THE IMPORTANCE OF FORENSIC ENTOMOLOGY IN CRIMINAL INVESTIGATIONS

Review Article

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Srđan B. Segic[1]
Faculty of Biology, University of Belgrade

Gordana B. Mauna
Faculty of Biology, University of Belgrade

Abstract: This paper demonstrates the importance of forensic entomology in criminal investigations and points to post-mortem interval estimation, procedures at the death scene, which are important for entomological research. The focus of the paper is on entomotoxicology, that is, how entomotoxicology can help determine the presence of toxins in the body at the time of death when this is not possible by means of traditional methods. The paper also demonstrates how insects can contribute to the discovery of mass graves and provide information that can help prove war crimes.

Keywords: forensic entomology, post-mortem interval, entomotoxicology, insects, war crimes, mass graves

INTRODUCTION

The term forensic entomology is derived from the Latin term *forensic,* which means of or before the forum, and the Greek words *entoma* – insect and *logos* – science, meaning the study of insects in the forum, which is explained by the fact that in Ancient Rome, in the event of an unknown cause of death, the body was displayed in the forum and " *forensic examination*", that is, the determination of the cause of death, took place there, so it is about determining the cause of death based on the knowledge of insects (Janković-Rapan, 2009).

Forensic entomology is important both in human medicine and law and in veterinary medicine and law. By studying the insects found on or around the corpse, we can get answers to some questions important for death investigations, such as the time between death and the collection of insects and larvae from the body (the post-mortal interval – PMI), the place of death, whether the body has been moved to a second site, including the cause of death (poisoning, explosion, neglect...) (Lindgren et al., 2015). Forensic entomology is the

1 Corresponding author: Srđan B. Segić, MA, Faculty of Biology, University of Belgrade. Email: segicsrdjan@gmail.com

broad field where biology and the judicial system interact, because biologists or entomologists are the ones who collect evidence that will be used in legal proceedings at a later time. Thus, forensic entomology, like other forensic sciences, calls into question the traditional division of sciences into natural and social sciences, because the question arises as to whether a forensic science is a natural or social science.

It can be said that forensic entomology is still an emerging field of forensic science; however, although forensic entomology (hereinafter: FE) has been around for hundreds of years, forensic entomology literature is scarce and the number of forensic entomologists is insignificant. Evidence provided by forensic entomologists is of great importance, because the exact time and place of death, the cause of death, and so on, can be key answers that should steer both investigations and legal proceedings in right directions.

THE IMPORTANCE OF FORENSIC ENTOMOLOGY IN FORENSIC INVESTIGATIONS

There more than 1,000,000 species of insects and the number is still not final; such a large number of species indicates that insects are adaptable to any habitat and all kinds of environmental conditions, therefore it can be said that insects can be found in almost every conceivable type of habitat. It is impossible and pointless to know all species of insects, which is why entomologists specialize in a single order or even a family of insects.

Saprophyte and facultative saprophyte insects are of great forensic importance – namely necrophagous insects that feed directly on remains. Within minutes after death (it is not uncommon for necrophagous insects to colonize a dying host) necrophagous insects arrive at a dead human or animal body. According to Byrd (1998), insects will rapidly locate a body regardless of how it is "protected" – except for those kept in a completely protected area, which is possible only in specialized institutions. A buried or wrapped body or a body protected by chemical means is not an obstacle for insects and other invertebrates to perform their natural function – help to decompose the body into mineral matter that will serve as a building block in a new life cycle in nature. The arrival of insects at the place of death is as certain as the death itself. To take advantage of the potential forensic value of insects and other invertebrates, evidence must be systematically collected and processed. According to Castner and Byrd (2000), for investigators to collect and process such material at a crime scene, they must know what to look for, and be familiar with insect biology and anatomy.

Four orders of necrophagous insects are important for the purpose of FE – *Diptera*, *Coleoptera*, *Hymenoptera* и *Lepidoptera* (Ilić, 2019).

The order *Diptera* includes the following families:

- *Calliphoridae*
- *Muscidae*
- *Phoridae*
- *Piophilidae*
- *Sarcophagidae*
- *Sepsidae*
- *Sphaeroceridae*
- *Stratiomyidae*
- *Psychodidae*

The order *Coleoptera* includes the following families:

- *Staphylinidae*
- *Histeridae*
- *Silphidae*
- *Dermestidae*
- *Cleridae*
- *Scarabaeidae*
- *Nitidulidae*
- *Trogidae*

The order *Hymenoptera* includes the following families:

- *Formicidae*
- *Chalcidae*
- *Diapriidae*

The order *Lepidoptera* includes the following families:

- *Tineidae*
- *Vespidae*

Since in our region entomologists rarely get opportunity to attend a crime scene, even less often forensic entomologists because there are very few qualified practitioners in FE, it is important that crime scene technicians conducting investigations be familiar with the procedures related to collecting entomological evidence at the crime scene and in death investigations.

According to Joseph et al. (2011), the importance of FE is reflected in the following:

- Assist in establishing a period of insect activity – PIA and time of colonisation –TOC, and at the same time determine the minimum post-mortal interval – *mPMI*
- Assist in determining the geographic location of death

- Assist in determining whether the body was moved and whether the site where the body has been found is the primary or secondary site where death occurred
- Insects found at the death site can be used for toxicological analyses
- Insect gut content found at the death site can serve as a basis for DNA sampling
- Based on the insects found, injuries on the body can be classified into antemortem, perimortem or postmortem injuries

To use insects as forensic evidence, it is necessary to accurately identify, collect, store, and ship entomological evidence found at a crime scene. Immediately upon arrival at a crime scene, the procedures important for the entomological part of the investigation should be followed, which concern the location where the corpse was found, the possibility of infestation by insects, that is, their larvae, clothing and objects found around the body (Sharma, 2003). According to the manual by Catts and Haskell (1991), the entomological sampling procedure itself can be partially invasive in terms of damaging the integrity of the body (especially in an advanced stage of decomposition), so before taking entomological samples, photographs of the body should be taken and the body should be accurate positioned in relation to the environment. It is important to record all the facts regarding the growth and development of insects – particularly temperature and humidity, because this can be of crucial importance when drawing conclusions regarding entomological evidence. The slightest mistake in the procedures can lead to a wrong conclusion, and consequently to a wrong decision by the judicial authorities. For example, a body was found in the warm period of the year, let's say, in June, and based on the developmental stages of the larvae, the entomologist drew a conclusion that death occurred seven days before the larvae had been collected from the body; however, it was not mentioned during the investigation, for example, that the body had been found in a dark-colored car parked on the asphalt that was exposed to sunlight, where the temperature is significantly higher, so the development of the larvae is faster, while the main suspect had a viable alibi for a time period of seven days before the death had occurred. In that case, based on the erroneous conclusion reached by the entomologist, the court must order a release of the person, because someone failed to mention, during the crime scene investigation, a detail important for the forensic entomological investigation as stated by White (2021).

FORENSIC ENTOMOLOGICAL PROCEDURES AT THE DEATH SCENE

The collection of entomological evidence begins a few steps from the body at the death scene and it consists of several stages:

1. Observation and notation of general scene characteristics

At this stage, visual observation of the site where the body was found should be made, in terms of the appearance of the site itself, the position of the body, exposure of the body to sunlight or shade depending on times of the day, etc. Observation should be made at a distance of at least 6 m so as not to disturb adult insects because they can either fly away or otherwise move away from the body itself. The time when you arrive at to the scene is also important because some adult insects (flies) are active only in daylight. If traces are collected at the site where the body was found at night, this must be noted because it cannot be expected to find adult flies. Photographs should be taken of and notes should be made about all the characteristics of the place where the body was found, because some details that are irrelevant to the entomologist can be extremely important for other experts investigating the place where the corpse was found and vice versa.

2. Visual observation and notation of insect infestations at the scene

The body itself and the immediate surroundings are observed, photographs are taken and written notes are made about what can be observed on and around the body, which parts of the body are infested by insects, the degree of colonization, the forms of the insects observed (adult insects, larvae, pupae or eggs); notes about the presence of insects in the close proximity of the body and the developmental stage of insects or the presence of insects that should not be expected are also made. This is important because it can indicate if there were antemortem injuries on the body, because in the case of antemortem injuries, if the time from the moment of death to the arrival of the investigator is short enough for the body to be infested with insects post-mortem, and infestation can be observed on the body, this indicates antemortem injuries, and death occurred subsequently. Attention should be paid to every detail that can provide information to entomologists or other types of investigators (White, 2021).

3. Collection and notation of climatological and microclimatological data.

At this stage, data on temperature and air humidity are collected at the site, where it is necessary to determine whether the body was found in an enclosed, semi-enclosed or outdoor environment, where ambient air temperature should be taken first (if it is an enclosed environment, the temperature inside and outside the room should be taken), air humidity in the room as well as outdoors must be taken. After measuring ambient air temperature, body surface temperature is taken, then ground surface temperature or floor surface temperature if the body was found in an enclosed environment, including under-body interface which is taken by sliding the thermometer between the body and the surface. The metabolic temperature of the maggot mass is also important information, which is measured where the largest number of maggots is by directly inserting the thermometer into the maggot mass. The metabolic temperature of the maggot mass is significant because due to metabolic processes the temperature in the mass itself rises, which can be significant because differences in the speed of maggot development can occur due to differences in temperature. In addition to this data, it is important to determine and record some other facts that may be important, such as cloud cover, fog, smoke, etc. All data is recorded immediately to avoid subsequent errors.

4. *Collection of adult insects*
5. *Collection of eggs, larvae, and pupae at the scene*
6. *Collection of specimens (imago, pupae, larvae, eggs) from the surrounding area 5-6 m from the body*
7. *Collection of specimens (imago, pupae, larvae, eggs) from under the remains after the body has been removed*

These phases are completed simultaneously, so they will be explained accordingly.

Flying adult insects are collected out with an areal insect net, by performing movements above the body in the form of a horizontal figure eight, that is, in the form of a sign for infinity – ∞, or by holding the net above the body until a sufficient number of flying insects is collected. Ground crowling insects can be collected with forceps or fingers, so as not to damage the insect's body. After collecting a sufficient number of insects, they are placed into a killing jar containing ethyl alcohol which kills insects; then they are transferred into vials containg 70-80% ethyl alcohol.

According to the protocol explained by Haskell et al. (2000), a data label completed in pencil on a regular cotton bond paper is placed inside of the collection container together with an individual insect, while a data label completed in ballpoint pen is affixed to the outside of the collection container. Both labels contain the same information about location of adult insects on the remains, time of collection, location, case number, and the collector's initials. In this way, adult insects and insects in all other developmental stages are collected, but it is important to note that the samples prepared in this way – killed insects and their developmental stages are stopped and the developmental stage cannot be completed, but based on a developmental stage, the time of PIA, TOC, and mPMI can be determined. Eggs of larvae and pupae are collected separately from each area of the body colonized by insects (body cavities are mainly colonized – oral cavity, nasal openings, genital or anal area, etc., the whole body is covered with eggs, larvae and pupae in the advanced decomposition stage). Eggs are collected with a soft moistened brush. Larvae and pupae are more visible and easier to collect; they can be collected with fingers, fine point forceps or a brush. More than 50 eggs and larvae should collected, which should not a problem considering their number, and it is important to label the samples for each area of colonization and record the temperature of the area of colonization itself (Petrović, 2012). After collecting samples of larvae and eggs, they need to be preserved by immersing them in hot water for a few minutes or using previously prepared fixatives. Following immobilization, eggs and larvae are preserved in 70-80% ethyl alcohol solution. In order to rear eggs and larvae in laboratories, living samples are also collected according to the already described principle; the collected living samples should be packaged in a glass vial with a piece of dump cotton wool (to prevent dehydration), in case it takes longer than 1 hour to reach a laboratory. The living samples are packaged in special shipping containers.

Pupae as the last developmental stage are easy to collect due to their size; they can be collected with fingers or fine point forceps and they are packaged in glass vials:

- The living pupae to be transported to the laboratory are placed in glass vials lined with cotton wool or paper, in order to prevent damage to the pupae.
- Pupae that need to be preserved at the stage in which they were found at the scene, after having been immersed in fixative, are placed in glass vials filled with 80% ethyl alcohol (Fujimura et al., 2009). For the purposes of further research, larvae and pupae of insects found at the site must be collected and preserved alive. Further research and rearing of larvae in laboratories is important to determine the species of insects based on imago, but also to compare the speed of development with that estimated development at the scene. Also, development in laboratories can be of importance due to entomotoxicological analyses. In larvae (maggots) rearing containers, a substrate is placed as a base (soil or sand), then a source of food (beef or pork liver) and a piece of dump paper towel is placed into a tinfoil bag (aluminum foil) to preserve humidity in the container and prevented the drying of larvae, food and substrate (Miller & Naples, 2002). The container prepared in this way is labeled and prepared to be shipped to entomological laboratories, which must be notified of the arrival of the larvae rearing container and to be able to accept the samples (White, 2021). Samples of adult insects, larval pupae and eggs are collected both from the close proximity of the body and under the body, because larvae at the final stage of development will leave the place of their previous life and development and move away in order to enter the pupa stage, that is, the last stage of metamorphosis, from which they will develop into adult insects. When larvae complete their development and enter the pupa stage, feeding is over – pupae and adult insects do not feed, they only aim to reproduce, that is, lay eggs.

8. *Documentation of historical climatological and microclimatological data (depending on the stage of decomposition of the body and the estimated length of time the body had been lying)*

Data on air temperature and air humidity from the desired time frame should be obtained from the nearest hydro-meteorological station, so that entomologists can calculate the time required for individual insects to undergo their development (Gennard, 2012). These data are necessary to calculate ADD – Accumulated Degree Days and ADH – Accumulated Degree Hours – these two parameters allow forensic entomologists to estimate the time required for insects or its larva to reach a certain degree of development based on the accumulated heat during hours or days .

9. *Assessment of the ecological characteristics (soil, plant, animals, water...) at the recovery site*

Ecological characteristics can provide valuable information not only to entomologists but also to other experts involved in death investigations.

If it is necessary to examine a body that has already been buried (legally sanctioned or in order to hide evidence), the procedures are similar to those described for a body found on the surface of the ground. The only difference is that soil is sifted from the surface to the remains in order to find imago, pupae, larvae, and eggs. After removing the body, the soil under and to the side of the body is examined and sifted with the same goal (White, 2021).

DETERMINING THE TIME OF DEATH

Determining the time of death is of crucial importance in investigations of homicides and other untimely natural deaths (related to legal and economic matters concerning insurance, inheritance, the conclusion of a *dubious* contract...), missing persons cases, in cases when it is not possibile to identified a person, the time when the person was last seen alive is matched with the time elapsed since death, which was determined on the basis of entomological evidence. The time elapsed since death is called postmortem interval – PMI. Determining the PMI can be quite a difficult task because even in the initial stage of body decomposition when the physical and chemical changes accompanying the decomposing body are predictable, they depend on many environmental factors that determine the speed of these physical and chemical processes. However, as the time since death increases, all methods based on physical and chemical changes become less useful. In this case, methods in forensic entomology, even after a long period of time since death, can help to determine the time of death, that is, the PMI, quite accurately: samples of all the insects present in all developmental stages are collected from the body found and for which the PMI needs to be determined, and based on the immature imago necrophagous insects, which fed on the body, we can, based on microclimate conditions to which the corpse was exposed, determine the PMI, not as precisely as when the period is short, but an accurate PMI can be determined with an error as law as one day.

Isomegalen and isomorphen diagrams can be used to determine PMI. Isomegalen diagrams represent the determination of the developmental stage of the larva since the larva hatched to the stage found depending on the temperature. The length of the largest larva found is measured and the time since the larva hatched is determined based on the curve dimension in the isomegalen diagram. This method is quite accurate only if the body was not undergoing fluctuating temperature, for example, in an enclosed environment where the temperature was nearly constant, but if the body was found outdoors and underwent daily temperature fluctuations, the mean temperature between daily minimum and daily maximum is taken. The specified time is approximate.

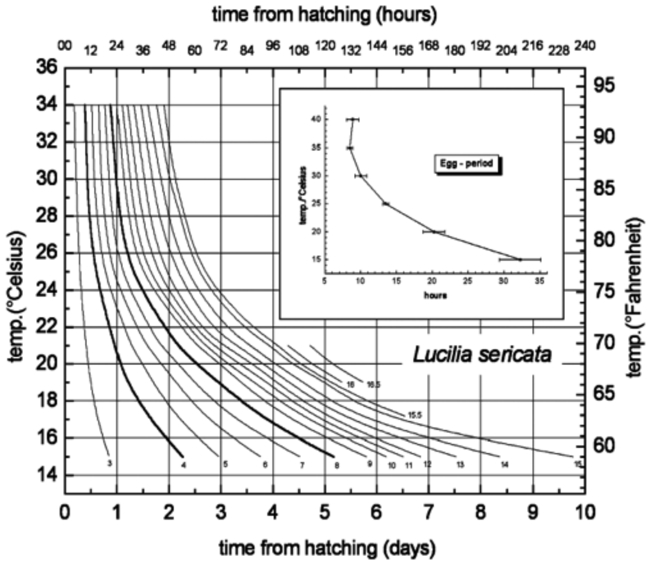

Figure 1. Isomegalen diagram (Grassberger & Reiter, 2001)

An isomorphen diagram is used when post-feeding larvae or pupae are recovered from the body, and the last metabolic stage of the pupa-to-larva transformation remains. It is especially useful when larvae that have already left the carcass they were feeding on are recovered from the body. Based on all insect developmental stage in the diagram, from egg laying to the transformation of a pupa into an imago, the period from egg laying to the developmental stage observed can be determined on the basis of the determined temperature of the environment, or the mean temperature per day due to daily temperature fluctuations.

The second method is based on the succession of insect species that inhabit the decomposing corpse, because it is possible to form models for which insect species inhabit the corpse and in what period depending on the PMI, but the formation of these models requires a comprehensive knowledge of the insect fauna in a given area.

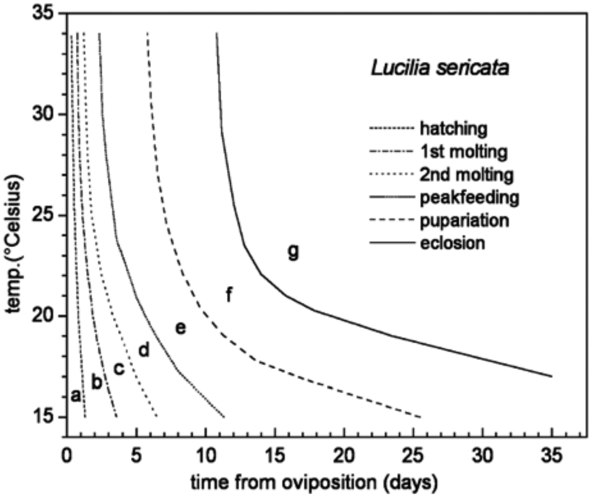

Figure 2. Isomorphen diagram (Grassberger & Reiter, 2001)

Factors impacting the development cycle:

1) Temperature and seasonality – the growth and development of insects is temperature-dependant, but due to normal distribution, temperature values for individual phases depend on insect species. We distinguish 5 points:
   - cold death point, where development is irreversibly interrupted and the larva dies (these values are -10 ºC до 0 ºC)
   - cold stiffness point, when all developmental processes stop, but with an increase in temperature they will continue – hibernation
   - optimal development point is said to develop the fastest and the optimal development values are 22-26 ºC
   - thermal stiffness point, as temperature rises above optimal growth and development slows and stops and protein coagulation begins, warm stiffness is irreversible and very close to the warm death point
   - thermal death point is the temperature at which proteins coagulate and death occurs.

Depending on the season, insects in certain stages of development can enter the cocooned larva or pupa stage, when in that stage they spend a certain amount of time in hibernation, waiting for a season that is favorable for their further development (Vasić, 1971). These data are important because, based on season and temperature data, one can predict and determine the time spent in certain developmental stages of insect species, as well as “abnormalities” related to accelerated or arrested development due to temperature effect.

2) Presence of a maggot mass

If a number of larvae is large enough, the so-called maggot mass is formed where, due to the metabolic processes carried out by the larvae themselves, the temperature is substantially higher than the temperature in the environment – this is important during cold weather when maggot mass temperature can deviate significantly from temperatures in the environment. In the case of a maggot mass, a complex phenomenon occurs and the oldest larvae develop faster. Based on the metabolic temperature of a maggot mass, the larva development period that developed preferentially can be determined, because the development period would have been significantly extended if there was no effect of the maggot mass temperature.

3) Food type

Some larvae found on the remains do not feed exclusively on decaying animal organic matter; some larvae can also feed on decaying plant organic materials, or only on plant matter, and some larvae have even been found feeding on any food type and even on paint. This is important because the larvae of insect species that are facultative necrophages can be found on and around the body, so based on knowledge of the specifics of the diet of certain insect species, some answers can be found that are significant for the forensic entomological investigation itself. Sometimes insect species that feed exclusively on plant remains can indicate facts that are of interest for the investigation, especially if there is a primary and a secondary site, and when the primary and secondary site should be linked.

All these factors indicate development rate and a diet type of the larvae of certain insect species, and these are facts that can provide the entomologist with enough information on the basis of which he can determine the elapsed time since death. According to Wells & LaMotte (2017), there are computer programs hat simulate insect development and thus provide data to entomologists about the length of development up to a certain stage. All this can help to determine the PMI as accurately as possible. However, insects don not only play an important role in determining the PMI; necrophagous insects have a much wider importance in FE, and they can, as silent witnesses, provide a lot of information on the last moments of people whose fate is being investigated. We can find out from the larvae of necrophagous insects not only when death occurred, but also, in some cases, the cause and manner of death.

ENTOMOTOXICOLOGY AND THE PRESENCE OF PSYCHOACTIVE SUBSTANCES

An autopsy is ordered when the cause of death of a person whose body is found is unclear or it is about a suspicious death and available body fluids, blood and urine, and tissues if necessary, are used for toxicological analysis

This is possible only if the body found is preserved, but what to do in a situation in which the decomposition of the body has advanced and is in the stage of active decomposition or even skeletonization. In this situation, the larvae of necrophagous insects or adult insects found on or around the body can provide the answer. In cases when only a skeleton is found, meaning there is no tissue to analyze, no living larvae of necrophagous insects, no living imago in the close proximity of the skeleton, insects are the ones that can provide answers by collecting cast larval skins or empty pupal cases during the molting process. In the skins and cases, which should be carefully analyzed in laboratories, using chromatographic methods, according to Milošević (2022) (immuno-chromatographic tests, gas chromatography, gas chromatography, headspace – gas chromatography with) the presence of toxins or drugs can be found, which could have been the cause of death of the person whose skeleton was found. Toxins and/or controlled substances are found as accumulated and unmetabolized products that insects ingest while feeding, and as harmful, rather than non-nutritive substances, they are accumulated in the insect's body, and thus in the skin, which remain after the development of the insect larva is finished. According to Sohal & Lamb (1977), insects have inhabited the world much longer than all mammals, so during evolution they have adapted even to the presence of heavy metals. Heavy metals, especially mercury, can accumulate in organisms, which may lead to the death of a warm-blooded organism, and as such the body will be exposed to decomposition. Larvae of necrophagous insects will arrive at the body and feed on the tissues containing high mercury concentrations. The mercury ingested by insect larvae will be retained in their organisms and based on the mercury content found in the larvae, poisoning death can be suspected; however, caution should be exercised when deciding whether it is poisoning during the analysis of larval pupae and adults. If only pupae, or only imago, were to be analyzed, the concentration of mercury and other heavy metals would be significantly lower, because insects have the ability to partially eliminate heavy metals in the larval or pupal stage. In addition to mercury, recent studies demonstrated similarities with the concentrations of some other metals – iron, zinc, copper, lead, etc. The concentration detected during the analysis indicates that metal poisoning should be suspected. Utsumi (1958) observed that, while studying housefly larvae, adult female flies behave differently toward rat cadavers depending on which poison caused death. In this study, no further research into toxins in the larvae was conducted, but it was indicated that insects easily detect the presence of substances that humans are insensitive to. Although research has been conducted at the Fraunhofer Institute in Hanover and Braunschweig, Germany, it is still not possible to determine, based on the toxin concentrations in the larvae, whether the toxin is the immediate cause of death. It may lead us to think that it is still not possible to convert the concentration measured in the larva to the concentration in the body of the person whose death has been investigated, because no certain correlation can be established between the level of the toxin found in the larva and the level of the toxin found in the body in the moments when the larvae used the body to feed on, but the presence of toxins in the larvae can indicate what should be investigated because sometimes something may arose sufficient suspicion to conduct a more detailed investigation during which overlooked details can be noticed, which can provide an answer as to the cause of death. The importance of toxicological analyses of larvae, cast skins or pupal cases lies in providing answers as to whether the person whose death is investigated consumed certain substances or not. It is significant that the skin shed by larvae and pupae during the molting process can be found in a preserved state for a long time after the decomposition of the body, therefore we are not limited in time as in the case of larvae that can only be found during decomposition. If psychoactive substances are present in tissues and blood, the same substances will be found in larval or pupal skins.

Human medicine deals with how certain substances, specifically cocaine, affect the human body, but what is important for FE is how cocaine can affect the development of larvae. In the study by Goff et al. (Goff et al., 1989), it was determined that if larvae are offered liver tissue containing sub-lethal and lethal concentrations of cocaine, the larvae that consumed the sub-lethal dose of cocaine have approximately the same period of development, but the larvae that consumed significantly higher concentrations of cocaine (a lethal concentration or as twice as lethal) develops significantly faster. In both cases, pupal development duration was the same for both groups of larvae.

Forensic entomology has the possibility, but also a scientific and moral obligation, to provide answers to questions concerning human remains, because the family, society and the general public have the right to know how a member of the social community ended his life. These questions are much more complex than PMI, therefore forensic investigators asked to provide answers to the questions of where the death occurred, how the death occurred, whether the diseased was tortured before death, sexually tortured, whether there were indications of abuse of narcotics and substances, and so on. These and similar questions cannot often be answered by forensic investigators, therefore experts such as forensic entomologists, forensic pathologists and other experts must be included in the investigation. According to Rasmy (2008), insects as silent witnesses can provide an answer as to whether there was antemortem torture, because the victims' hands are usually tied, they are often unconscious as a result of the torture, so they cannot defend themselves against the attacks of the flies that can lay eggs on fresh wounds or natural openings of the body. Thus, the presence of wound scabs and myiasis on the body (infested with fly larvae antemortem) indicate that injuries were inflicted antemortem, which indicates torture. Insects can often provide answers as to where a substance comes from. For example, when the Drug Enforcement Administration – DEA seized marijuana packed in a so-called "brick" for which none of the suspects claimed responsibility, and an insect larva was found on the packaged marijuana, they called in entomologists. In this case, the task for the entomologists was easy because it was determined that the type of insect larva found lives only in

Colombia, so it was easy to link the perpetrator who traveled from Colombia to the drugs found. In cases when a completely decomposed body of a woman was found, it was necessary to determine whether she had been raped antemortem. Due to putrefactive changes, it was not possible to extract the semen of the possible rapist; however, the DNA of a man was extracted from the larvae found, which indicated that the victim was also raped (Rasmy, 2008). Insects can also provide answers in cases of mass graves, whether the grave found is an original primary grave (the term original primary grave means a grave in which bodies were first placed after death, which has not been excavated and the bodies have not been moved from it), or a secondary or tertiary grave (the term secondary grave means a grave to which the remains of victims were moved from the primary grave, often with the aim of disguising the crime and making it difficult to find and identify the victims). It often happens that after the crime has been committed, in order to disguise it, bodies are moved from the primary grave to the secondary or tertiary grave, and those attempting to disguise their crime often make "mistakes" during the relocation of the bodies, because new fly larvae invade the bodies in the advanced stage of decomposition, which have already been buried once. It is impossible to encounter fly larvae underground, which indicates that the bodies were in the light of day and they had been moved. FE can provide answers related to terrorism. According to Cruz (2006), if a plane crashed and there were no survivors, and it is unclear how the plane crashed, by examining insect larvae we can establish whether there was an explosion.

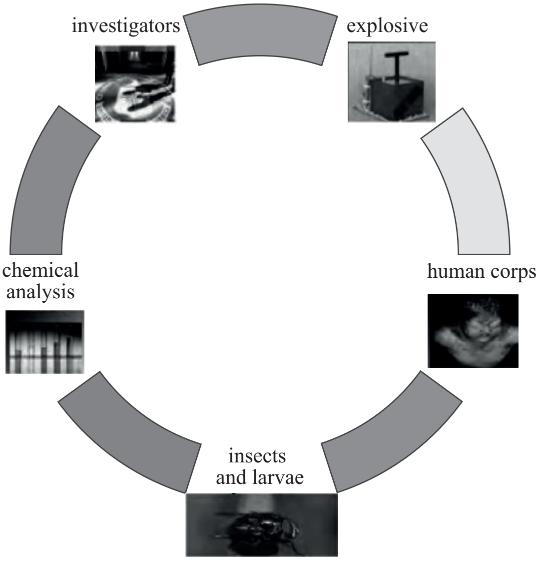

Figure 3. Explosive detection cycle (Cruz, 2006)

Specifically, traces of explosives will be found in the system of digestive organs of the larvae, because the bodies were blown up by the effect of pyroclastic impact due to the explosion and part of the burned and unburned explosive particles remained on them. After feeding, these same particles can be found in insect larvae or cast larval skins during the molting process, which can be preserved for years at the site where the traces were found. It was this method, that provided the answer as to how the Korean plane crashed in 1983, because the Soviets did not want to accept responsibility for shooting down the passenger plane, but the larvae found on the remains of the victims provided evidence there was an antemortem explosion and traces of TNT were found (English, 2022).

FORENSIC ENTOMOLOGY AND WAR CRIMES

It has already been mentioned that FE can provide answers concerning war crimes indirectly. If a mass grave is found that is suspected of containing victims of war crimes, it is first necessary to determine whether it is a primary or secondary grave – this answer can be provided by necrophagous insects because there is a precise succession of species as the body decomposes. Thus, if insects are found on the bodies in the advanced stage of decomposition, which primarily invade fresh corpses, it is clear that the bodies were moved to a secondary grave in order to cover up war crimes. Also, before the excavation of a grave site suspected of being a mass grave site, the fauna of the specific area should be thoroughly examined, because species that "do not belong" to the specific location can also be found. According to the data obtained by Jugo and Muzaferović (2008), mass graves vary in their dimensions and depth. For example, graves over 8 m deep were dug in Bosnia and Herzegovina, and since mass graves were hidden, the most demanding task was to uncover mass graves. What was observed in the search for mass graves were the so-called "geophysical anomalies". In the search for mass graves sites suspected of being mass graves, a large number of blue butterflies were observed. Margaret Cox explained this phenomenon described as a "geophysical anomaly" – it was observed that mass graves were mostly covered with *Artemisia Vulgaris*, a species of plant (mugwort), which these insects feed on (Cox et al., 2001). Areal images, according to Redmon (2019), showed that parts of the land on which mugwort prolifically grew show geophysical anomalies – the soil is slightly warmer than the environment (this is explained by the thermal energy released during the decomposition of organic matter). The soil where mugwort grows is richer in nitrogen than the surrounding soil (this is also explained by the nitrogen coming from the decomposing body), the geophysical structure of the soil has been changed (digging the soil to bury the body changes the soil structure in the sense that the soil is no longer as compact as before digging, but also the layers of soil that are at a greater depth appear on the surface, primarily clay). The presence of mugwort can be easily noticed by observating blue butterflies, which pollinate mugwort, according to Warner (2004). Insects only signal us where the remains of victims might be found and where we should investigate, because the presence of mugwort and a blue butterfly does not necessarily mean that a mass grave containing human remains is there. All the aforementioned geophysical anomalies can also occur due to the burial of organic matter that does not have to be human (for example, by burying slaughterhouse waste). Certainly, geophysical anomalies and the presence of mugwort and blue butterflies can be a sign that something needs to be investigated, because there is no perfect crime, there are always witnesses, it is up to people to notice these "witnesses" and understand what they are saying. Blue butterflies signaled mass graves in all climates, and they were observed in Rwanda, Sudan, Iraq, Bosnia and Herzegovina, Serbia (Cox et al., 2008).

CONCLUSION

Insects and their developmental stages can provide answers to questions that are important both for individual criminal cases and very complex cases, such as terrorism and war crimes. Forensic entomologists are employed in cases in which the cause of death of the person whose body is found is unclear, because the behavior and metabolism of insects may provide investigators with answers they are looking for. The involvement of forensic entomologists in criminal investigations will not solve all cases, but we can certainly expect some answers. The importance of forensic entomology is growing, and training in forensic entomology is organized throughout the world. Serbia and the countries in the region still do not have adequate staff in the field of forensic entomology; therefore, crime scene technicians and investigators need to be properly trained to deal with insects and larvae encountered during investigations, as well as to consult forensic entomologists during investigations. Only a professional approach and use of entomological procedures can provide authoritative and court-acceptable evidence.

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