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Field Testing of a Prototype Acoustic Device for Detection of Mediterranean Fruit Flies Flying into a Trap

R. W. Mankin[1], R. Machan[2], and R. Jones[2]

[1]United States Department of Agriculture, Agricultural Research Service*, Center for Medical, Agricultural, and Veterinary Entomology, 1700 SW 23rd Dr, Gainesville, FL 32608 USA [2]Sigma Space Corp., 4801 Forbes Boulevard, Lanham, Maryland 20706

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ABSTRACT: An instrument that identifies Mediterranean fruit flies entering a trap by detecting and discriminating their wingbeat sounds from background noises was developed and tested in an anechoic chamber and in field environments. Although the system works well in the absence of background noise, it has some difficulty identifying the wingbeats in high levels of background noise, and additional versions of the instrument are under development to improve operations in high-noise environments.

Key Words: *Ceratitis capitata*, sound

INTRODUCTION

Worldwide, hundreds of thousands of traps are used seasonally in surveillance and mass trapping programs against the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (California Department of Food and Agriculture 2003). An automated system for remotely detecting and identifying trapped insects would have considerable potential for reducing the costs of servicing traps and increasing the timeliness of collected information. One of the systems under consideration includes a microphone, amplifier, and acoustic signal processing system that detects and discriminates wingbeats of insects flying into a trap (Beroza & Machan 2006). To be successful, the system must be able to reliably identify weak wingbeat signals of flying insects in a variety of environmental contexts. Here we report on a series of tests conducted with a prototype Mediterranean fruit fly detector system in a worst-case, highway noise environment.

MATERIALS AND METHODS

Flies and Test Arenas. Male-only-strain *C. capitata* (e. g., Caceres 2002) were obtained as pupae from the sterile-fly rearing facility in El Pino, Guatemala. After emerging, they were maintained as described in Mankin et al. (2004). Tests of flight detection in a quiet environment were conducted with groups of 25 males (4-7-days after emergence) in a 20- by 21- by 21.5-cm screened cage in the Center for Medical, Agricultural and Veterinary Entomology (CMAVE) anechoic chamber (Mankin et al. 1996). A camcorder (DCR-TRV27, Sony, Tokyo, Japan) was used to enable remote observation of recorded flights. Two series of tests of flight detection in a noisy environment were conducted with groups of 125 males in a 316-diam.- by 220-cm-height octagonal field cage (Calkins & Webb 1983) in a wooded area about 50 m from a 6-lane highway. The first series of tests included a Jackson trap baited with trimedlure (e.g., Jang et al. 2005). In the second series, the insects were placed in a 38.75- by 39- by 46-cm screened cage to increase the density of flies near the microphone and reduce the time needed for data collection. Flights in the field cage were monitored visually during recording sessions.

Corresponding author:
Richard.Mankin@ars.usda.gov

Acoustic Detection System. The flight detection system was a portable prototype device, modified from a MobilePre USB preamplifier and audio interface (M-Audio, Irwindale, CA), that provided 40-70 dB amplification through two variable-adjustment gain controls. In the anechoic chamber, the background noise was low enough that we could use a 16-16 level of amplification (ca. 60% of maximum) to detect flights from long distances. In the field cage, however, it was necessary to reduce the amplification to 12-12 (ca. 44% of maximum) to avoid clipping the signal. A low-pass, 1800-Hz filter was implemented to avoid aliasing of the 8-kHz analog/digital conversions. An AT803B omnidirectional lavalier microphone (Audio-Technica, Stowe OH) provided signal input. The digitized signal was transferred to a laptop computer through a USB port and processed by custom-written Matlab (MathWorks, Natick, MA) software. The interface/preamplifier system sent two audio signals to ring buffers in the laptop memory. One was the amplified signal from the microphone. The second was a gated version of the signal, passed to the laptop whenever a tone detector was triggered by a 166 ± 23 Hz signal. This frequency range had been selected in the early stages of this study as approximately the range of wingbeat frequencies typically produced during flights of a previously bioassayed, bisexual strain of *C. capitata*.

When a signal triggered the tone detector, the customized software collected 4096 signal samples (0.512 s) from each of the two channel buffers into a log file, beginning 0.128 s before the trigger to ensure capture of early wingbeats of a fly-by. In these tests, we usually collected 50 sets of triggered signals into each log file. After a log file was saved, it was analyzed by custom-written signal processing software that displayed oscillograms and spectra, and had partial capability to predict whether signals were *C. capitata* flights, other insect flights, or background noise. For this report, we were concerned primarily with whether or not the system could reliably detect flight signals in high levels of background noise, so the tests included only *C. capitata* males, and we did not test the reliability of distinguishing among different species.

RESULTS AND DISCUSSION

The sounds produced by *C. capitata* flights past a microphone are typically brief, but easily identifiable signals, as in the example of Figure 1. This example was one of a series of 50 flights recorded by the prototype detector in the anechoic chamber. The signal waxed and waned within about 10 ms (Fig. 1A), and the peak energy occurred at the 185-Hz wingbeat frequency (Fig. 1B). Lower, but energy significant peaks occurred at the second and third harmonics of the wingbeat frequency, 370 and 555 Hz, respectively. The wingbeat frequency depends on many factors, including the temperature (Unwin & Corbet 1984), the size of the fly (e.g., Darveau et al. 2005), and whether it is in lifting or falling, straight, turning, or hovering flight (Hedrick & Daniel 2006). The mean and standard error of 10 randomly sampled flights in the 50-flight series was 190.5 ± 3.04 Hz. Our experience with several hundred flights of different groups of males and females (unpublished) is that the fundamental frequency of *C. capitata* flight is typically between 150 and 220 Hz. The results here and below suggest that the prototype detector would operate correctly over the entire range of frequencies we have observed.

The primary effects of background noise on the operation of the prototype wingbeat detector can be seen in comparisons of the oscillogram and power spectrum in Fig. 1 with those obtained from flights detected in the field cage. For example, the fly-by signal in Fig. 2A is noticeable but somewhat obscured by noise compared to the flight observed in Fig. 1A. However, the obscuring noise separates out clearly from the wingbeat harmonics in the field-cage power spectrum because its energy is primarily below 100 Hz (Fig. 2B). The wingbeat frequencies (and the corresponding 2nd and 3rd harmonics) differ by about 20 Hz, but both wingbeat frequencies lie within the expected 150-220 Hz range.

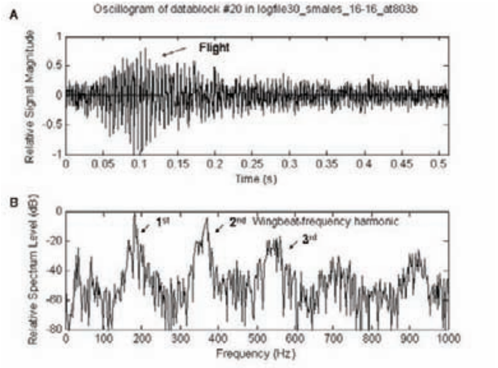

Figure 1. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by male *C. capitata* flight in quiet background of anechoic chamber.

The flight in Fig. 1 was 2-4 cm farther than the 1-2-cm distance of the fly from the microphone in Fig. 2, estimated by visual observation, but it was still detectable, due to the low level of background noise. As the level of noise increases, the fly will not be detected unless it approaches closer to the microphone. If it approaches too closely, however, the signal may exceed the amplification range of the microphone. All the flights in Figs. 2-5 approached close enough that the signal peaks exceeded the amplification range and were clipped. Fortunately, the clipping affected only the high-frequency components of the signal and not the portion in the 150-550-Hz range of most interest to us.

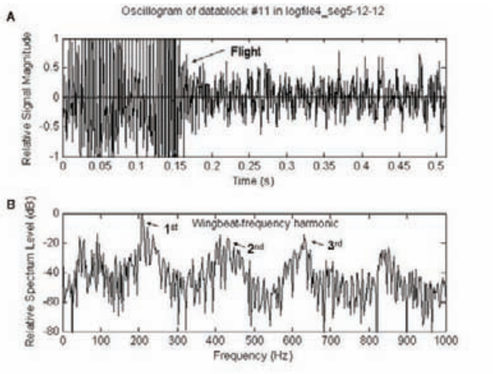

Figure 2. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by male *C. capitata* flight in high-noise environment near traffic.

As expected, the noise was highly variable. In Figure 3, background noise obscured the oscillogram, and noise near 100, 300, and 600 Hz interfered with interpretation of the spectrum.

A particularly loud 80-Hz signal appeared in Fig. 4 but not in a sample recorded a few minutes later, shown in Fig. 5. In each of these spectra, a first harmonic is observed between 150-220 Hz, and 2nd and 3rd harmonics are seen at multiples of 2 and 3 times the first harmonic. These harmonics are likely to be key features of any automated wingbeat

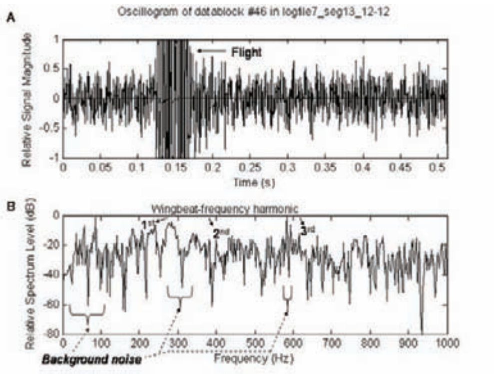

Figure 3. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by male *C. capitata* flight during an interval with high levels of background noise at 100, 300, and 600 Hz.

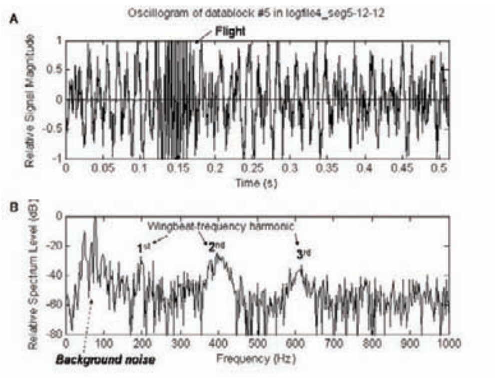

Figure 4. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by male *C. capitata* flight during an interval with high levels of background noise at 80 Hz.

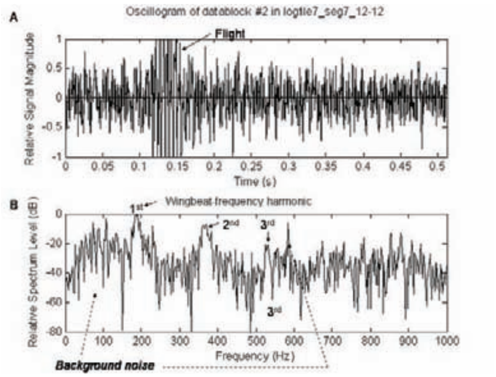

Figure 5. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by male *C. capitata* flight a few minutes after the flight in Fig. 4, showing effects of changes in background noise.

identification system ultimately developed. The wingbeat harmonics were barely observable in Fig. 4, so this flight was probably at the lower limit of signal to noise ratios in which flights can be detected.

In contrast to the tests conducted in the anechoic chamber, where almost all of the tone detector triggers resulted in the capture of a flight, only 4 of about 200 triggers that occurred in a typical field cage test captured a flight. The other triggers in the field cage test captured background signals that either had a significant component at frequencies in the triggering range, or were so loud, e.g., Fig. 6, that the relatively low level of signal in the triggering range was nevertheless strong enough to trigger the tone detector. In a lower-noise environment, the rate of triggering on edge-of-range signals could be reduced by decreasing the amplification levels, but this also would reduce the distance over which the flight could be detected.

During this study, we observed an unexpected trigger of the system by a male flying directly into the side of the trap. The prototype did not detect any wingbeats, but it did trigger on the impact of the fly striking the trap (Fig. 7). In the absence of an observer, such an event would simply be deleted as background noise. Raindrops or other impacting objects can produce spectra similar to that observed in Fig. 7.

The results of these studies with the prototype detector suggest that future versions of the system may need to implement an additional prescreening stage between the signal triggered by the tone detector and the signal that ultimately will be sent to automated wingbeat identification software. A spectral filter could be implemented, for example, to discard signals that do not contain significant harmonic components. In envi-

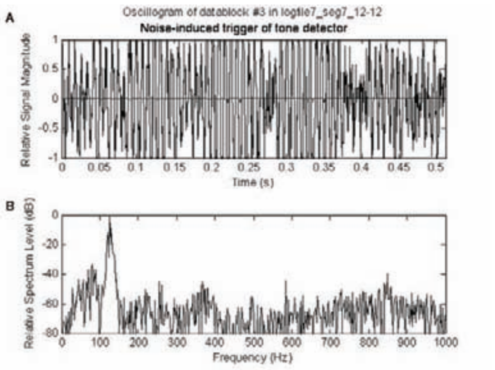

Figure 6. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by high levels of background noise at 120 Hz.

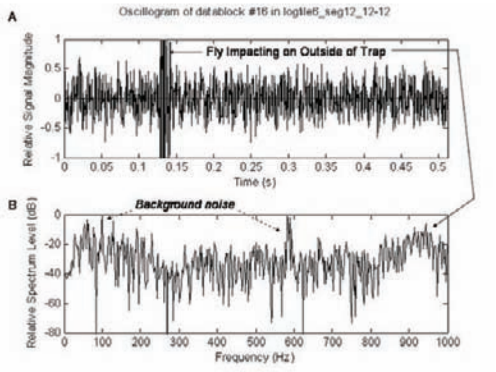

Figure 7. A) Oscillogram and B) power spectrum of signals captured by prototype system triggered by impact of male *C. capitata* striking the exterior of Jackson trap.

ronments with high levels of background noise, this would greatly reduce the rate of storage of signals that incorrectly trigger the tone detector. Also, we continue to search for high-gain, low-cost portable microphones that would enable detection of flights at longer distances. Although the prototype cost > $300 to assemble, a goal is to reduce overall costs ultimately below $50.

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