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RELATIONSHIP BETWEEN FORENSIC ENTOMOLOGY CRIMINOLOGY: HOW BUGS ARE USED TO SOLVE CRIME

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Abstract

Forensic entomology refers to the process of retrieving, analyzing and presenting insect evidence to aid forensic investigations. The results of such forensic investigations can provide invaluable evidences in both civil and criminal cases (including matters of law enforcement, resolution of conflicts, national security etc.), and are accepted by numerous judicial systems in different parts of the world. The present paper focuses on the criminal law aspect of forensic investigations, more specifically, on the role of forensic entomology in the field of criminology.

The main role of forensic investigations in criminal cases (more specifically, murder cases) is to answer the questions of 'when', 'where' and 'how' related to the crime. However, if a significant amount of time had passed since death, and most other biological evidences become nonexistent or irretrievable, then insect evidence found from the corpse can be analyzed to find information regarding the death of the victim. This is where forensic entomology comes into the picture, which is the primary focus of this paper. The following review encompasses information regarding the history, methodology, and scientific principles of forensic entomology, its utility in criminal investigations, the landmark cases which have been solved with the help of entomological evidences, and the scope in the field for future development.

Keywords: Criminology, Forensic Science, Forensic Entomology, Criminal Investigation, Criminological Sciences, Insects, Larva(e), Maggots, Postmortem interval, PMI, Entomotoxicology.

Introduction:

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Forensic entomology, also known as "medico-legal" entomology, is the study of arthropods, especially insects, maggots, vermins, etc., which are associated with crimes. This branch of forensic sciences usually entails the task of identification of insects and other arthropods associated with remains of corpses, which are then used as an aid to determine the place and time of death. Arthropod evidence may help in discovering that the body had been moved to a secondary position/place after the death of the victim, or that the body had been disturbed at different places, either by animals, or by the murderer returning to the crime scene. However, the primary purpose or "rationale" of the study of forensic entomology is to find or determine how much time had elapsed since death. The results of these studies are then presented as evidence in the courts in criminal cases.

As we know, various factors, such as, ambient temperature and other weather conditions over the days at the crime scene following the crime are often used to ascertain the time of death of an individual. This can be taken a notch further, by correlating the information related to the aforementioned factors with the rates of development of the key arthropod species present on, or in, the corpse. These arthropods in question are usually maggots (also known as fly larva), which are considered to be the primary and secondary decomposers of animal remnants and carcasses. By knowing the developmental rates and other relevant information regarding these decomposer species at different temperatures, it is possible to quite accurately estimate the time of death of an individual more often than not.

The location where a crime took place sometimes may be different from the site where the body of the victim is discovered. This piece of information can sometimes be determined based on the presence of unique arthropods with known distributions that are not found in the area where the body was discovered. Similarly, careful study of collected insect evidence can help in solving other crimes such as, sources of vehicles and other accessories used in crimes, the origin of drug shipments, etc. Such information can be deduced from the characteristic geographic distributions found from arthropod evidence.

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Research Questions:

Some questions of utmost importance which are always asked while conducting a forensic entomological research, and the answers to which have been discussed in details in this paper, are as follows:

(i) What is the postmortem interval of the deceased, and how can it be deduced most accurately?
(ii) How to identify the variable factors which determine the results of PMI and minimize errors as much as possible?
(iii) How to preserve the insect samples collected from the body of the deceased for longer periods of time to allow forensic experts more time for their work?

BRIEF HISTORY OF FORENSIC ENTOMOLOGY:

Though the references of a field of science resembling forensic entomology could be found in historical texts from as far back as the early 13th century, the concept of forensic entomology, as a tool for solving crimes, is fairly new. The first documented case of forensic entomology was chronicled by one Chinese lawyer/investigator named Sung Tz'u, who wrote about the same in his book named, "Hsi Yuan Lu" (translated in English as "Washing Away of Wrongs" or "Instructions To Coroners").[2] In that book of his, Mr. Tz'u recounted a particular peculiar event in his career, where he used flies to catch a murderer. A man's dead body had been found near a rice field. He had been stabbed to death. The next day, Mr. Tz'u gathered all probable suspect and asked them to produce their farming tools for examination. Though no direct evidence could be found, after some time, flies started swarming around one of the tools. These flies were the same ones which were found on the dead body. This led to the investigator right to the murderer, who later confessed to his crimes.

While this case laid the groundwork for future developments in the field of forensic entomology, no further documentation related to the subject could be found in the subsequent years. It only gained some semblance of prominence in the late 19th, and played a significant role in some very major cases in the late 20th century. The first

[2] O'Neill, Y., Chan, G. (1976) 'A Chinese Coroner's Manual and the Evolution of Anatomy', *Journal of the History of Medicine and Allied Sciences*, 31(1), p15-16.

modern case related to forensic entomology was recorded in the year 1855, in which a French physician named Louis François Étienne Bergeret (now referred to as the "father of forensic entomology") used the insects found on the corpse of the child victims to pinpoint the time of their death correctly, which led the investigators right to the door of the murderer.[3]

However, apart from a handful of famous cases here and there, the use of forensic entomology in criminal investigations was not a common practice till the late 20th century. A sharp rise in popularity and increase in usage of forensic entomology in police investigations only occurred in the past 30-40 years.

STAGES OF DECOMPOSITION:

The process of forensic entomology can only begin once the process of decomposition is completed, which can broadly be divided into five stages. They are as follows:

(i) **Fresh stage**: This stage lasts for the first two days after the person dies. It starts from the moment of death, and ends when bloating begins. Insects begin getting attracted to the body around 10-15 minutes after death, but they do not begin the process of laying eggs till much later. Significant morphological changes are usually not observed during this stage. However, the chemicals released by the body during this stage are important in drawing the insects closer.

(ii) **Bloated stage:** This stage begins right after the 'Fresh Stage' ends and continues till the 7th day after death. Putrefaction starts during this time. Activities of anaerobic bacteria cause an excess production of gases in the body, which leads to the body getting bloated. This, combined with arthropod activities in the body causes the temperature of said body to rise. This stage mainly attracts a large number of Diptera larvae, which can easily be recovered by the beginning of Day 2.

(iii) **Decay stage:** This stage lasts from the 7th till the 13th day since death. During this stage, the abdominal wall gets penetrated, which results in deflation, and puts an end to the bloated stage. Temperature rises to about 10-14 degrees, before coming down eventually by the end of this stage. The carcass biomass are then converted into dipteran larval biomass, which then escape from the carcass to pupate.

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[3] Michaud, J., Schoenly, K., Moreau, G. (2015) 'Rewriting ecological succession history: Did carrion ecologists get there first?', *The Quarterly Review of Biology*, 90(1), p50.

(iv) Post-decay stage: Begins roughly around Day 10 and extends up to Day 23. This stage begins once the dipteran larvae depart from the carcass, leaving behind a huge amount of material which is known as 'byproducts of decay' (BOD).

(v) Dry stage: This is the very last stage of the process of decomposition, and lasts from Day 20 to Day 90 since death. By this time, the BOD is supposed to have dried up, leaving behind only dry bones. The transition from Post-decay to Dry stage is the slowest amongst all the stages.

TYPES OF INSECTS USED IN FORENSIC ENTOMOLOGY:

When death occurs, the cells in the body of the victim start decomposing (or digesting themselves inside out) through a process called autolysis. The soft tissue of the gastrointestinal tract starts getting destroyed by a mixture of fluids like carbon dioxide, hydrogen sulphide, sulfur dioxide, ammonia, methane etc. Molecules known as 'apeneumones' escaping from the body attract arthropods.[4] Such molecules, escaping at different stages of body decomposition, can be isolated and separated by experts. Said molecules can influence insect behaviour.[5] For example, sulfur-based compounds usually attract flies to decomposing corpses, whereas ammonuim-rich compounds induce them to lay eggs, i.e., influence the oviposition of said insects.[6]

According to popular research, insects found on decomposing corpses can broadly be divided into four categories:[7] (I) Necrophages, that is, the species of insects that feed on carcasses (II) Parasites or hunters/predators, the species that feed on the aforementioned necrophagous species (III) Omnivores, that feed on both carcasses and insects like wasps, ants etc. (IV) Incidentals, i.e., the other species like arachnids and springtails that sometimes make carrions their habitats.

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[4] Joseph, I., Mathew, D. G., Sathyan, P., Vargheese, G. (2011) 'The use of insects in forensic investigations: An overview on the scope of forensic entomology', *Journal of forensic dental sciences*, *3*(2), p89–91.

[5] Michaud, J.P. (2015) 'Rewriting Ecological Succession History: Did Carrion Ecologists Get There First?', *The Quarterly Review Of Biology,* 90, p60-62.

[6] Weidner, L., Tomberlin, J., Hamilton G. (2014) 'Development Of Lucilia Coeruleiviridis (Diptera: Calliphoridae)*'*, *The Florida Entomologist*, 97, p849-851.

[7] McNeil, J. (2010) 'The Ecology of Death: Forensic Entomology as a Teaching Tool*', The American Biology Teacher*, 72, p153-155.

The first two types of insects are found to be primarily important for the purpose of forensic entomology. The most important ones amongst them are beetles (coleoptera) and flies (diptera). The predominant species amongst flies are: house flies (muscidae), blow flies (calliphoridae) and flesh flies (sacrophagidae).[8] Blow flies and flesh flies are usually the first ones to arrive as soon as the corpse starts decomposing. House flies arrive much later (during the bloated stage of decomposition). These flies lay eggs in usual openings or wounds of the body, which then hatch to produce a larvae called maggots. These maggots then start feeding, and once that is done, they migrate to drier places to begin pupariation.[9]

METHODOLOGY AND DISCUSSION:

In this sub-division, we attempt to discuss the "research questions" which were mentioned earlier, i.e., try to analyse the methods of forensic entomology which are widely practiced, talk about the variable factors which determine the results of PMI, and discuss methods of preserving insect samples for longer periods of time.

(I) **Methods of forensic entomology**:

There are mainly two main steps involved in carrying out studies of forensic entomology. First step is called the Principle Component Analysis (PCA). It is a statistical comparison based upon 365 cases of each species. It is used to describe statistical unit of each species. Second step involves analysis of 86 cases with verified PMI using the Wagner parismony method.

A. Principle Component Analysis (PCA)[10]: This is a method of analysis in which the oldest development stages of each species is sampled as a function of the oldest development stage observed of a typical group. Three stages are taken into consideration for this: larva, pupa, and puparia. The first one (larva) is considered to

[8] Caneparo, M., Fischer, M., Almeida, L. (2017) 'Effect of temperature on the life cycle of Euspilotus azureus (Coleoptera: Histeridae), a predator of forensic importance', The Florida Entomologist, 100(4), p795-801.
[9] Id.
[10] Jolliffe, I. T., & Cadima, J. (2016) 'Principal component analysis: a review and recent developments', Philosophical transactions. Series A, Mathematical, physical, and engineering sciences, 374(2065), [online]. Available at: https://royalsocietypublishing.org/doi/10.1098/rsta.2015.0202 (Accessed: 02 February 2015).

be the active stage of immature development. The second stage (pupal or nymphal stage) is labeled the very opposite of the previous stage, i.e., the passive stage of immature development. Last stage (also known as exuvia stage) represents the end of the development cycle. Among these species which were taken into consideration, the oldest immature specimen of each species was noticed case by case. Next, the oldest developmental stage of the 'typical group' is identified. Thereafter, the development stages of the sampled species are compared taxa by taxa to each of the development stages of the 'typical group'. This helps in identifying the rate of presence of the species. They are then statistically analyzed by the descriptive method of the principal component factor analysis (PCFA).[11]

B. Wagner Parsimony Analysis: The principle aim of application of Wagner Parsimony Analysis to synecology is to find an hierarchy of a set of 'objects' based on the presence or absence of certain characters. In the present case, the object in question are cadavers and the classification is done on the basis of presence or absence of certain taxas. Three stages are taken into consideration: '0' for absence, '1' for presence of living immature stages, and '2' for presence of mature stages signifying the end of the development cycle. These guidelines are following while examining cadaver samples, and the data collected is then represented in the form of a character matrix.[12]

(II) Factors which influence PMI:

Some factors which help in determining Postmortem index are as follows:

A. Rigor Mortis: Rigor mortis refers to the contraction of muscles and sudden stiffening of the body after death. This happens due to the presence of two fibres (actin and myosin), and a substance known as adinosine triphosphate (ATP) in the body. Rigor becomes visible in body 2-6 hours after death. After a while, it disappears as well once the cells in the dead body start decomposing. The period of time it takes

[11] Siljic, M., Salemovic, D., Jevtovic, D. (2014) 'Forensic Application Of Phylogenetic Analysis – Exploration Of Suspected Epidemiological Linkage', *BMC Infect Diseases*, 14, p1471-2334.
[12] Id.

for a body to develop rigor, as well as the time it takes for it to wean itself off of it, are both intrinsic factors in determining the PTI, i.e., the time of death of a person.[13]

B. Livor Mortis: Liver mortis refers to the discoloration or blanching of a body after death. It occurs about 30 minutes to an hour after the time of death. This happens when the heart stops pumping blood into the veins and the blood begins to settle down in the lower parts of the body due to gravitational force. It gains more and more prominence and becomes more visible over time. Observing the extend of discolouration can provide valuable insight to a pathologist in determining the time of death of an individual.[14]

C. Algor Mortis: Algor mortis refers to the phenomenon of the cooling down of the body following death. Under ideal circumstances (considering the temperature of the surroundings to be between 70-75 degree Farenheit), the temperature of the body drops by 1.5 degree Farenheit every hour. Hence, temperature of the body must be measured as soon as one arrives on the scene, and consequently after every one hour later on. With the help of these readings, immense clues can be deduced which help in estimating the time of death, also known as the PMI.[15]

D. Advanced decomposition: Rigor mortis, algor mortis, and ligor mortis can only be used to determine PMI when the body is recovered within 2-3 days of death. However, if the body is recovered while in the late stages of decomposition, the same methods cannot be used. In such circumstances, two other processes, known as Putrefaction[16] and Autolysis[17] are used to determine PMI. Two other notable factors which help in determining time of death of body in late stages of decomposition are adipocere and mummification. In all these processes, observation of the bacterial growth can give an indication of the PMI.

(III) Methods of preserving insect samples for longer periods of time:

The success rates of entomological studies depend greatly on proper collection and preservation of insect samples. Proper techniques must be utilized for preserving said

[13] Shedge, R., Krishan, K., Warrier, V. (2020) 'Postmortem Changes', *Treasure Island (FL),* [online]. Available at: https://www.ncbi.nlm.nih.gov/books/NBK539741/ (accessed: 27 July 2020).
[14] Id.
[15] supra, note 12, at 8.
[16] Pennington, E. (1978) 'Postmortem Care: More than Ritual', *The American Journal of Nursing*, 78(5), p846-847.
[17] Id.

samples. Collection must be done at the earliest possible notice, otherwise the adult insects may start leaving the site. After collection is done, proper methods must be used to retain the samples indefinitely for tests to be conducted later on. In order to do that, the samples are placed in a solution of ethanol and water (at 7:3 ratio)[18]. Collection must always be done using forceps or fingers while wearing surgical gloves. Direct touch must be avoided to prevent contamination of samples. Air tight plastic bags must be used for sealing the samples. Careful analysis of soil beneath the insect samples is also important, and hence, soil samples must also be collected along with insect samples. All such samples must be sealed in plastic bags and refrigerated till they are to be tested by trained pathologists or forensic experts. Samples of immature, or soft-bodied insects must be divided into two parts, as they are especially important for forensic analysis. One part must be preserved immediately (for future use), while the other must be saved alive for rearing of adult insects. In order to preserve the sample, the same 7:3 ethanol-water solution can be used as mentioned previously. Samples of marine and aquatic plants are animals can be best preserved in a solution of 10% neutral buffered formalin.[19] The containers containing these samples must always be kept in well-ventilated, cool environments. In addition to all that, a chain of well documented legally acceptable evidence possession (including information such as: date, time, location of collection, area of body infested, name of collector etc.) must continuously be maintained.

SIGNIFICANCE AND UTILITY OF THE STUDY:

(i) Sometimes, the place where the corpse is recovered from is not the place where the death took place. The presence of insects on the body which are not found in the site of recovery can indicate that the body had been moved. Careful study of the insect evidence might also help specify in which area the death took place.[20] From this, not only can the day of death be determined, but also the day of the return of the killer can be discovered.

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[18] Schiller, E., Haring, E., Däubl, B., Gaub, L., Szeiler, S., Sattmann, H. (2014) 'Ethanol concentration and sample preservation considering diverse storage parameters: A survey of invertebrate wet collections of the Natural History Museum Vienna', *Annalen Des Naturhistorischen Museums in Wien. Serie B Für Botanik Und Zoologie,* 116, p48-52.
[19] Id.
[20] Saks, M.J. (2007), 'Remediating Forensic Science'. *Jurimetrics,* 48, p119-124.

(ii) If a person had been administered drugs and/or poison or any other such chemical substance before death, then the remnants of such substances linger in the body for a significant period of time. The maggots that feed on such corpses, on toxicology analysis, would exhibit the traces of the substances that the person had consumed before death.[21] This helps the forensic experts in confirming whether any foul play involving poisons or drugs had played a role in the victim's death.

(iii) Narrowing down the area where the death took place may help to place a suspect at the scene of the crime.

(iv) Insect evidence found on the person of a living individual (usually in open wounds of a child or senior citizen) normally indicates towards abuse or neglect. This could provide significant evidence for a criminal investigation.

LANDMARK CASES SOLVED WITH THE HELP OF FORENSIC ENTOMOLOGY :

The study of forensic entomology, though relatively new, has been successfully utilized in criminal investigation and helped in convictions in many jurisdictions. Some such important case laws, in which forensic entomology played an important role, have been discussed as follows:

A. Richie v. Mullin, [417 F.3d 1117]:

In the present case, various methods of forensic entomology were used to identify the cause, time, and place of death of the victim (Mrs. Launhardt). The victim was kidnapped from the parking lot of a mart in Tulsa, Oklahoma, taken to an abandoned house in a rural area, and killed by way of strangulation. All circumstantial evidence placed Mr. Richie (the defendant) as the most probable suspect. Mr. Richie was charged with first degree murder with malice aforethought. However, the defense counsel challenged the "malice aforethought" charge on the basis of the fact that the kidnappers, though restrained, had left the victim alive. This was supported by the results of forensic entomology which established the time of death to be 19:00 on 30th August. No other evidence retrieved from the scene was inconsistent with that theory. The court admitted the results of the forensic reports regarding the time of death, but

[21] supra, note 10, at 8.

held the "left-alive" theory of the defendant to be unpersuasive. Hence, the defendant was convicted on malice aforethought murder.

B. Reference Re: Steven Murray Truscott, [(1967) SCR 309][22]:

The defendant (Mr. Truscott) had been convicted for the rape and murder of his childhood best friend (a 12 year old girl named Lynn Harper) when he was only 14 years old himself by the Supreme Court of Canada. As a result, he spent 10 years in jail and spent many more years in the shadow of an unwarranted conviction. However, results of the forensic entomology tests made it clear that the girl had been killed on the morning of 10th June, 1967, not during the narrow window of the night before when it was possible for Truscott to have committed the murder. The forensic experts proved that by measuring the size of the larvae (or maggots) found from the girl's body, which were captured in the early photographs. They found that the maggots were not nearly as large as they would have been if they had been present on the body since the early evening of June 9. Thus, after a trial that went on for almost 50 years, the courts finally declared Mr. Truscott a free man and dismissed the case.

C. Lobato v. State of Nevada, [267 P.3d 65, 68 (N.M. 2011)][23]:

In this case, an 18 year old girl, Kristin Lobato, was convicted for the assault and murder of a homeless man in Las Vegas in the year 2001. The man had been brutally stabbed and slashed multiple times, had his rectum cut open, and his penis cut off. Though there was no physical evidence tying Lobato to the case, she was booked as a suspect by the police simply because a few months prior to the case, another man had attempted to rape Kristen, from whom she defended herself by slashing his genitals. The pathologist first determined the time of death to be around an hour before discovery of the body. However, he changed his statement multiple times over the course of the trial and finally settled for the time of death to be 14 hours before discovery. Though Kristen had an almost solid alibi for the rest of the day, she could not prove her alibi during that narrow time frame that the pathologist had suggested,

[22] Dye, L. (2007) '48 Years Later, Bugs Clear Convicted Murderer', *ABC News*, 24 October [online]. Available at: https://abcnews.go.com/Technology/DyeHard/story?id=3769512&page=1.

[23] Anderson, G. (2018) 'How blow flies helped in detection of wrongful murder conviction in Nevada', *The Conversation*, 10 December [online]. Available at: https://theconversation.com/how-the-absence-of-blow-flies-overturned-a-wrongful-conviction-107865.

and hence, she was convicted. The case was overturned due to errors, and reopened again a few years later. At that point, another pathologist was recruited, who noticed the lack of insect evidence on the body of the deceased. This led him to deduce that the body had been retrieved not 14 hours after death, but immediately after it. For that time frame, Kristen had an alibi, and thus, she was acquitted solely on the basis of entomological evidence (or more specifically, the lack of it).

D. State v. Neal, [1 Utah 2d 122, 262 P.2d 756]:

In this case, the defendant (Kevin Neal) had reported that his step-children had been missing in the year 1997. After investigations took place, the bodies of the two children were found in the neighborhood's cemetery. The cause of death was found to be asphyxiation, and Mr. Neal was booked as a prime suspect. However, Mr. Neal's argument was that he had been in jail (for another unrelated crime) when the children went missing. Therefore, he could not have possibly killed the two. The forensic results however gave a very different view. The size of the larvae found on the dead bodies proved that the time of death was in fact far earlier than the date on which Mr. Neal reported that the children had been missing. It was on a date during which Mr. Neal was not in prison. Therefore, his alibi was proved to be fake and he was convicted to life imprisonment for the murder of the kids.

E. The case of Jonathan Blackwell[24]:

In this case, a man named Jonathan Blackwell had gone missing from his job in the year 2004. His body was found in a grave in 2006. However, the insect samples found from his body were only seven days old. This put forth a question regarding the time of death of the man. A renowned entomologist from North Carolina was consulted to solve this riddle, and following thorough investigations, he came to the conclusion that the grave that Blackwell was found in had not been his first grave. The killer had somehow preserved his body, leaving tissue for new blowflies to colonize after digging him up. This was the first report of blowflies emerging from soil covering a corpse. If it hadn't been for the maggots, a crucial piece of evidence would have been

[24] Parry, W. (2011) 'Bugs of Death May Help Solve Murder Cases', *Live Science,* 11 November [online]. Available at: https://www.livescience.com/16987-blow-flies-csi-forensics.html.

overlooked: the fact that the body had been moved. A few days later, the killer turned himself in to the authorities, and was sentenced to life imprisonment in 2010.

LIMITATIONS OF THE STUDY:

(i) Estimation of time of death depends heavily upon accurate temperature retrieval. But local weather patterns can differ depending upon how far the station is from the crime scene, which can mess with the accuracy of the temperature readings.
(ii) As evident from the name itself, forensic entomology depends upon availability of insects in the scene of crime. Some areas where a crime might take place, especially hot and dry places, might lack such insect growth. Also, availability of insects during winter is usually scarce.
(iii) Forensic entomology cannot reap immediate results, as the process of decomposition takes a significant amount of time.
(iv) Freezing, burying or wrapping the body in plastic or any other similar material might prevent insects from reaching the corpse.

FUTURE SCOPE:

Forensic entomology is a very valuable tool in the field of forensic studies and research. The experts in this field can determine the age of the insects found in crime scenes, which in turn can help in determining their behaviors and activities. This helps in correctly narrowing down the time range of insect colonization. By doing so, immense amount of information can be extracted regarding the time, place and manner of death of an individual (as has been discussed at length above). A better understanding of the variables and error rates involved in these studies will allow the forensic experts to offer better assistance to law enforcement and medical officials responsible for investigating crime scenes, and in turn, help in making the crime investigation procedures more precise.

CONCLUSION:

Forensic entomology is an emerging field in the ambit of forensic technology and sciences. It has increasingly gained massive popularity and has become an vital tool in criminal investigations. In today's world, the role of forensic experts is not limited to

the examination of hard tissue alone. Every new day sees a rise in the instances of forensic experts being involved in criminal investigations as part of the forensic teams. This has necessitated the need for an increase in awareness of emerging sciences like forensic entomology and its applications in forensics. However, for a majority of members of the forensic science community, insects have an exotic status. This might be one of the reasons behind why forensic entomology has not yet achieved the widespread recognition within the forensic community that it deserves.

From a scientific perspective, as discussed in details in the present paper, the study of necrophagous insects can open the doors to various fields which were previously considered uncharted territory. However, there are still some blank spots on the research map which are to be eradicated, the results of which might only give rise to new questions and studies, but no final answers. It is double-edged for a forensic discipline. As is already known, forensic science depends on reliability and fulfillment of specific criteria. The experts are expected to follow the standards for sampling and evaluation of entomological evidences. However, forcing too many guidelines and standards on forensic entomology may hamper the development of the discipline. A reliable chain of custody and associated steps and processes for sure improve the quality outcome of an entomological expertise. But in every report, there will be not just an evidence of fact, but also an evidence of opinion, as entomological expertise is often based not only on the expert's knowledge, but also on his or her experience. It has to be acknowledged by the judges that each case has unique features and maybe not just one answer.

Though the field of forensic entomology has to face its fair share of challenges before achieving mainstream acceptance, it is well on its way to doing so. In the future, a collaborative effort between classical forensic scientists like, for example, forensic entomological experts and natural history academics could potentially be a solution to many of the aforementioned problems. It could potentially be the only way to ask the right questions and provide answers with an appropriate forensic and scientific expertise. It might also help to bridge the gap between basic research and applied science, and remove all oversized expectations while giving realistic answers instead.

References

1. Anderson, G. (2018) 'How blow flies helped in detection of wrongful murder conviction in Nevada', *The Conversation*, 10 December [online]. Available at: https://theconversation.com/how-the-absence-of-blow-flies-overturned-a-wrongful-conviction-107865.

1. Caneparo, M., Fischer, M., Almeida, L. (2017) 'Effect of temperature on the life cycle of Euspilotus azureus (Coleoptera: Histeridae), a predator of forensic importance', *The Florida Entomologist*, 100(4), p795-801.

2. Dye, L. (2007) '48 Years Later, Bugs Clear Convicted Murderer', *ABC News*, 24 October [online]. Available at: https://abcnews.go.com/Technology/DyeHard/story?id=3769512&page=1.

3. Jolliffe, I. T., & Cadima, J. (2016) 'Principal component analysis: a review and recent developments', *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences*, 374(2065), [online]. Available at: https://royalsocietypublishing.org/doi/10.1098/rsta.2015.0202 (Accessed: 02 February 2015).

5. Joseph, I., Mathew, D. G., Sathyan, P., Vargheese, G. (2011) 'The use of insects in forensic investigations: An overview on the scope of forensic entomology', *Journal of forensic dental sciences*, *3*(2), p89–91.

6. McNeil, J. (2010) 'The Ecology of Death: Forensic Entomology as a Teaching Tool*', The American Biology Teacher*, 72, p153-155.

7. Michaud, J., Schoenly, K., Moreau, G. (2015) 'Rewriting ecological succession history: Did carrion ecologists get there first?', *The Quarterly Review of Biology*, 90(1), p50.

8. O'Neill, Y., Chan, G. (1976) 'A Chinese Coroner's Manual and the Evolution of Anatomy', *Journal of the History of Medicine and Allied Sciences*, 31(1), p15-16.

9. Parry, W. (2011) 'Bugs of Death May Help Solve Murder Cases', *Live Science,* 11 November [online]. Available at: https://www.livescience.com/16987-blow-flies-csi-forensics.html.

10. Pennington, E. (1978) 'Postmortem Care: More than Ritual', *The American Journal of Nursing*, 78(5), p846-847.

11. Saks, M.J. (2007), 'Remediating Forensic Science'. *Jurimetrics,* 48, p119-124.

12. Schiller, E., Haring, E., Däubl, B., Gaub, L., Szeiler, S., Sattmann, H. (2014) 'Ethanol concentration and sample preservation considering diverse storage parameters: A survey of invertebrate wet collections of the Natural History Museum Vienna', *Annalen Des Naturhistorischen Museums in Wien. Serie B Für Botanik Und Zoologie,* 116, p48-52.

13. Shedge, R., Krishan, K., Warrier, V. (2020) 'Postmortem Changes', *Treasure Island (FL),* [online]. Available at: https://www.ncbi.nlm.nih.gov/books/NBK539741/ (accessed: 27 July 2020).

14. Siljic, M., Salemovic, D., Jevtovic, D. (2014) 'Forensic Application Of Phylogenetic Analysis – Exploration Of Suspected Epidemiological Linkage', *BMC Infect Diseases*, 14, p1471-2334.

15. Weidner, L., Tomberlin, J., Hamilton G. (2014) 'Development Of Lucilia Coeruleiviridis (Diptera: Calliphoridae)', *The Florida Entomologist*, 97, p849-851.