical applied to control disease-carrying insects. A maximum threshold of mosquito population is established. The threshold determines the point at which it is beneficial to apply insecticides to control the mosquito population. An environmental injury level can be used in conjunction with

IVM to decide when population control is necessary despite the environmental impacts (Higley and Pedigo 1993). Without reliable data, the threshold for applying insecticides to prevent the spread of disease cannot be effectively balanced with the threshold for protecting the environment.

AUTOMATED INSECT DETECTION

Most research and development of automated insect detection techniques was conducted about a decade ago. No documentation has been found on the automation of a mosquito trap; however mosquito detection has been researched. Mankin (1994) acoustically detected swarms of mosquitoes in salt marshes. The mosquitoes were distinguished as male or female by their wingbeat frequency. Mankin also suggested distinguishing insect species by their flight sound (1994).

Other research on insect detection provided insight for the automated mosquito enumerator. Optical detection has been used to count the number of tobacco budworms and boll weevils entering inverted cone traps (Hendricks 1985 and 1990). Radio telemetry was used to transmit the collected data from these inverted cone traps. Schouest and Miller (1994) counted bollworms using acoustics. A microphone detected the bollworms as they were knocked down to the bottom of the trap. The vibration of the insect hitting the bottom was detected as opposed to the frequency of the insect's flight sound. A modem connection was incorporated into the system to transmit the bollworm count data. These studies support consideration of optical and acoustical detection methods as well as radio telemetry and modem data transmission techniques.

BODY

The automated system for monitoring mosquito populations was selected from six design solutions based on the previously defined design criteria.

PROBLEM

Mosquitoes transmit a number of deadly diseases. Public health agencies use the integrated vector management technique to protect human health by applying the minimum amount of insecticide necessary to control mosquito populations. Efficiently and effectively controlling disease carrying mosquito populations requires knowing the population density of mosquitoes in an area of concern. Currently, public health agencies use a mosquito trap designed by the Center for Disease Control (CDC) to catch mosquitoes. Each trap is visited about once a week, and the mosquitoes are counted manually. This process is labor intensive and time consuming. The labor force available to monitor the traps limits the number of traps used in an area and the frequency at which counts are obtained. Therefore, the temporal and spatial resolution of the data can only be improved by either increasing the number of mosquito monitoring personnel or by automating the mosquito enumeration process. The later option is pursued in this study.

DESIGN SOLUTIONS

The automated mosquito enumerator will consist of two subsystems. The two subsystems are the detection and data transmission components. First, feasible methods of detecting mosquitoes were identified. Then, appropriate data transmission systems were examined. The detection and data transmission systems considered are presented below.

Optical, acoustical, and capacitance based detection systems were the three methods considered for implementation in the CDC mosquito trap. Optical based systems have been used by Hendricks (1985 and 1990) to automate tobacco budworm and bollworm traps. Hendricks' optically based trap was 96% accurate at detecting the moths. This precedence is an advantage of using an optically based detection system for mosquito detection. However, the geometry of the CDC trap poses problems with implementing such a system. An acoustical-based detection system would use a microphone to distinguish the mosquito flight sound as it enters the trap. A microphone is easy to implement in the trap and is relatively inexpensive. The desired accuracy can be achieved with an acoustical system; however, ambient noise can affect the ability of an acoustical system to distinguish the sound of mosquitoes. Signal processing can be used to minimize the effects of varying environmental noise inputs. Capacitance was the third method researched. No other use of capacitance to detect insects was found, but this system would be very low cost and easy to install in the CDC trap.

Two data transmission techniques were selected as viable means of remotely sending the mosquito count to a central location, such as a public health organization. Radio telemetry is a reliable method of transmitting data. Radio telemetry systems scan the radio channels for data transmission to find an unused frequency before sending any data. This feature is to ensure that data is not lost or embedded in other data on a busy frequency. Despite its accuracy, reasonably priced radio telemetry devices are only capable of transmitting data from 0.5 to 12 miles. Modem connections are capable of transmitting data over an almost unlimited distance. A modem, however, is dependent on reliable cellular phone signals. A radio telemetry device must be near the central data collection station; whereas, a modem connection can be established anywhere except extremely remote locations.

EVALUATION

The six design configurations were evaluated using a decision matrix or Pugh chart. Each alternative design solution was scored relative to the other options on its ability to meet the design criteria. Table 1 is the Pugh chart developed for the automated mosquito enumerator design selection.

Table 1: Pugh Chart for Design Selection.
An acoustical/modem design was selected.

		A	B	C	D	E	F
Detecting	**Method**	*Optical*	*Optical*	*Capacitance*	*Capacitance*	*Acoustical*	*Acoustical*
	Accuracy	4	4	5	5	7	7
	Obtrusiveness	3	3	5	5	9	9
	Power Req	3	3	7	7	7	7
	Cost	5	5	8	8	7	7
Transmitting	**Method**	*Radio Tele.*	*Modem*	*Radio Tele.*	*Modem*	*Radio Tele.*	*Modem*
	Distance	5	10	5	10	5	10
	Power Req	7	4	7	4	7	4
	Cost	5	5	5	5	5	5
	Total	32	34	42	44	47	49

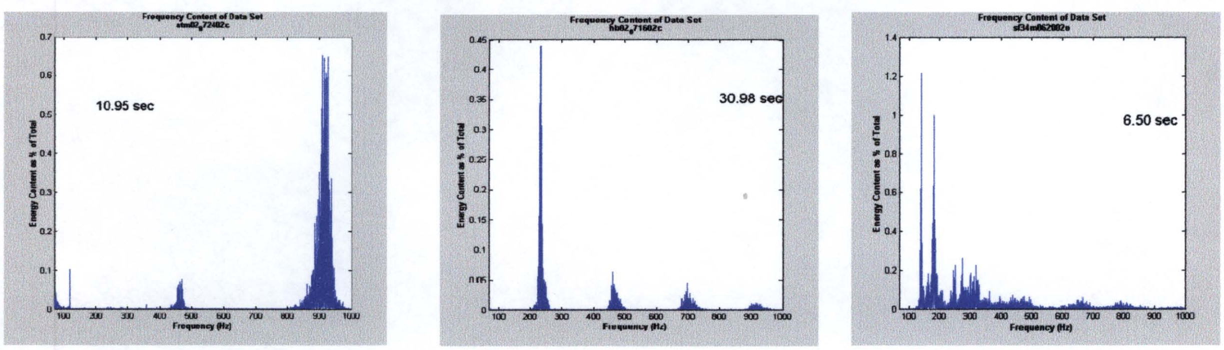
The detection and transmission systems were given a relative score from 1 to 10 for each of the criteria. The design configuration with the highest score was determined to be the recommended automated mosquito enumerator design. The acoustical detection and modem transmission system combination was selected as the best design solution.

SELECTED DESIGN

The recommended design is acoustical detection combined with a modem connection for data transmission. This system configuration best met the design objectives. An overview of how this system will automate the mosquito enumeration process follows.

How Acoustical Detection Works

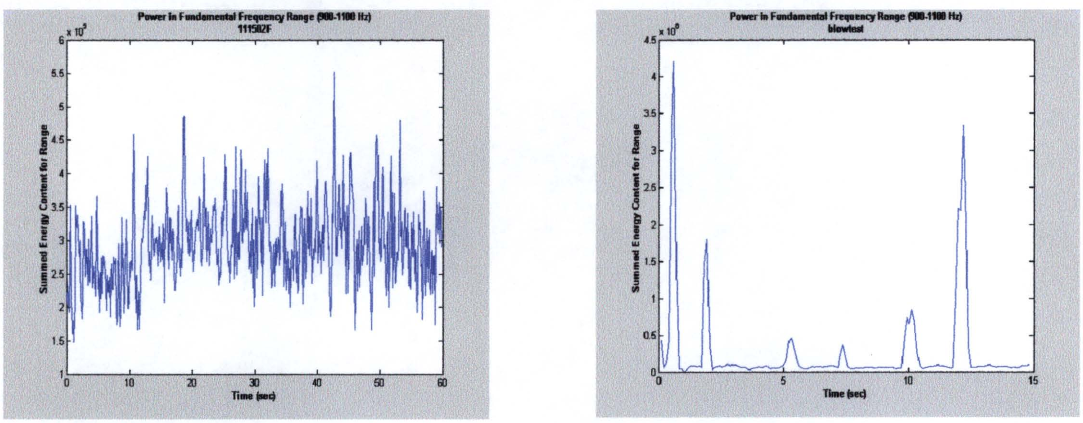
Acoustical detection uses a microphone to distinguish the flight sound of a mosquito. Every insect species has a unique flight sound that is determined by the insect's weight, sex, and wing surface area. To detect a mosquito, the acoustical system is designed to "listen" for the frequencies produced by a mosquito in flight. Figure 1 illustrates the differences in flight sound signatures of a mosquito, stable fly, and honey bee.



Mosquito | Honey Bee | Stable Fly

Figure 1: Insect sound signatures. Insect species show distinctive flight sound frequencies. Each plot shows the percent of total power in the flight sound recording versus frequency. Mosquitoes produce a high-powered frequency in the 850 to 950 Hz range.

The high-powered frequency in the 850 to 950 Hz range for the mosquito is called its fundamental frequency. As the microphone in the trap records, signal processing is used to calculate the power in this fundamental frequency range. Generally, the power is relatively low, representing noise in the trap's vicinity. A mosquito count is made each time the calculated power exceeds the power of the noise. Counting a mosquito based on the power in the fundamental frequency range allows for noise levels to vary without affecting the accuracy of the count. The illustration below, Figure 2, shows a 60-sec noise signal and the expected signal change when 6 mosquitoes enter the trap.



Noise signal

Signal produced by mosquitoes

Figure 2: Microphone recordings. Energy content, or power, is plotted versus time for two recordings. Each recording was 60 seconds. The noise signal has less energy than the peaks representing a mosquito entering the trap.

Each peak in the signal would represent one mosquito entering the trap. Mosquitoes approach the microphone at varying distances; therefore, the magnitudes of the peaks would vary. Figure 2 represents the expected signal that would be generated using an acoustical detection system. However, these results should be verified by testing an implemented acoustical system. Signal processing is used to eliminate the effect of variations in noise levels. The environmental noise will be different for each trap location. Field-testing is also needed to provide a foundation for the noise elimination signal processing.

How Modem Data Transmission Works

A cellular phone connection is needed for data transmission with a modem. A computer at the public health organization (central location) would call the modem on the CDC mosquito trap. Data would be downloaded to the computer for analysis. This method of data transmission was selected because modems have an almost unlimited transmission distance. Traps in very rural locations may not be easily accessed with a modem if there is no cellular phone tower in the area. However, this limitation is not a problem based on the assumption that most mosquito monitoring is conducted in urban or developed areas.

CONCLUSIONS AND RECOMMENDATIONS

An automated mosquito trap could significantly increase the ability of public health organizations to prevent potential epidemics by controlling disease carrying mosquito populations. The recommended design for automating the CDC mosquito trap is an acoustical detection system with a modem for data transmission. This design best fit the criteria for the development of a low-cost, low-power, accurate automated system that is easy to install in existing traps.

Although the acoustical-based detection system is the best detection system in theory, testing must be done to verify its accuracy. A lab experimental setup should consist of a microphone mounted in the top of a CDC mosquito trap. Recordings can be made of the noise in the lab. Then, live mosquitoes can be introduced to the trap and recorded as they enter. This procedure will allow for the comparison of the noise and mosquito signals to validate the system.

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