Proceedings of the Eleventh International Conference on Urban Pests 2025
AF-Borgen, Academic Society, Lund, Sweden
William H Robinson, editor

SOME ARE BORN GREAT COUNTERS, SOME ACHIEVE GREAT COUNTING, AND SOME USE A.I.

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Abstract Insect Light Traps (ILTs) have been extensively used in food manufacturing sites for monitoring insect activity through fly catch analysis. This is a necessary but laborious task that requires a highly skilled technician to analyse the insect catch. A digital counting system has been developed to conduct the fly catch analysis without requiring the technician to be on-site and allowing analysis at any time. To be implemented by the pest management industry, the solution needs to be as accurate as human counts and improves the working conditions of a technician or company. When assessing if a digital count can be as accurate as humans, the digital system was able to perform as well when counting during daylight settings. There is also a range of methods technicians will use to count the insects, varying in accuracy and precision with some technicians choosing the most time-efficient method. When counting the same glue board, total insects caught had a wide variability depending on the method used. This highlights that data generated from fly catch analysis in the field will vary significantly depending on the technician.

Key words Light trap, monitoring, digital

INTRODUCTION

Fly catch analysis of Insect Light Traps (ILTs) is a requirement of a pest management programme in food, drink and pharmaceutical manufacturing. Performed a minimum of four times per annum but usually recommended weekly or monthly depending on the site risk level, the technician removes the glue board (or, catch tray) to count the number of insects in a specified group. Typically, insects are grouped into the following categories: house flies, blow flies, fruit flies, phorid flies, filter flies, SPI beetles, SPI moths, night flying insects, occasional intruders and more (Acheta, 2014; McCloud, 2015). Through categorising the insects and using knowledge of pest biology and behaviour, technicians can quickly identify the breeding source - whether inside or outside the facility - and highlight the measures that need to be implemented to lower insect counts.

With the onset of new developments in technology, there is now the possibility to conduct fly catch analysis without human physically being on site, potentially change standard practices across the industry. Notably, insect counts could be performed remotely, and at any time which would alter the service routine currently implemented by technicians. Additionally, insect counts can be performed at shorter, fixed intervals to determine microtrends, e.g. daily to show spikes in insects being caught. Currently, there is no way to determine when an insect is caught on a glue board in a potential three-month period. Counting insects digitally would lead to more reliable counts, as there is no standard practice for counting insects, and users vary in skill. Many technicians will adopt the most time-efficient method of counting, to maximize productivity while on site. This can result in a deluge of data being produced rapidly, but this data could be inaccurate and ineffective for better pest management of the site. Human count accuracy will also be linked to size of insect and density of insects caught, lower catches on glue boards (<50 insects) will be easier to count than high catches (>250 insects). Therefore, some areas on site will be surveyed in a less precise manner.

Implementation of a digital counting system in the pest management industry relies on the system being at least as accurate and reliable as human counts, if not more. Without this, individuals will find it difficult to adapt to a new method with the upfront cost of purchasing the system. Digital fly catch analysis will have to fit traditional methods, namely it will have to be within an ILT with a glue board. Alternative methods could be developed, but these would likely require larger changes such as rewording auditing standards and contracts which would be too challenging to amend.

The digital system comprises a camera placed within an ILT. The camera captures a picture of the whole glue board. An A.I. system detects areas of contrast on the board (indicating an insect) and places a boundary box around the insect. The number of boxes their sizes - small (<5mm), mixed (5 – 7mm) size or large (> 7mm) are calculated to give the number of insects caught in different size categories. The system has the potential to detect foreign objects that are not insects such as dust, small specks of dirt, glue board patterns and therefore the system has to be trained to ignore 'noise' that could be present on the board. Currently, small, mixed and large flies are detected to help differentiate insects, as small flies typically breed within a site, while large flies breed externally. Mixed-sized insects can breed internally and externally.

The aim of this experiment was to determine if a digital counting system could count as accurately as humans. Comparing firstly different densities of insects caught on glue boards and secondly different human count methods.

METHODOS

A digital counting system, hereafter known as digital comprised of a fish-eye lens placed within an ILT (either a Cobra LED or a Halo LED) to capture an image of the glue board. Two generations of software were used to count the insects caught, see F**igure 1.**

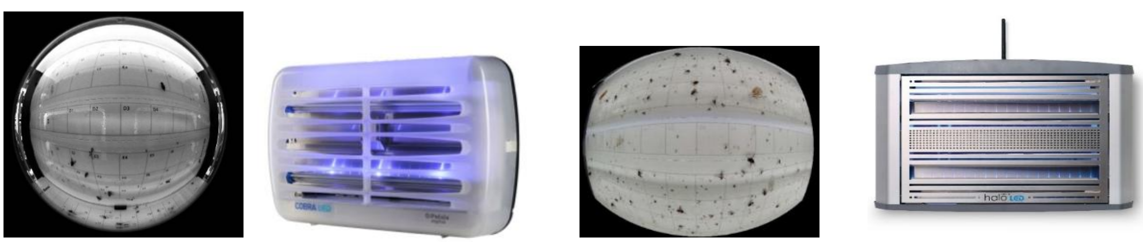

Figure 1. Left to right, image taken through camera in 1st generation software and Cobra LED, image through 2nd generation software and Halo LED

Testing involved two stages, the first analysed the impact of insect catch density on human and digital count accuracy. Three glue board densities were used throughout the test, the glue boards were of low (<50 insects), medium (100-200 insects) and high density (>250 insects). Six participants counted each glue board three times, the first counting small insects, the second mixed sized insects and thirdly large insects. The digital ILT was then asked to count a different set of glue boards six times with the same parameters. Two researchers counted each of the glue boards square by square to give the true value of insects caught, this was performed three times.

Secondly, the accuracy of the counting method by humans was evaluated and compared to digital counts, for this, participants were not asked to differentiate insect size. 10 participants were asked to perform counting from a glue board that a mixture of insects had been caught on. The participants were asked to count the number of insects caught in three ways, in the following order: **quick glance** (30 second estimation count), **quarter board + extrapolation (**the same quarter of a glue board counted and then multiplied by 4 for total board count and **full count** (all insects counted) with the time taken to count recorded. The glue board was counted by digital 10 times, a mean of the counts was taken. 3 months later (a maximum interval for the fly count analysis to take place) 3 participants were chosen to recount the glue board in the same methods.

Statistical analysis. Data was presented in box and whisker charts to display the spread of the data; accuracy was calculated by dividing the mean count by the true count. A t-test was performed on the different count methods and a paired t-test to compare counts from participants 3 months later.

RESULTS

First stage - Low density glue boards had the smallest variation in counts, all participants counted a similar number of insects for each of the size categories and out-performed digital. At medium density human counts varied substantially resulting in a wider variation than digital. At high density glue boards both humans and digital had a wide variance of counts depending on the size of insects counted, see **Figure 2.**

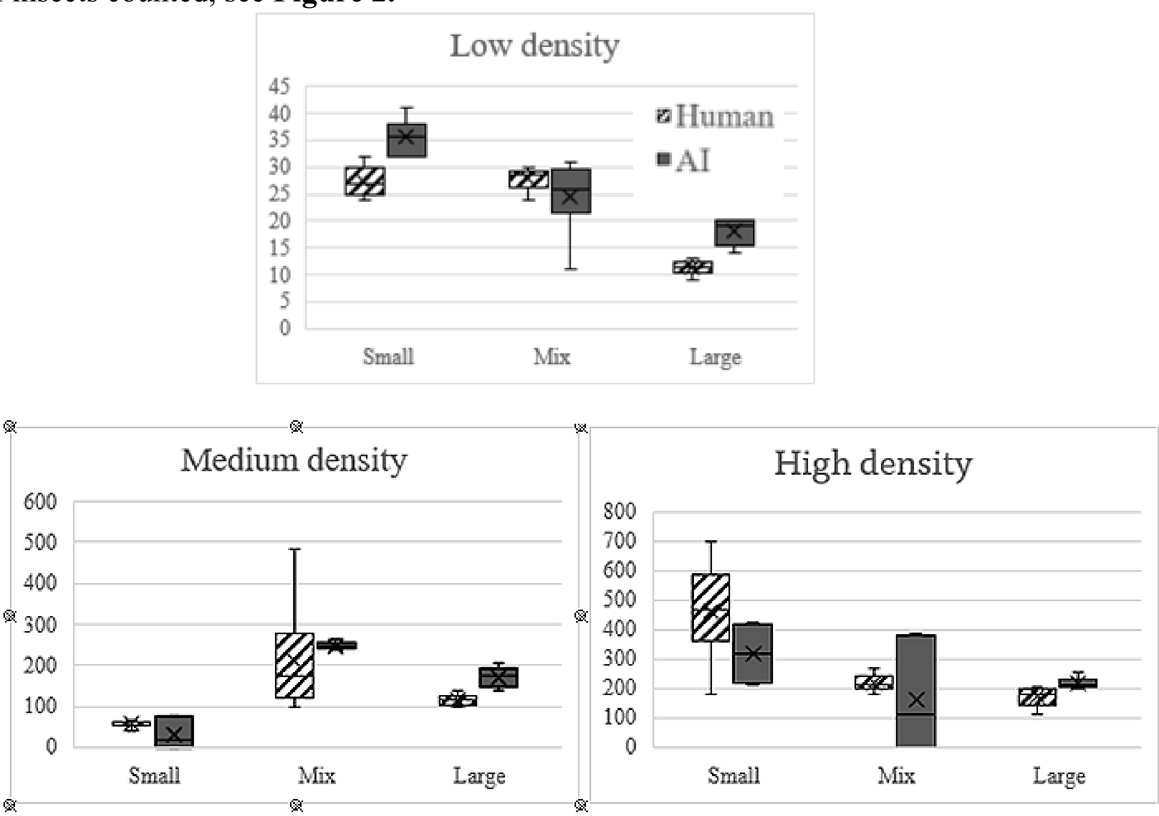

Figure 2: Human and digital counts on low, medium and high density insect catches. Counting was performed individually for small insects, mixed size insects and large insects.

Digital counts were performed at a variety of time points during the day where there were different light levels. Images captured showed that the glue board was not fully illuminated and a high proportion of insects on the glue board were not being counted. Therefore, counts taken by digital were analyzed by time of day and those falling outside daylight levels were removed. Figure 3 below shows that without these poor lighting digital counts lead to substantial decrease in the variability of the counts. Notably at high density, previously there was a large variance for the mixed sized flies (SD = 188.57) this reduced substantially with the removal of counts taken in poor lighting (SD = 4.24).

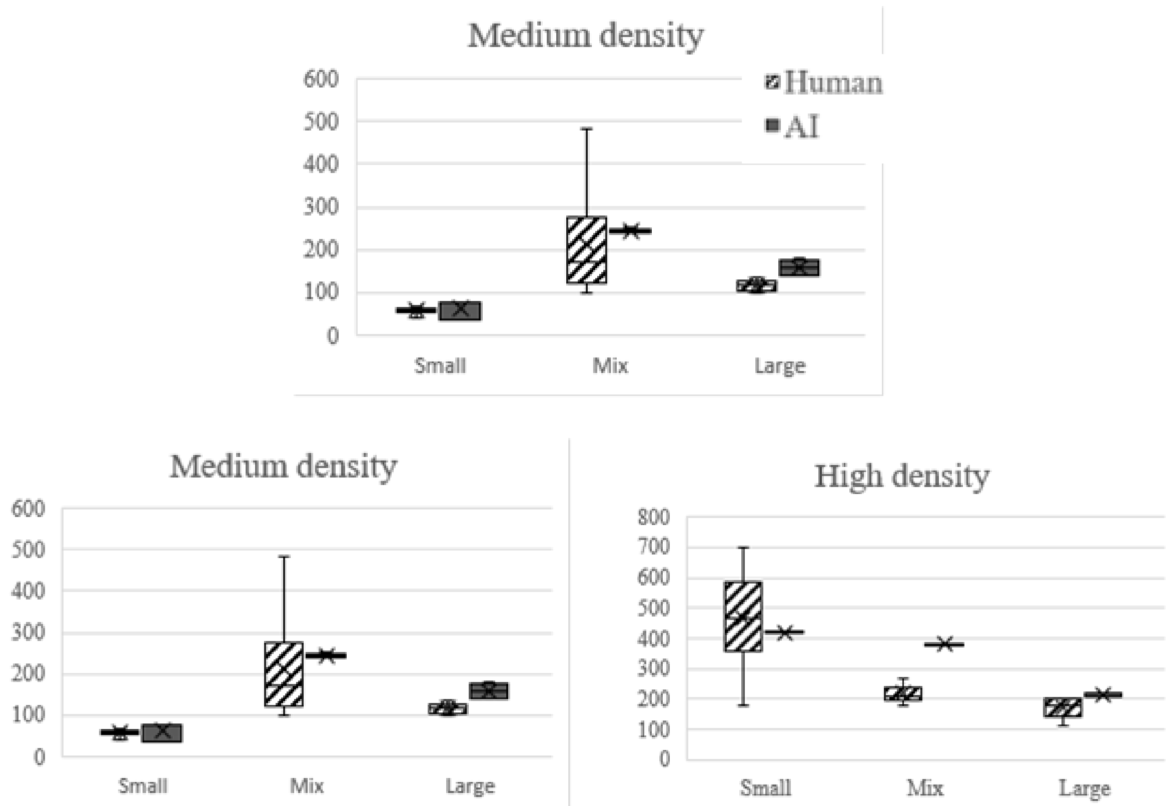

Figure 3. Human and digital counts on low, medium and high density insect catches only in daylight conditions. Counting was performed individually for small insects, mixed size insects and large insects.

Removing counts by digital performed not in daylight improved the accuracy of the counts for all different densities of fly catch on the glue board. The accuracy was calculated to be higher in medium and higher density glue boards compared to human counts. However, human counts had a higher accuracy in low density glue boards compared to digital only in daylight.

Table 1. Mean accuracy of Human, digital and digital only in daylight counts across low, medium and high-density glue boards.

Mean Accuracy	Human	Digital	Digital only daylight
Low	0.91	0.68	0.72
Medium	0.78	0.78	0.95
High	0.73	0.67	0.90

Second stage - The lowest variance in count for human methods was the full board (SD = 56.75), followed by the quarter count and extrapolation (SD = 78.25) and then the quick glance (SD = 149.92). Digital had the lowest variance overall when using the same glue board to count (SD = 24.4), **see figure 4.**

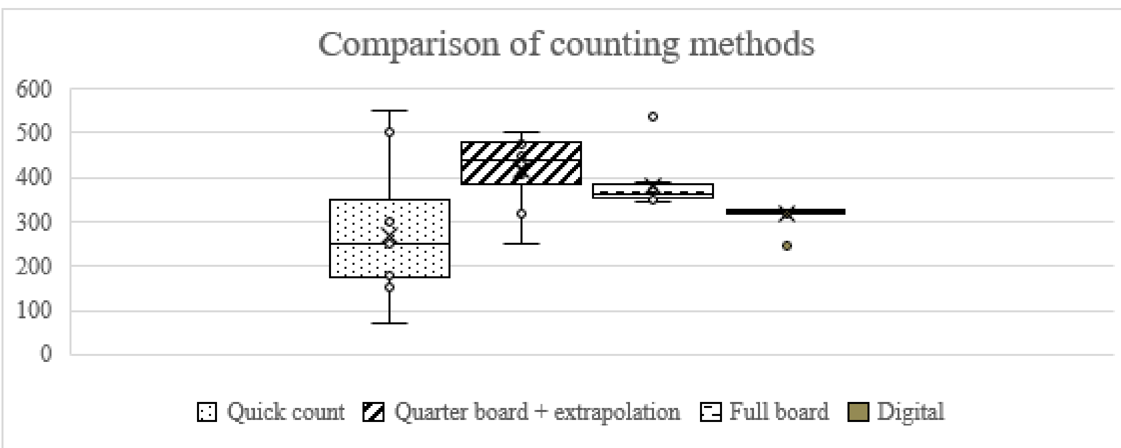

Figure 4. Human and digital counts on same glue board, humans used 3 different methods to count the number of insects.

When counters were asked to re-count the glue board 3 months later, there was no significant difference between the counts. However, human counters all increased their quick count from 3 months before, indicating there may be some residual knowledge of total number of insects caught. Total count of insects remained similar from 3 months ago, indicating that human counters have a similar skill and will count the same objects as insects as before.

DISCUSSION

The digital counting system achieved the same counting accuracy as humans on medium and high-density glue boards when counts were conducted during daylight hours. However, the system must provide an accurate count under different light settings as ILTs will be placed in areas of low and high light levels. Furthermore, many sites are operational overnight, and some pests are nocturnal, therefore, a system needs to be accurate 24/7 to detect pest activity. Counting at night can provide additional value compared to human counts, as an influx of insects could be detected overnight. Currently, human counts provide only a cumulative total over a set period, making it impossible to determine whether most insects were caught in a single day or spread over a week. A digital counting system can be programmed to an interval as short as 15 minutes to identify trends, which could also aid the technician in deploying the right management method and at the right time.

In the field, technicians deploy a range of techniques to count the insects caught on a board, here we used three common methods to analyse the accuracy of each. Unsurprisingly, this study found that the full count was most accurate method. However, due to time and space constraints, technicians will rarely perform a full count of the board in the field, as observed by the authors. Human counters took a mean time of 215 seconds (3.5 minutes) to fully count one glue board whereas, the digital system takes approximately 10 seconds to perform the same task. A limitation of this experiment was that all counters were able to sit down with the glue board in front of them. This situation is rarely available on-site, so the technician will likely opt for a less time-consuming practice with a higher rate of inaccuracy. This has unrealistically set expectations for a digital system much higher than what occurs in a real-life situation, as the assumption is that technicians always perform a full board count. Furthermore, there is still variation among individuals when they count the same glue board, even when they are given unlimited time. This can greatly influence the recorded insect activity at a site if the technician carrying out the counts is not the same each time. A digital system will provide consistent counts for every unit at every site, meaning that overall data will be more comparable and true trends can be identified.

The digital counting system needs to be reliable across a variety of sites where there will be a diverse prevalence of pests. Human counters on-site will have the advantage of observing the ILT's surroundings, which influences how they categorise the insects caught. For instance, at a fruit processing site, there will be a greater influx of fruit flies (*Drosophila* sp*)* as they are attracted by the smell. The digital system is impartial and entirely dependent on what is on the glue board. However, many small flies that look similar to the fruit fly such as *Phoridae* or *Sciaridae* species, making it more difficult for the system to categorise species than it is for a human. Nevertheless, species categorisation, is a requirement at many sites due to auditing guidelines (BRC, 2022; AIB, 2013), which may limit the adoption of a digital system, even if it is able to count more accurately than a human. The underpinning element of fly catch analysis is the analysis to improve the pest management (Acheta, 2014), therefore, total counts remain relevant for overall insect reduction on site. Furthermore, peaks in insect activity can be investigated remotely by analysing images of the glue board to categorize the insects caught for pest improvement. However, many professionals in the management industry will not adopt a digital system without species categorisation, as this is the standard practice used to comply with the auditing standards.

Information provided in auditing standards on fly catch analysis should be updated to reflect the current practices and emphasise its importance. A universal method for performing fly catch analysis reflects standard practices and allows for the inevitable future adoption of digital solutions that needs to be established. As shown in this study, counting insects on a glue board can be performed more accurately and quickly than using a digital system than humans at medium and high densities. Digital solutions also provide more valuable data, as counts can be conducted at shorter intervals and during atypical working hours, providing better visibility of the pest management on site.

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