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Authors: Mankin, R. W., Burman, H., Menocal, O., and Carrillo, D.

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Acoustic detection of *Mallodon dasystemus* (Coleoptera: Cerambycidae) in *Persea americana* (Laurales: Lauraceae) branch stumps

R. W. Mankin^{1,*}, H. Burman², O. Menocal², and D. Carrillo²

Mallodon dasystemus Say (Coleoptera: Cerambycidae: Prioninae) is a hardwood tree pest that is native to the southern United States and Mexico (Linsley 1959; Thomas 1977). Historically, *M. dasystemus* has been reported to attack species of several different orders, including oak, *Quercus* spp. (Fagales: Fagaceae); hickory, *Carya* spp. (Fagales: Juglandaceae); willow, *Salix* spp. (Malpighiales: Salicaceae); maple, *Acer* spp. (Sapindales Sapindaceae); sweetgum, *Liquidambar styraciflua* (Saxifragales: Altingiaceae); and sugarberry, *Celtis laevigata* (Rosales: Cannabaceae) (Baker 1972; Solomon 1995; Yanega 1996). Females oviposit near the base of stressed and dying host trees, or near wounds where wood is exposed (Linsley 1959). The larvae feed briefly under the bark and then tunnel through the sapwood and heartwood (Hanks 1999), damaging the integrity of the tree structure.

Recently, *M. dasystemus* has been observed attacking avocado trees, *Persea americana* Miller (Laurales: Lauraceae), in Miami-Dade County, Florida, USA. The infestation begins in lower cut branches or the main trunk, especially in areas with sunscald injury. Larvae bore into the sapwood and heartwood making large tunnels moving downwards to the base of the tree.

Avocado is Florida's third most important fruit crop after citrus, with a farm gate value of \$21.5 million and an economic impact of \$55 million (De Oleo et al. 2014; USDA/ERS 2016). Because the larvae feed hidden inside the stump, and adult attractants have not been commercialized (Paschen et al. 2012), it was of interest to consider the potential use of insect acoustic detection devices to help survey the magnitudes and locations of *M. dasystemus* populations in commercial avocado groves, and to facilitate targeting of management efforts. Two grove owners authorized acoustic inspection of several avocado trees followed by subsequent dissection of the surrounding wood tissue to verify the presence or absence of *M. dasystemus* (target) insects or nontarget organisms. Coauthors DC and OM preselected trees for inspection that had wounds similar to those from which adults or larvae had been recovered previously. Tests were conducted primarily between sunrise (about 7:00 AM) and 11:00 AM to avoid high levels of wind and traffic noise.

The insect acoustic detection device included an AED-2010 amplifier system (Acoustic Emission Consulting [AEC], Sacramento, California, USA) previously used to detect hidden infestations of larvae in trees (Dosunmu et al. 2014; Mankin et al. 2016). A 1.6-mm screw was inserted into solid wood near the wound. The probe of a sensor-preamplifier module (SP1L, AEC, Sacramento, California, USA) was attached to it with a magnet. The sensor output connected to the AED-2010. The

system amplified the sensor signals 40 to 60 dB and saved them onto a digital audio recorder (model H2-P2 Tascam, Montebello, California, USA). In addition, signals were monitored with headphones to obtain a subjective assessment of insect presence or absence and avoid interference from background (nontarget) noise.

For this feasibility study, recordings of 50 to 110 s were analyzed from 11 trees. Raven Pro software (Charif et al. 2008) was used to identify noise-free periods containing 2 distinctive types of sound impulses representative of impulses, multiple examples of which are displayed in Figure 1A, that experienced users identified as insect-produced sounds (Mankin et al. 2011). Spectral profiles of the 2 representative impulse types were constructed using custom-written signal analysis software (Mankin et al. 2008b, 2011), 1 as an average spectrum from a 63 s period containing 64 impulses (*dualfpk*), and the second from a 47 s period containing 257 impulses (*highfpk*). The strongest background noise interference was intermittent wind that caused leaf-tapping impulses. To discriminate leaf-tapping from insect sound impulses, a wind profile was constructed from a 27 s period of wind containing 183 impulses. The profiles are displayed in Figure 1B. The spectra of impulses detected in all tree records then were matched against the 3 profiles. Impulses were classified according to the profile to which their spectra had the smallest total mean-square difference and were classified as insect impulses if their spectra matched either of the 2 insect profiles. If the smallest total mean-square difference exceeded a preset threshold, impulses were classified as unspecified noise.

The temporal patterns of insect-classified impulses were analyzed as an additional precaution to reduce misclassification of nontarget signals as insect sounds. Trains containing ≥ 6 and < 200 insect impulses separated by < 200 ms were classified as insect sound bursts based on previous studies (Mankin et al. 2008a, b) indicating that insect movement and feeding activity typically produced impulse trains in this range, but background noises usually contained shorter or longer impulse trains. An example of an insect sound burst is shown in the box in Figure 1A.

The rate of insect sound bursts, r_b , in recordings from each tree was used to estimate the likelihood that the tree was infested. The likelihood of infestation was rated high (H) if $r_b \geq 0.06 \text{ s}^{-1}$, medium (M) if $0.02 \text{ s}^{-1} \leq r_b < 0.06 \text{ s}^{-1}$, and low (L) if $r_b < 0.02 \text{ s}^{-1}$ (Mankin et al. 2008a). A Wilcoxon 2-sample test was performed using the SAS NPAR1WAY procedure (SAS Institute Inc. 2012) to determine if the distributions of infestation likelihoods predicted from burst rates were significantly different between infested and uninfested trees.

¹U.S. Department of Agriculture, ARS, Center for Medical, Agricultural, and Veterinary Entomology, Gainesville, Florida 32608, Email: Richard.Mankin@ars.usda.gov (R. W. M.)

²University of Florida, Tropical Research and Education Center, UF-IFAS, Homestead, Florida 33031, Email: dancar@ufl.edu (D. C.), hburman@ufl.edu (H. B.), omenocal18@ufl.edu (O. M.)

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

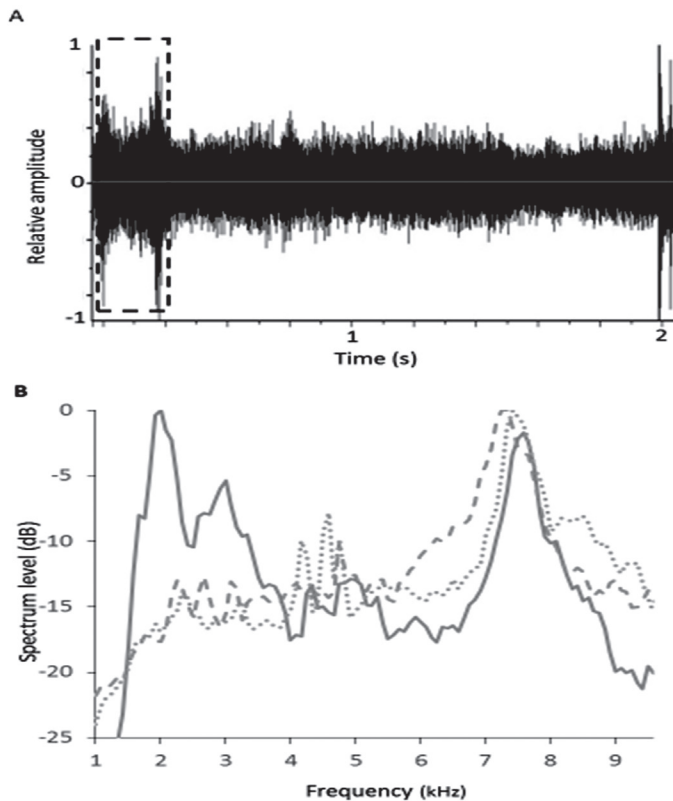


Fig. 1. (A) Oscillogram of a 2-s period with multiple impulses of different sizes and 2 different spectral types recorded from a stump where larva was recovered. Dashed box outlines an interval containing 8 impulses that was classified as an insect sound burst. (B) Spectral profiles of: *dualfpk* insect sound impulses, solid line; *highfpk* insect sound impulses, dashed line; wind sound impulses, dotted line. Spectrum level indicates the relative magnitude of signal energy at specified frequency.

The rates of insect sound bursts recorded from different trees are ranked in order from highest to lowest rates in Table 1 along with the predicted infestation likelihood and the numbers of *M. dasystemus* larvae and nontarget sound sources recovered or identified. All of the actual infestations were predicted correctly, but 1 of the 3 recordings with significant wind was a false positive for infestation. A Wilcoxon 2-sample test indicated significant differences in the infestation likelihood predictions from different trees.

Extensive tunneling was found in the branch stumps where larvae were present in these and other trees inspected during the 2017 season. Tunnels that extend into the trunk toward the base of the tree could cause considerable unseen structural damage. The findings of this study suggest that acoustic methods can be useful for surveys of *M. dasystemus* populations and damage, although care must be taken to avoid recording during periods of high background noise.

Summary

Mallodon dasystemus Say (Coleoptera: Cerambycidae: Prioninae) is a pest of hardwood trees in the southern United States that recently began attacking trees in avocado groves in Miami-Dade County, Florida. The larvae feed hidden inside the tree, and adult attractants have not been commercialized; consequently, this species is difficult to find in field environments. It was of interest to consider the potential use of insect acoustic detection devices to help survey the magnitude and locations of *M. dasystemus* populations in commercial avocado groves so that the extent of their economic damage could be estimated. An insect acoustic detection system was tested in 2 avocado groves on 11 trees suspected of harboring infestations. Four infested trees were identified and 6 were correctly classified as uninfested. One uninfested tree was classified as infested, possibly due to the occurrence of wind during signal recording. The use of acoustic methods to detect *M. dasystemus* can be of benefit in estimating its economic damage to the Florida avocado industry already facing losses from laurel wilt, caused by *Raffaelea lauricola*, Harrington, Fraedrich, and Aghayeva (Ophiostomataceae), vectored by redbay ambrosia beetle *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae) (Ploetz et al. 2017), and *Fusarium* (Hypocreaceae) dieback, vectored by *Euwallacea* nr. *forficatus* (Coleoptera: Curculionidae) (Carrillo et al. 2016; Kendra et al. 2017).

Key Words: avocado, hardwood stump borer, survey, cryptic infestation

Sumario

Mallodon dasystemus Say es una plaga de árboles de madera dura en el sur de los Estados Unidos que recientemente comenzó a atacar árboles en las plantaciones de aguacate en el condado de Miami-Dade, FL. Las larvas se alimentan de manera oculta dentro del árbol y los atra-

Table 1. Number of *Mallodon dasystemus* larvae and other sound sources recovered or observed at different avocado trees, rates of insect sound bursts, and predicted likelihood of tree infestation by *Mallodon dasystemus*.

Tree	No. larvae	Nontarget sound sources	r_b (bursts per s)	Likelihood ^a
1	1	—	0.140	H
8	2	—	0.069	H
2	2	—	0.043	M
11	1	lizard	0.038	M
5	0	wind	0.118	H
6	0	wind	0.015	L
3	0	1 click beetle, 1 roach, 1 Scarabaeid	0	L
4	0	1 spider	0	L
9	0	—	0	L
7	0	—	0	L
10	0	wind	0	L

^aWilcoxon 2-sample test comparing infestation likelihood values for infested and uninfested trees, sum of scores = 35, $P = 0.0284$.

yentes adultos no se han comercializado; en consecuencia, esta especie es difícil de encontrar en ambientes de campo. Fue de interés considerar el uso potencial de los aparatos de detección acústica de insectos para ayudar a estudiar la magnitud y la ubicación de las poblaciones de *M. dasystomus* en las plantaciones comerciales de aguacate, de manera que se pueda estimar el alcance de su daño económico. Se probó un sistema de detección acústica de insectos en dos plantaciones de aguacate con 11 árboles sospechosos de tener infestaciones. Se identificaron cuatro árboles infestados y 6 se clasificaron correctamente como no infestados. Un árbol no infestado se clasificó como infestado, posiblemente debido al viento que sucedió durante el registro de la señal. El uso de métodos acústicos para detectar *M. dasystomus* puede ser beneficioso para estimar su daño económico a la industria del aguacate de la Florida que ya enfrenta pérdidas por marchitez de laurel, causada por *Raffaelea lauricola* Harrington, Fraedrich y Aghayeva, transmitido por *Xyleborus glabratus* Eichhoff, el escarabajo descortezador de “redbay” (*Persea borbonia*) (Ploetz et al., 2017), y muerte regresiva por *Fusarium*, transmitida por *Euwallacea cr. fornicatus* (Carrillo et al., 2016; Kendra et al., 2017).

Palabras Clave: aguacate, barrenador del trunco de madera dura, sondeo, infestación críptica

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