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11. Towards user-friendly early detection acoustic devices and automated monitoring for Red Palm Weevil management

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Abstract

Early detection of hidden Red Palm Weevil (RPW) infestations in field environments is a difficult but important component of RPW management. Unfortunately there are few externally visible signs of early infestation, and scouts trying to survey and target them must carefully inspect the bases or crowns of palm trees to discover adult entry holes in individual trees. Larvae can be detected by acoustic methods, but with current technology, skilled persons must identify where to insert acoustic probes, and they must use complicated signal analyses to help distinguish RPW sounds from other insects and background noise. Each field location has somewhat different background noise, and it is best to measure general background noise spectral profiles, i.e., "background sound fingerprints," in advance to optimize RPW identification. In addition, inspections must be done when it is quietest, usually early in the day, to optimize detectability. With the adoption of such measurement procedures, current technology has been successful in detecting RPW infestations in field tests in the Caribbean, Spain, Saudi Arabia, and Israel. Experience gained from these studies is being applied towards development of user-friendly, low-cost detection devices.

Recent increases in the computing power and a decrease in the costs of microcontroller systems has generated considerable interest in their use for insect pest management. In this report, we present examples of how combinations of microcontrollers with extremely sensitive piezoelectric devices or inexpensive microphone systems can be used for auralization, storage, and digital signal processing of insect sounds in trees in field environments. Progress also is occurring in the development of Matlab and other software to automate and optimize the discrimination of insect sounds from background noise on microcontroller platforms. Further development of these hardware and software tools has potential to expand the applicability of early detection technology so that it is not just useful for research but becomes a widely used tool for RPW pest management.

Keywords: behavior, spectral fingerprint, microcontroller, scouting, mapping.

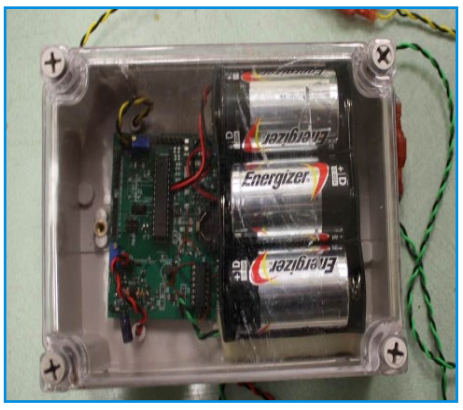
1. Current acoustic detection technology

Because RPW larvae feed internally in palm tree trunks, they are difficult to detect in palm groves before the occurrence of economic damage, and infested offshoots or trees often are transported inadvertently to nearby orchards; consequently, early detection has become an important component of RPW management (Mukhtar *et al*., 2011). Acoustic technology has been used for detection of hidden RPW infestations since von Laar, 2002 and Al Manie *et al*., 2003, began investigations early in this century. All stages of large *Rhynchophorus* spp. can be detected acoustically except for the egg (Herrick and Mankin, 2012; Dosunmu *et al*., 2014).

Several different types of acoustic detection system have been used successfully to detect RPW larval sounds in the laboratory and the field, e.g. (Pinhas *et al*., 2008, Potamitis *et al*., 2009, Siriwardena *et al*., 2010, Rach *et al*., 2013, Mankin *et al*., 2016a), and automated systems have been developed that identify spectral and temporal patterns in the RPW larval feeding and movement activities which help distinguish the larval sounds from background noise (Pinhas *et al*. 2008, Mankin *et al*. 2008a,b). It is frequently observed, however, that scouts and grove managers would benefit from lower-cost, more user-friendly and more automated systems. In addition, some of the components of the originally developed systems are no longer sold, including the digital recorders previously used in field studies (Model HD-P2, TEAC Corp. Montebello, CA; and model PMD661, Marantz, Mahwah, NJ). Thus it is necessary to update recommendations continually for equipment most useful for RPW acoustic detection. To address such concerns, electronic microcontroller systems and embedded software have been developed that reduce costs and improve the user-friendliness of the acoustic detection systems.

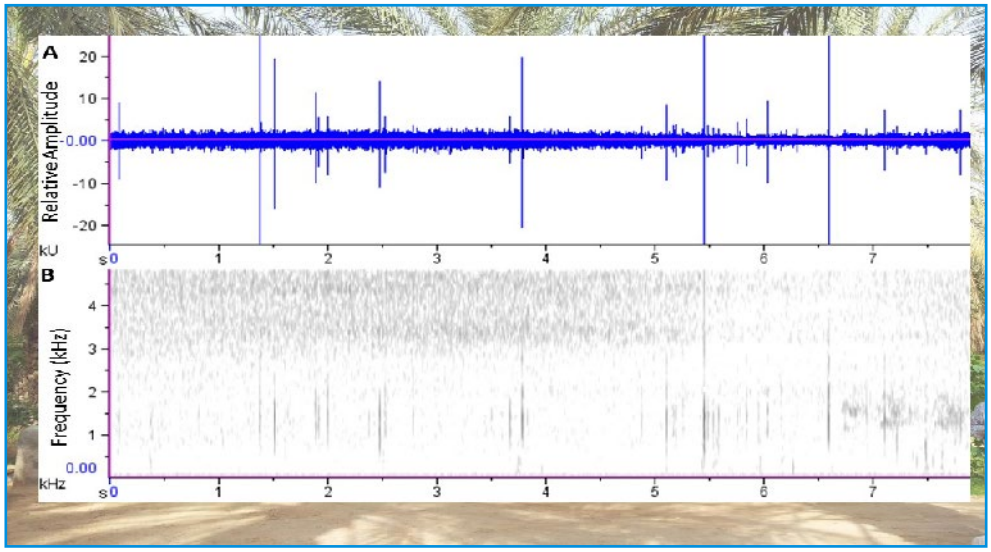
2. Novel automated microcontroller platforms for RPW acoustic detection

Figure 9. Prototype insect acoustic detector in a waterproofed box with external connections from two contact microphones



The introduction of microcontroller platforms such as Arduino Uno (Arduino Inc., Ivrea Italy) and Atmel SAMG55 (Atmel, San Jose, CA) has enabled development of low-cost detection systems that retain many features of the existing instruments while providing on-board signal processing and memory storage (Mankin *et al*., 2016b), a prototype of which is shown above in Fig. 1. In field studies with red maple trees infested with Asian longhorned beetle larvae that are similar in size to RPW (Mankin *et al*., 2008b), the effectiveness of low-cost electret microphones was compared to piezoelectric sensors that had greater overall sensitivity but much higher cost. The primary microphone was attached to the trunk near the expected location of a larva. To reduce the effects of background noise, two microphones were included in the system and signals from the second microphone, connected to the trunk about 0.5 m from the recording site, were subtracted from the primary microphone. This canceled out many background signals initiated at long distances from the recording site. Examples of sounds collected by the prototype are shown in Fig. 2.

Figure 10. Examples of vibrational signals recorded from Asian longhorned beetle larvae (horizontal axis is scaled in seconds): A) oscillogram showing multiple impulses, B) spectrogram showing signal energy at different frequencies, with darker shades of impulses indicating frequencies of greatest energy.



The prototype system recorded and analyzed larval sounds with frequencies up to about 5 kHz with good fidelity for 10% of the cost of an AED-2010 system with digital recorder. However, the microphone was damaged easily when moving among different recording sites, and other options to improve the robustness and

ease of use of the prototype are being tested. Some of the software needed for improved automated discrimination of insect sounds from background noise can be implemented only on larger microcontroller platforms that are more costly than the current version. Consequently, it is anticipated that newer versions will include faster digital processing and more memory, and power will be consumed at a lower rate to extend battery life. Because many of the current field studies make use of Global Positioning System (GPS) coordinates for mapping of RPW infestations (e.g. Mankin *et al*., 2016a), the new devices could be made more user-friendly by including GPS features in the software. Additionally, prototypes are under construction that incorporates piezoelectric sensors, which are more sensitive to insect vibrations than the lower-cost electret microphones.

3. Other recently reported automated RPW monitoring devices

In addition to the prototype acoustic detection device, reports of other automated monitoring devices have been advertised recently or reported in journals. An example is a report from www.agrint.net about seismic, smart sensors for in-tree RPW detection. Potamitis and Rigakis (2015) reported on an automated pheromone E-trap for RPW that uses an optoelectronic sensor coupled to a microcontroller platform to sense when the insect falls into the pheromone trap and then transmits time of detection to a cell phone or network interface linked through a Global System for Mobile communications protocols. Psirofonia *et al*. (2017) reported on the use of unmanned aerial vehicles to identify visible signs of RPW infestation in palm tree plantations. Agenor Mafra-Neto of Iscatech (Riverside, CA) produces similar technology. Pontikakos *et al*., 2015, reported on a location-aware risk assessment system for management of RPW in urban areas. Real-time mapping of field-site status is offered by DroneDeploy.com (San Francisco, CA), which may be useful to identify potentially infested trees in areas without access to cloud services. All of these devices have incorporated GPS features into their software for ease of mapping infestations.

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References

Al-Manie, M. A., Alkanhal, M. I., Al-Ayedh, H. Y., and Al-Zaid H. M. 2003. Signal processing detection of acoustic emissions produced by the red date palm weevil. In: AsiaSENSE 2003 SENSOR 269-274.

Dosunmu, O. G., Herrick, N. J., Haseeb, M., Hix, R. L., and Mankin R. W. 2014. Acoustic detectability of *Rhynchophorus cruentatus* (Coleoptera: Dryophthoridae). *Fla. Entomol*. 97: 431-438.

Herrick, N. J., and Mankin, R. W. 2012. Acoustical detection of early instar *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in Canary Island date palm, *Phoenix canariensis* (Arecales: Arecacae). *Fla. Entomol*. 95:983-990.

Laar, B. 2002. The bioacoustic detection of the red palm weevil. http://www.laartech.biz/data/pdf/Red Palm Weevil.pdf; accessed on 9 April 2017.

Mankin, R. W., Al-Ayedh, H. Y., Aldryhim, Y., and Rohde, B. 2016a. Acoustic detection of *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae) and *Oryctes elegans* (Coleoptera: Scarabaeidae) in *Phoenix dactylifera* (Arecales: Arecacae) trees and offshoots in Saudi Arabian orchards. *J.Econ. Entomol*. 109:622-628.

Mankin, R. W., Mizrach, A., Hetzroni A., Levsky, S., Nakache, Y., and Soroker, V.2008a Temporal and spectral features of sounds of wood-boring beetle larvae: identifiable patterns of activity enable improved discrimination from background noise. *Fla. Entomol*. 91: 241-248.

Mankin, R. W., Rohde, B., and McNeill, S. 2016b. Vibrational duetting mimics to trap and disrupt mating of the devastating Asian citrus psyllid insect pest. Proc. Meetings Acoustics 25, 010006.

Mankin, R. W., Smith, M. T., Tropp, J. M., Atkinson, E. B., and Jong, D. Y. 2008b. Detection of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) larvae in different host trees and tissues by automated analyses of sound-impulse frequency and temporal patterns. *J. Econ. Entomol*. 101:836-849.

Mukhtar, M., Rasool, K. G., Parrella M. P., Sheikh, Q. I., Pain, A., Lopez-Llorca, L. B., Aldryhim, Y. N., Mankin, R. W., and Aldawood, A. S. 2011. New initiatives for management of red palm weevil threats to historical Arabian date palms. *Fla. Entomol*. 94: 733-736.

Oehlschlager, A. C., McDonald, R. S., Chinchilla, C. M., and Patschke, S. N. 1995. Influence of a pheromone-based mass-trapping system on the distribution of *Rhynchophorus palmarum* (Coleoptera: Curculionidae) in oil palm. *Environ. Entomol*. 24:1005-1012.

Pinhas, J., Soroker, V., Hetzroni A., Mizrach, A., Teicher, M., and Goldberger, J. 2008. Automatic acoustic detection of the red palm weevil. *Comp. Electron. Agric*. 63: 131-139.

Pontikakos, C. M., Kontodimas, D. C., and Tsiligiridis, T. 2015. A location aware system for integrated management of *Rhynchophorus ferrugineus* in urban systems. *Comp. Environ. Urban Syst*. 50:74-88.

Potamitis, I., Ganchev, T., and Kontodimas, D. 2009. On automatic bioacoustic detection of pests: The cases of *Rhynchophorus ferrugineus* and *Sitophilus oryzae*. *J. Econ. Entomol*. 102, 1681-1690.

Potamitis, I., and Rigakis, I. 2015. Smart traps for automatic remote monitoring of *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). PeerJ PrePrints doi: 10.7287/peerj.preprints.1337v1.

Psirofonia, P., Samaritakis, V. Eliopoulos P., and Potamitis, I. 2017. Use of unmanned aerial vehicles for agricultural applications with emphasis on crop protection: Three novel case-studies. *Int. J. Agric. Sci. Tech*. 5: 30-39.

Rach, M. M., Gomis H. M., Granado, O. L., Malumbres, M. P., Campoy, A. M., and Serrano Martín, J. J. 2013. On the design of a bioacoustic sensor for the early detection of the red palm weevil. *Sensors* 13: 1706-1729.

Siriwardena, K.A. P., Fernando, C. P., Nanayakkara, N., Perera K. F. G., Kumara, A. D. N. T., and Nanayakkara, T. 2010. Portable acoustic device for the detection of coconut palms infested by *Ryncophorus ferrugineus* (Coleoptera: Curculionidae). *Crop Prot*. 29: 25-29.