Automated monitoring of Olive Orchards

Ilyas Potamitis[1], Iraklis Rigakis[2]

[1]Department of Music Technology & Acoustics, Technological Educational Institute of Crete, Greece, e-mail: potamitis@staff.teicrete.gr
[2]Department of Electronics, Technological Educational Institute of Crete, Greece, e-mail: rigakis@chania.teicrete.gr

Abstract. We present an industry paper on novel insect monitoring appliances in the field of Information and Communication Technologies in Agriculture, Food and Environment. We augment typical, low-cost, plastic McPhail-type traps, with an optoelectronic sensor that identifies the incoming fruit fly from its wingbeat. The insect counts, environmental parameters, time stamps and GPS coordinates are transmitted wirelessly from the field, straight to the remote monitoring agency. We believe that smart traps that report daily the state of the infestation can, in the very near future, have a profound impact on the decision making process in crop protection and will be disruptive of existing manual practices.

Keywords: *Bactrocera oleae*, *Ceratitis capitata*, electronic McPhail trap.

1 Introduction

In the context of Integrated Pest Management (IPM), insect pest population monitoring is crucial [1-3]. The decision of taking action against pests using chemical or biological measures is based on insect population measurements. These measurements define the Economic Injury Level; the landmark point in time after which an economic damage appears. The simplest method to monitor the population of insects is through the use of insect traps that are commercially available for all common pests. Insect traps are usually plastic or glass, low-cost containers coming at different configurations and carrying a pheromone or food attractant. The cost of applying population monitoring through a network of traps is mainly due to expenses of manual practices (i.e. wages for placement of traps, scouters that report counts, zone-managers that pay attention to scouters etc.) As reported in [4], the California Department of Food and Agriculture operates a network of roughly 63000 attractant-based traps and in Israel, approximately 2600 traps monitor 20,000 ha of citrus orchards, both cases against Diptera: Tephritidae. The manual monitoring plan costs millions of Euros and is a common situation in many countries. We aim at replacing this manual monitoring procedure with an automated, cost-effective alternative.

Different types of the McPhail trap are commonly used for monitoring and/or mass trapping of insect populations of fruit flies (Diptera of the Tephritidae family). The aim of the electronic McPhail trap is to diminish the complicated chain of events

---

Proceedings of the 8th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2017), Chania, Greece, 21-24 September, 2017.

related to manual checking of a large network of traps deployed at large spatial scales. The counts of the captured fruit-flies as well as environmental parameters and GPS coordinates of the trap are transmitted daily through the mobile network straight to a central monitoring agency. The central agency can then proceed in the visual assessment of infestation maps constructed out of interpolating the counts delivered from the traps. An automated surveillance network is expected to increase credibility of data, significantly reduce labor costs related to manual scouting, allow timely gathering of data and reliable situation assessment. The cost of the trap is currently around 60 € (12/04/2017) for bulk orders and is power sufficient for two months using rechargeable batteries. In this work, we focus on the industrial characteristics of the electronic McPhail trap. We elaborate on the design of the trap, its mechanical components and the assembly and test of the functional prototypes of these traps currently used for laboratory and field tests.

2 Description of the electronic McPhail Trap

The technical details of the optoelectronic sensor system are described in [6-8]. The housing of the electronics is placed on top of the trap. Fig. 1, illustrates all the control and processing electronics of the optical sensor. The case is waterproof and made of white Plexiglas® XT to protect the electronic components against direct sunlight. In Fig. 2-3 one can see different views of the industrial version.

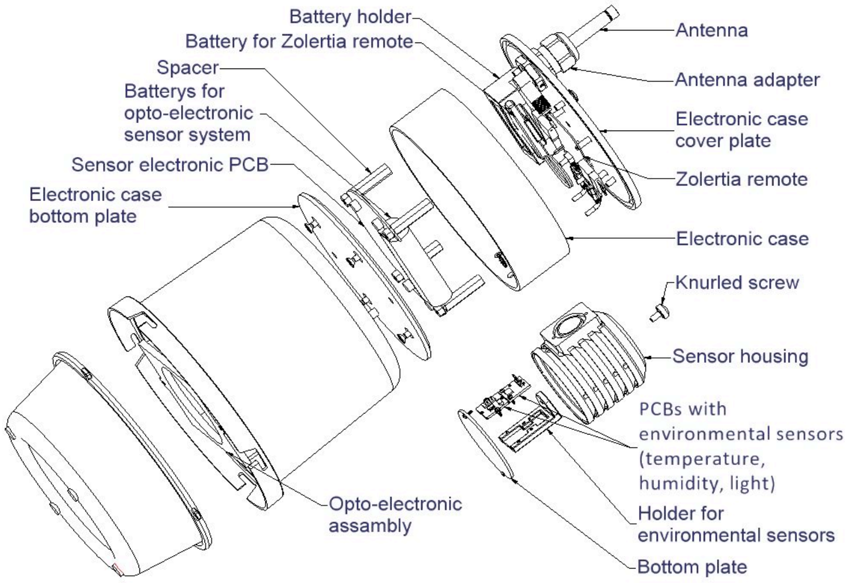

Fig. 1 CAD design of the electronic McPhail trap.

Fig. 2 (LEFT) Embedded electronics. (RIGHT) The electronic McPhail trap.

Fig. 3 Mass production of the electronic McPhail trap has started.

We cover the walls of the McPhail traps in Fig. 3 with a transparent sheet of plastic on which we apply a transparent thin layer of glue. As a means for verification data, to validate the automatic counting module, we compare the insects' stack in the glue and the reported results on the server. We further examine the recordings that are stored in the SD card to assess the situation. See also Table 1.

Table 1. Open access videos demonstrating the functionality of the electronic trap.

LINKS	DESCRIPTION
https://www.youtube.com/watch?v=IdWVaCyHEVI	The Electronic McPhail Trap
https://www.youtube.com/watch?v=7-bKiarPlPs	In Lab Experiments

3 Inside the trap – Looking at the recordings

Section 3 is directed to the generally knowledgeable and interested reader, therefore, the description is non-technical. In this section we visualize what the recordings in the SD card of the trap look-like so that the reader can have a view of the internal process. The top picture is a typical recording of a *B. oleae* taken from the SD card of the electronic trap. We know that is *B. oleae* positive because we released a number of them below the trap and this one entered flying-in. In the second figure we see the spectrum of the wingbeat (i.e. which frequencies constitute the ‘signature’ of the wingbeat in the frequency domain). The mountain-like structure is typical of an oscillatory movement. The first peak is the wing-beat frequency corresponding to the so-called fundamental frequency (f_0). One can see that is located at 200 Hz as expected. This figure is a typical situation of the spectral pattern originating from a *B. oleae*. In [8] figure 5, one can verify in another set of recordings that the wingbeat of *B. oleae* is a consistent, repeatable and identifiable pattern. The peaks numbered 1-5 are the so-called harmonics f_1-f_5 approximately at integer multiples of f_0. One can see that the detection algorithm attributes a high SNR value to this recording, much higher than 0. The zero threshold is the one under which a recording is classified as non-*B.oleae* (i.e. is rejected as being *B. oleae*).

The third in row figure is a recording of an insect flying in the trap but not *B. oleae*. One can again see the structure of a wingbeat (i.e. multiple peaks in the frequency domain at integer multiples of a fundamental frequency). Note in the 4th in row figure that the fundamental frequency is around 130 Hz and this is impossible for *B. oleae* the beats its wings around 200 Hz. Note that the detection algorithm attributes <0 SNR to this recording and, therefore, rejects the signal as originating from *B. oleae* although it is a perfectly valid wingbeat signal. Last, in the two figures at the bottom we have the case of an interference. We know that as there is no wingbeat structure in the signal. The recording cannot be originating out of any insect, as there is no oscillation. Instead we see a shock-pulse. Note that the algorithm attributes a large value below zero and confidently rejects the signal as originating from *B. oleae*.

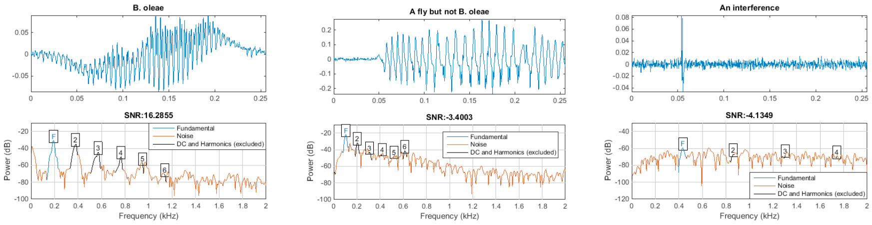

Fig. 4 The harmonic detector applied to recordings of the e-trap (Left) A True positive case. Note the fundamental at 200 Hz. SNR calculation according to the process in Section 3. (Middle) a non-target signal rejected (SNR<0) for not having the f0 and its associated harmonics in the spectral area where *B. oleae* is expected. (Right) a rejected interference (SNR<0).

4 Field results

In this paragraph we present manually verified counting results of all 5 traps deployed in the field in the island of Crete in Greece. The experiment took place in 1-12 July 2017, using 5 Entomatic electronic traps (see Table 1). The numbers correspond to flies-only (manually counted flies against reported number of flies). During July 2017 in Crete, the temperature was quite high and we did not encounter *B. oleae* in the traps. The pheromone traps (*B. oleae* pheromone dispenser NOVAGRICA inc.) have been found empty. The device has been switched to higher frequencies to count flies in general and food-attractant based on gel and hydrolysable protein. The following are some random files from the SD card. The symbol 'T' denotes Temperature and can be see that the temperature was quite high (as regards our examples 37.6, 42.4, 43.1 ^{o}Celsius). Note also the extremely low humidity sensor readings denoted with symbol 'H'. This may explain the fact that we did not encounter *B. oleae* in the trap at all, and we therefore switched the algorithm to detect flies in general. Therefore, results focused on *B. oleae* only are pending.

F170709_102816_0017_T37.6_H21.3
F170709_120334_0022_T42.4_H15.5
F170709_120154_0021_T43.1_H15.0

Table 2. Summarization of results of all traps deployed in Crete-Greece, in July 2017.

#	LOCATION	GPS	TRUE*	REPORTED
1	FANEROMENI	Lat:35.0732651, Lon:24.8377113	71	67
2	CHANIA	Lat: 35.50775644 Lon: 24.0046709	106	126
3	ASTRIKAS	Lat:35.471774, Lon: 23.747486	135	117
4	SITIA 1	Lat: 35.194653, Lon: 26.110065	212	202
5	SITIA 2	Lat: 35.194653, Lon: 26.110065	142	119

*Manual counting of flies trapped in the glue of the trap.

5 Discussion

We have been observing the traps in the field for several months. Hereinafter, we summarize our observations regarding their operation in the field:

- The trap does not report false alarm due to sun or other reasons. Although triggering from non-insect sources occurs at low rates, the recordings produced by false alarms are successfully rejected by the frequency analysis of its content. Triggering due to sun appeared only during the hot months of summer.
- The trap has sustained bad weather condition including rain and strong winds without malfunctioning.
- The detector of the trap discerns the wingbeat of insects and is able to lock on a specific wingbeat pattern.

- There is a very close correlation between insects found trapped inside and insects counted automatically.
- At its current form, the trap can attract and count flies quite reliably. It can further focus to *B. oleae* only if a suitable pheromone attractant is applied or in orchards where *B. oleae* is dominant among other flies.
- The device offers the possibility of transmitting the wingbeat snippet to be classified on a server. In such case, and as reported in [8], there is encouraging evidence that we could discern *B. oleae* even with the use of a general purpose food-bait. This is not investigated yet due to time constraints.

Acknowledgments. We acknowledge Dr. Frank Spiller from the institute for Microelectronic and Mechatronic Systems in Germany (IMMS) for manufacturing the housings of the trap and granting permission to use Fig. 1. This research was funded by EU under grant agreement n° 605073 project ENTOMATIC.

References

1. Oerke, E.C., Dehne, H.W., Schönbeck, F., Weber, A., (1994). Crop Production and Crop Protection: Estimated Losses in Major Food and Cash Crops. Elsevier Science. Amsterdam.
2. Flint, M. L., & Van den Bosch, R. (2012). Introduction to integrated pest management. Springer Science & Business Media.
3. Pedigo, L. P., & Rice, M. E. (2014). Entomology and pest management. Waveland Press.
4. E. Goldshtein, Y. Cohen, A. Hetzroni, Y. Gazit, D. Timar, L. Rosenfeld, Y. Grinshpon, A. Hoffman, A. Mizrach, Development of an automatic monitoring trap for Mediterranean fruit fly (Ceratitis capitata) to optimize control applications frequency, Computers and Electronics in Agriculture, Volume 139, 15 June 2017, Pages 115-125, ISSN 0168-1699, https://doi.org/10.1016/j.compag.2017.04.022.
5. Potamitis I, Rigakis I, Fysarakis K (2015) Insect Biometrics: Optoacoustic Signal Processing and Its Applications to Remote Monitoring of McPhail Type Traps. PLoS ONE 10(11): e0140474. doi: 10.1371/journal.pone. 0140474.
6. Potamitis I.; Rigakis I. (2015). Novel Noise-Robust Optoacoustic Sensors to Identify Insects through Wingbeats. IEEE Sensors Journal, 15, no.8, 4621, 4631, Aug. 2015, doi: 10.1109/JSEN.2015.2424924.
7. Potamitis I.; Rigakis I. (2016). Large Aperture Optoelectronic Devices to Record and Time-stamp Insects Wingbeats, IEEE Sensors Journal, 16, no. 15, pp. 6053-6061, Aug.1, doi: 10.1109/JSEN.2016.2574762.
8. Potamitis, I.; Rigakis, I.; Tatlas, N.-A. Automated Surveillance of Fruit Flies. *Sensors* 2017, *17*, 110.