

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Distance Master of Science in Entomology
Projects

Entomology, Department of

8-2018

How do Entomologists use insects to determine PMI

Johnnie Erskine

Follow this and additional works at: <https://digitalcommons.unl.edu/entodistmasters>



Part of the [Entomology Commons](#)

This Thesis is brought to you for free and open access by the Entomology, Department of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Distance Master of Science in Entomology Projects by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

The use of forensic entomology is one of the fastest growing methods used to determine the cause of death by law enforcement personnel. This paper explores and examines the various insects that are found on dead bodies during different time periods. The purpose of this paper is also to analyze and evaluate how forensic entomology is beneficial when compared to the other methods of forensic science that are used in crime investigations. Goff (2000) states, “anyone involved in death investigations quickly becomes aware of the connection between dead bodies and maggots.” (Goff, 2000). Insects are used to help with the recycling and decomposition process of carcasses, and in the cleaning of the environment; this is particularly true when looking at the remains of corpses.

During and soon after the time of death there are many different species of insect that will quickly cover a corpse and break it to minute pieces. Maggots will start to appear from all cavities, open wounds, pubic hair, or hair on the head of the cadaver. It was only recently that many death investigations regarded insects as an indication of a dead body being present in the vicinity and this evidence being used in the solving of criminal cases. However, the use of insect evidence was not a first in criminal investigations - in the early thirteenth century- insect evidence was used to solve homicides. In particular in 13th Century China, an investigator found that a victim was murdered with a sickle, which he determined by using different tools to kill animals to achieve the same patterns as those found on the victim. He further called together all those in the area who worked with sickles and asked them to lay down their tools.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

Unbeknown to the murderer, his sickle still had traces of the victim blood which immediately attracted some flies, thus pointing the finger of murder to the perpetrator. (Tz'u, 2017).

Over the years the availability of forensic insects has become of paramount importance to investigators in solving crimes. Forensic entomologists examine the various types of insects that are found both inside and outside of dead bodies to help them determine the postmortem interval which in layman terms means the time that has passed since the death of a victim. When bodies are buried or decomposed, "insect activity is always present; however forensic entomology is not just restricted to the grave or to remains found in the open, but it can be used to determine the cases where the time of death cannot be determined simply by studying the type of insect activity that is found. Some of the types of insects that are found around the grave or the pieces of decomposing remains are flies, beetles, ants and wasps" (Gardner, 2005).

The first stage of decomposition occurs from death to approximately two days following death; at this stage one will observe different species of blowflies that will be drawn to the body. The adult flies will immediately lay their eggs on the dead body; after the eggs are laid they will hatch and go through four stages of development, and during these stages the larvae (maggots) will feed on the decaying body. After their final stage of feeding, the maggots will change to pupae. It is at this stage that the maggots move from the corpse to another location preferably a safe location where they can complete their

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

life cycle of becoming flies. The appearance of the adult flies will be seen, which indicates the life cycle is repeating. As the body goes into the advanced stages of decomposition, there will be an odor that will be present which will attract even more flies and other insect species like beetles. Based on the types of insects that are present together with the amount of insects that are present, entomologists will be able to estimate the postmortem interval. For the entomologist to determine the postmortem interval they have to collect all the specimens and observe them carefully in a lab, but sometimes that is difficult and alternative specimens are collected such as pupae, maggots or adult flies. Some of the specimens that will be used as evidence are preserved and the remaining samples will be left alive to allow for them to mature. It is recommended that the collections be done as soon as the bodies are found to prevent the flies and beetles from moving away because of disturbance. When collecting the specimens it is recommended to collect between 20-30 larvae and store them with a moist paper towel or piece of meat to prevent them from eating each other.

When collecting adult flies and wasps, it's easier to catch them with a net. Beetles are usually located in the soil and clothing around the body. Pupae are found in drier areas that are removed from the maggot mass, and in order to prevent predators, the samples must be collected in live and preserved states. There are various ways of preserving samples, for example one simple solution would be to use the boiling method - HWK (hot water kill) to kill the maggots, another method would be to place the maggots into a vial containing a solution of 80% ethyl or 10% formaldehyde (J.R.Hall,

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

2003). Live specimens are kept in an area with moisture and in carefully sealed containers because they can emerge from the pupae without warning. The sample should be properly labeled showing the type of the specimen, when collected, where collected, time and date of collection, temperature and size data, and the amount of larvae, as well as the exact location of where the body was found.

A description of the area is essential information and should contain the weather conditions; for example if the place is sunny or raining or there is grass, trees, or shade. All descriptions must be documented, including all insects and the estimated number of insects present. Entomologists may be required to provide the crime scene management technician with a death scene study form that contains details of all relevant data that is needed. If the form is completed and is accompanied with the specimens, it is advised that the crime scene team locate an entomologist ahead of time.

Another suborder of forensic entomology “is entomotoxicology, which deals with drugs and toxins that are found in insects that feed on decaying organisms and the effect of drugs on insect development” (Gains, 2014). It is important to know that when a person dies, flies will land on the body within minutes; however, the types of flies vary depending on the location of the corpse, but commonly you will always see blue and green blowflies immediately when garbage is placed in an area. As soon as they arrive they deposit their eggs in openings such as nostrils, eyes, anus, and genitals. In cases where a person sustains injuries from gunshot and knife wounds, the eggs will be deposited in the soft tissue of the wound.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

When the blowfly maggots are hatched and multiply they do it in high numbers while feeding on the corpse and undergo stages called instars. The larvae will then shed their skin and go through three different stages of instars. Once they get to the third instar stage, they will pupate and leave the body in abundance, leaving a large amount of trail markings on the ground as they leave. One of the newest technologies that is now available in the investigation of crime is the way in which toxic substances are detected from entomological specimens harvested at crime scenes. However, persons who are suspected of drug related deaths are not generally found in a timely manner and consequently, when the remains are located, the biological substances such as urine, blood, and soft tissue organs that are used in analyzing drugs may no longer be available. In those instances, alternative cause of death methods like examination of insect larvae, living adult insects, and cast-off larval and puparial skin are used. The insects are processed using traditional chemical techniques that are able to reveal the chemical that the insects had digested.

The most common techniques that are used to find chemicals in insects are the gas chromatography, chromatography-mass spectrometry, radioimmunoassay along with a thin-layer of high performance liquid chromatography - mass spectrometry. Some of the drugs that are mainly found when doing entomotoxicology cases are found in people with addiction and those who abuse drugs such as morphine, cocaine, heroin, diazepam, phencyclidine, amitriptyline, and a range of antidepressants. The most common insects that are used to conduct entomotoxicological investigations are true flies that belong to

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

the order of Diptera. In current investigations entomotoxicology is used to help scientist who are curious about the effect of drugs and the development of insects, especially blowflies and flesh flies. Their main focus was to minimize the potential error that might occur in forensic investigations, so they developed techniques to measure drug-related alternatives in the larval stages of insects. The findings showed that there was a statistically significant increase in the rate of how maggots are developed that consumed tissue containing lethal doses of cocaine.

The variation in drugs in the development of insects can make a difference of up to several days when estimating the time of death. It is thought that the discrepancy occurs when comparing the effects of cocaine on maggots with its effects on humans. A Study from the National Institute on Drug Abuse shows “that human take a small amount of cocaine, initially become excited and quite talkative” (Riezzo I, 2016). And become very energetic and hyperactive, and unusually alert due to high heart rate. As the cocaine is broken down in the human body, the person slows down while in maggots their feeding habits change and they become more active when the more cocaine that they ingest causes them to feed more rapidly, resulting in an increase in larval stages, once they get to the third instar the craving for cocaine stops. The cocaine will then break down leading to the beginning pupal stage, and the rate of development returns to normal. Although it is not common to maggots, ingestion of drugs affects adult insects that feed on dead bodies. Forensic entomotocologists are extremely concerned about the major impact of illicit drugs; deaths due to the overdose of cocaine have been very disturbing. In 2006

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

there was a report that about 2.4 million-cocaine users was found in the United States, which led to 50,000 deaths. Cocaine is said to be one of the most potent CNS stimulants, but the form of intake determines its potency. When the drug is taken orally, it is quickly broken down, unfortunately people often inhale the drugs through their nose or intravenously.

The common use for entomological evidence is in figuring out approximately what time death happened or at least an estimated time that the death occurred, which is normally characterized as the time the death until the exact time is found. The benefits of insects to determine the time of death is often not given the efficacy it deserves, however, and the accuracy of the PMI is extremely important to medico-legal death investigations. Today there are two methods that are used to estimate time of death using insects as evidence; the first, Forensic Entomology, is the examination of the types of insects found and the different stages of development of those insects. Eggs found near a corpse indicate that death was fairly recent, since flies are immediately drawn to a corpse by the smell of blood or decaying flesh. The eggs will hatch to pupae, which indicate a longer time from death and the third stage of the blowfly cycle is the transition to adult blowfly. Following the blowfly cycle, other insects, particularly beetles, will be found on or near a body which indicate that the body has decomposed, leaving only bones, (Mangels, 2009). The other method is Forensic Pathology, carried out by a medical examiner who surveys the corpse for clues as to cause and time of death by calculating the level of rigor mortis, location and placement of the body and wounds on the corpse. The type of method used

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

is dependent on the severity of the decomposition of the body when it is found. Based on the effectivity of organisms and their ability to adapt to different environments, they have the capacity to provide further feeding grounds for other species of insects to feed on cadavers after the first pest has vacated the body. .. It is important when finding PMI to know that the “four stages of human decomposition should not be regarded as clearly identifiable, separate occurrences” (Allison Gaines, 2014). The decomposition process is dependent on several factors that are associated with the body until it is totally broken down. Environment plays a major role in decomposition, during the cold weather decomposition goes very slowly compared to when the temperature is hot, in addition bodies that are found on the pavement will decay more quickly compared to the ones that are buried.

Scientific research reveals that the further the body goes underground is the slower the decaying process, sometimes it will take as long as a few years. Based on “many television series that were broadcast depicting crime scene investigations and other crime scene shows, emphasis has been placed on the study of insects and arthropods found on cadavers and provides invaluable aid in many legal matters and homicide investigations” (O’Connor, 2015). A properly trained entomologist will be able to pinpoint the time of death and determine if the body was moved from the original place of death. Natalie K. Lindgren, a student of Houston State University, studied applied forensic science at a facility located in southern Texas. Her main focus was to make observations on cadavers that were donated by families for use in research. During

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

her observation she noticed that a caterpillar was moving on the toe of one of the cadavers; this was uncommon because caterpillars are normally found in vegetation and grass. On closer examination she was able to conclude that the caterpillar was eating the flakes of rough skin close to where the toenail was. Her findings reveal that they are opportunist like roaches, ants, crayfish, starfish, bees, and wasps which will feed on anything that is available.

The characteristic patterns that are created by these scavengers are helpful to entomologists because of the different markings each individual insect deposits. Studies from case files reveal that while the body is decomposing, the colonization of insects and other invertebrates will come to the body in an organized fashion and in specific numbers. Anderson believes “that after three reviews of the evidence obtained from the presence of insects, the scientist considered the evidence to be accurate” (Anderson 2006).

One police investigation that was done in the southeastern United States involved a call about a foul smell coming from a single-family home. According to the report, it did not take the police an enormous amount of time to discover that a body was buried in a shallow grave in the basement of the premises due to the quick thinking and observation of the forensic entomologist that was present at the scene. The entomologist pointed out that there were several larvae and pupae that belonged to two different fly species. A collection of the specimens were preserved, along with data of the weather conditions and the temperature of the soil, plus other surrounding areas which were later analyzed in a lab. After all of the different biological factors were scrutinized, the

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

entomologist was able to determine that the estimated time of death was approximately 28 days before the body was found.

This estimation of the time of death enabled the investigators to quickly solve their case, the suspect was a female who confessed that she killed the deceased and attempted to bury her. Another very interesting case was that of a mother that had been murdered in the town of Noosa Heads, on the Queensland Coast. Her body was found dumped in a park between flowering wattle trees native to Australia, the petals and debris from the plant littered the interior of the car.

The police called Dr. Milne to help in their investigation; she was able to determine that the plant matter from the trees in Noosa were different from those in Gympie. She then made comparisons from the sample on the victim as well as the car and those samples that were vacuumed up from the car and suspect's clothing. She was able to confirm that all the samples matched and the killer was later arrested and tried and as a result of the scientific evidence, he was sentenced to life. Historically the association of insects in the solving of crimes has not been a new phenomenon. About 2500 years ago Egyptians embalmed persons that were killed by diseases in an effort to prevent them from attracting insects and decaying. One of the first confirmed cases of forensic entomology that was used in the courtroom was in France in 1850 and is considered the breakthrough for the use of forensic insects.

The skeletal remains of a child that found by workmen behind a chimney during a remodeling, the insects found on the body were used as evidence. Because the science

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

was at the early stages, forensic entomologists were not equipped with a great knowledge of insect biology, therefore they had to rely on just basic observations. It was not until the first evaluation of insects and the succession on corpses by Yovanovich that ushered the birth of the science of forensic entomology, leading to the earliest study of forensic study by Mackenzie in Calcutta. His study was based on the observation of dead bodies and the time that eggs and maggots are found on the body. One of the benefits that was discovered was the forensic entomologists' ability to use information from the arthropod population in myriad ways. They were able to find out the cause and the way in which the person died to determine the death location even if the body was moved.

When comparing the investigation of a crime scene by a pathologist to that of an investigation by a forensic entomologist, the pathologist is able to accurately determine the cause of death based on the body condition, lividity, rigor mortis, post mortem cooling and changes of the chemicals in the body. They can provide the estimated time of death as early as 24-36 hours. Forensic entomology is able to provide information over a longer period of time from hours to years. Although flies and beetles are the most prevalent species that are present on a body, there are also many species of Lepidoptera that are present at the different stages of decomposition, which are due to the smell of urine, excreta and nitrogenous fluids. The presence of these insects and the amount that are seen will help to determine the amount of time that has elapsed since the time of death. A fly "is not just used to solve murders, but also plays a significant role in detection of child abuse, neglect and rape" (Vass, 2001). Studies on the behavior of post

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

feeding by maggots reveal that blow fly larvae that were found in the field travelled 6-10 m dispersal, additionally the depth at which blowflies can be completely excluded is 2.5 m , and several dipteran species can be found approximately 6 m from the corpse or directly underneath it.

The use of molecular entomology is used to accurately identify insect specimens. Species that are similar can vary in size, diapause response and ecological habits. It is important to bear in mind that forensic investigation is relevant as the study of insects involves a great amount of forensic knowledge in taxonomy. Even though there are keys that are designed to help with identification, only a few experts are able to properly identify immature insects and this ability requires a lot of time and effort as certain insect groups are difficult to identify. Due to these factors it can delay investigation or cause a tremendous amount of roadblocks to solving homicides.

Because of these problems, the introduction of molecular entomology is used. APCR amplification of suitable regions of the genome and a sequence of the amplicon is obtained and is aligned to the data sequence, which is a recommended procedure. Studies showed that the recommended sequence of choice is mitochondrial DNA because all of the small pieces of its structure and evolution make it a preferable tool because of the ease of isolation, high copy number, lack of recombination, conservation sequences, and structure across metazoan, and mutational rates in the different regions of the molecule.

Case studies by Benecke made reference to a vacant and an occupied apartment during the winter. They reported that on November 6, 1995 they found the body of an

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

elderly Caucasian woman on the top floor of an urban building with her skin partially detached due to decomposition. Further reports indicated that there were a lot of adults flies but no evidence of maggots on the corpse (Benecke, 1998). The apartment was disinfected, sprayed with pyrethrum, and totally renovated. Two months later, at the end of February 1996, the new resident saw five puparia and six post feeding, slightly darkened larvae from blowflies. In the apartment of the deceased there were three weak and one ill green-metallic 7mm flies in the bathroom and bedroom, four puparia under floor ledge, and four dying adult flies in cracks of concrete on the balcony. This is unexpected because the two adult blowflies should have been killed by pyrethrum, they think that the rapid drop in temperature, which happened six days before disinfection, may have caused this manifestation and because the corpse was at the maximum stage of decomposition before it was found. This suggested that the female flies had laid their eggs sometime in mid- September, leading to some eggs being developed. As the temperature dropped in the beginning of November, several maggots went in search for a safe place to diapause (Benecke, 1998).

This mimics the behavior of many insects under unfavorable conditions. When the apartment was renovated the temperature was about 14 ° C which allowed the hatching and pupation of some flies, but due to low temperature, they were unable to fly away. Comparisons done on flies in the laboratory at 22°C showed normal flying behavior. This proves that the maggots originated from the dead body and hid in the cracks of the floor ledges before it was disinfected due to the sudden drop in temperature.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

A second case study was on a 38-year-old heroin user who had committed suicide at the end of November 1995 by putting her head on the rail and was decapitated by a moving train.

During the autopsy, they found within the decomposed mush and the uncovered bones, masses of yellow piophilid larvae measuring 8 mm and increasing to 50 cm in height. Also found on the dried skin and hair, pale yellow eggs were observed. The breeding room was poisoned during the breeding of the eggs, so they had to make their determination by using a single body part of an adult fly which revealed that it was *Pedophilia casei*, which are settlers of corpses three to six months postmortem. Due to the female ability to lay approximately 200 eggs, the sighting of a massive amount of eggs covering the body indicates that a first and maybe a second generation of cheese skippers hatched on the body. When the condition is right, *Piophila* eggs will mature between 11 to 19 days; a postmortem interval of 90 day plus 22 to 38 days was calculated. Reports later reveal that the woman was missing for four months

This shows that the development of *P. casei* is not shortened by the consumption of heroin, although the concentration of heroin could not be determined due to the condition of the corpse.

A crime scene that was visited by the police on May 8, 1996, arrested a man who had given information to the police who told them that he was afraid to report his wife dead for 29 days because he was scared of losing his apartment. After careful inspection of the body, the police found a larger amount of flies and larvae on the body, which was

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

dried and covered with blankets. The mean of the outside temperature was calculated at 10.9° C, along with the covering of the corpse and the insect production heat, it was discovered that the temperature inside was 20°C higher.

During the postmortem examination the examiner found a large amount of maggots within the vaginal tract, and hair, the maggots were washed away before they could be inspected by the entomologist. This shows that the victim had sex before she was murdered.

A 46-year-old alcoholic was found dead in a bathroom on August 4, 1996. Tests revealed that he was dead for five days and had a blood alcohol concentration calculated at 1.9 parts per thousand. The man had a history of high blood pressure, and his body was in a state of decay. Evidence of cluster flies was found in his beard and pubic hair. Several larvae 2-3 mm long was detected beneath skin bladders due to rotting. The presence of *Lucilia ceasar* females releasing on the body in the autopsy rooms, motivated the entomologist to pay a close attention to two dark red pupae measuring 6 mm that was fastened to the surface of the abdomen of the body.

Experiments of pupae bred at 17°C to 20°C saw two adult *Muscina stabulans* emerge measuring 9mm 14 days later and developed in 28 days at 16°C which indicates that the larvae were feeding on the man while he was alive or when he was unconscious". Winley explained how "insects help to solve murders; she made reference to Kim Martello whose body was found in a Palm Springs desert in 1991" (Winley, 2015). She

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

states that when investigators took forensic entomologist David Faulkner to where the corpse was found. He was surprised to "find maggots that were not common in the Palm Springs desert. This fact indicated that she was killed elsewhere and her body dumped in the desert". (Winley, 2015). This finding was strictly based on the sighting of the first infestation of urban insects, and then the desert insect infested after.

Because of the forensic findings, it helped investigators lead to the charge of a business partner for homicide; after compiling their findings with other evidence, they concluded that she was strangled in a warehouse and dumped in the desert. Dr. Jason Byrd, president of the North American Forensic Entomology Association, stated "that the diversity of insects is critical to solving crime he emphasizes the importance of understanding insects' ability to camouflage, mimic and defend themselves" (Winley, 2015). They use sound, chemicals and touch to communicate with each other. Additionally, they can be found everywhere and the different species and locations that they inhabit and where they are found enable entomologists to find clues for solving criminal cases.

Research done by the Association in San Diego Natural History Museum reveal that although insects can be used to determine when a person dies, they can also be a valuable tool for many other things. Interestingly, when a person dies, many different types of insects are attracted to the body, but the study of maggots and flies are the most significant when solving crimes. It is essential that when a person dies the tissues breaks

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

apart and cause gasses and fluid to build up, giving off a smell which alerts flies that there is a suitable place for them to lay their eggs. Scientists reveal that after a person dies, flies will immediately go directly to the body and eggs could be observed within about 20 minutes. In 2002, forensic entomologists along with four other entomologists were assigned to investigate the case of a boy whose decomposed body was found along a Deshesa Trail. It was due to this case and others that led to the forming of the North American Forensic Entomology Association. The organization was instrumental in setting the guidelines for forensic techniques. Although there are advantages of forensic entomology there are also disadvantages, one of the major concerns is that the growth rate of maggots can be affected by changes in temperature or geographical location. If the “temperature is below 40 degree it will prevent the flies from laying their eggs” (Whigham, 2013). Another factor that can affect the results is the presence of any substance in the body that would prevent the insects from breeding or breeding rapidly. According to Whigham, depending on the type of environment insects will colonize a corpse instantly. In Australia, when there is a need for forensic entomology in criminal cases, the authorities acquire the services of Professors Wallman and Archer because of their knowledge, expertise, and experience. According to the reports they were able to sometimes correct the police who might think that a person’s body was dumped the night before, by showing them evidence that the body was dumped two weeks before. Bushland facilities in some parts of the world are used by scientists for experiments, such as the one in Sydney that was established by Professor Shari Forbes as the only body

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

farm located outside the United States. Both scientists spend two days per week doing an experiment, which includes analyzing the temperature and monitoring the development of maggots, which prepares them for what to expect when they are involved in a real crime scene investigation.

In 1935, the famous case of an Indian born physician named Buck Ruxton who was believed to have killed his wife and maid in a jealous rage occurred. He had tried to hide his crime by chopping up the bodies and dumping the parts. After the remains were found, the maggots and specimens were collected and sent to Dr. AG Mearns who was able to establish the date that the parts were dumped. This was the first time that insect evidence was used in the United Kingdom, resulting in the conviction and execution of Ruxton. In July 9, 1997, a stepfather reported his stepchildren missing. According to the article two small human skulls were found two months later in a nearby cemetery. The entomologist that studied the presence of the blowflies that were found at the location looked at the pattern in which the eggs were laid and determined that the children were killed by asphyxiation.

They also used the climatological data and life cycle of the blowflies to conclude the time of death. In 2004 Vincent Brothers was accused of co-conspiring in the killing of his brother's wife, mother-in-law and three children in California, but provided an alibi, he stated he was not present during the time of death as he was in Ohio visiting family. The FBI agent doubted the story so they removed an air filter and radiator and sent it to UC Davis insect expert Lynn Kimsey, too check where the bugs came from in the grill.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

After she investigated she discovered that the bugs found in the radiator came from California and another area west of Colorado Rocky Mountains. She testified that there was no way that those insects would have been in Ohio. Based on the time of the year that the insects were present indicates that Brothers had driven to California, committed the crime and drove back to Ohio. She also pointed out that there was no daytime insects found, therefore the car was driven at night. As a result, was found guilty of five counts of murder in 2007 and sentenced to death.

Another noteworthy case is that of Jonathan Blackwell who worked for the Goodyear Plant in Virginia and went missing in October 2004; his remains were found in December 2006 near a barn in North Carolina. The location of the body had caused the entomologists to be curious. They were surprised that blowfly larvae were present on the body that was missing over two years.

They contacted Wes Watson, a professor at North Carolina State University, and he was able to determine that the body was buried elsewhere and his body dug up. Watson stated that the first grave may have preserved a portion of his body, leaving some tissue for new flies to be colonized, and based on his explanation the killer, known as Stacy Maurice Webster, turned himself in and was convicted in 2010.

The body of Kristine Switzer was found with bullet wounds in an abandoned house in Beltzhoover, Pennsylvania on May 4, 2014. The report further stated that because there were no eyewitnesses, investigators decided to call forensic entomologist William Todaro because of the enormous amount of maggots crawling on the deceased.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

Todaro was able to theorize that the murder had occurred sometime between April 25 and April 27 in another location and the body was dumped in the abandoned building, he also mentioned that due to ideal temperature conditions in the abandoned building, it was suitable for the flies to lay their eggs. He said "that although April is normally cool; fly activities are visible at temperatures above 45 degrees" (Mcmillan, 2014).

As a result, he was able to conclude a timeline by using the weather conditions and the developmental stages of the flies. Due to his findings, along with the confession from Lenora Maiolo, who testified that while she was smoking crack and driving around with Kristine Switzer and a drug dealer Augustus Stewart, she witnessed him shoot her. Because of her testimony, it led to Stewart being charged, and found guilty, of first-degree homicide.

A review that was done by forensic scientists in the Egyptian Journal explained the advancement in forensic entomology, some of the complications, the methods that are used to estimate the post mortem, and the problems that can occur. The study states that measuring for estimation of the postmortem interval is based on the succession of the arthropod species on carrion. Because the succession of the communities of insects that will come to a body will vary based on the geographical location, it is recommended that successional analysis be used to estimate both the minimum and the maximum post mortem intervals. They state that the species will frequently occur in succession, and response to the different stages of the decomposition will vary. In addition, post mortem interval estimate is relevant to the remains in the more

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

advanced stages of decomposition. The review states that limitations are important when applying entomological evidence to the post mortem interval based on the state of succession.

The review recommends that it is important to properly identify the species of insects that are associated with the carcass, and that the succession patterns are typical for seasonal periods. Additionally the insect life cycles act exactly like time clocks, which occur immediately after death. The adult insect is drawn to the carcass by the odor of the decaying cadaver, and lays its eggs, from which the first instar will hatch. It then undergoes molting and forms the second, then third instar, which starts to move away from the carcass. According to radiological tests, an examination from the review shows that feeding behavior of the maggots stopped immediately after they reached their maximum length. While they are developing, their anterior intestine will remain empty. This report on the intestinal filling in blow fly maggots reinforces the fact that the post mortem estimate can be accurately estimated. The report also states that the entomological method based on statistics is more reliable compared to other commonly used methods. The formula that is used to calculate the time a person dies that can also be used to calculate from the stage of the insects' presence on the carcass is $T=A + B \times C$, where 'A' represents the stage of invasion, 'B' represents the stage of the life cycle, and 'C' the climate factor correction". The study calculates "the crawling speed of larva by using this equation $\text{speed (cm/ min)} = 5.45 \times \text{long [length (mm)} + 0.66 \times \text{temperature (degree C)} - 12.8$ "(Sharma, 2015).

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

Determining the size of the maggot is imperative in establishing when the blowflies first come to the body, since the developmental stage of the larvae dictates how and when they disperse to look for the perfect place to pupate. Further studies showed that the larvae crawl at faster speeds when the temperature increases. Moreover, speed increases as a function of body length, which is used to estimate the time that passes after the larva leaves the corpse. This time evaluation can help to provide a more accurate post-mortem-interval estimation. An ontogenetic study shows that hydrogen carbons are also found in insects' cuticles, which are seen in long chains with carbon atoms varying from 21 to 35 carbons. The study also uses volatile compounds to determine how the age of flies can play a vital role in estimating the age of the blow fly larvae and pupae.

The study was done “using a handheld solid phase microextraction, followed by gas chromatography mass spectrometry. This enabled the scientist to see that there are branched and unbranched hydrocarbons, alcohols, esters and acids present in the volatile organic compounds” (Dadour, 2011). According to Dadour, insects are found everywhere, based on their presence in the world and the fact that they are the largest groups in the animal kingdom” (2011). Blowflies normally stay away from animals until they are dead, comatose, unconscious, or in cases where people are intoxicated.

However, there are exceptions, sheep blowfly and myiasis flies strike live animals.

According to Dadour the discipline forensic entomology has developed into modern day treatment with maggot therapy. This theory is used as an alternative if antibiotics don't work; this phenomenon is administered with the placing of sterile

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

maggots into gangrenous wounds. Also, there are two other areas in which forensic entomology plays a role; (a) urban entomology, which is used in civil cases where structures are damaged by insects such as termites; these types of cases are commonly used with the reduction of the dangerous insecticides in the environment which do not have any real protective barriers against insect attack. (b) Stored product entomology, which is used in cases where insects infest commodities like floors, open bags of fruits, and nuts. According to Hall (1995), “forensic entomology intersects between insect science and the legal system” (Hall, 1995). Most of the attention has been placed on medicocriminal entomology, which is dependent on insect development and succession on corpses, however there are other areas of forensic entomology where insects have legal benefits.” (Hall, 1995). Insects such as powder post beetles can cause major damages to wooded structures and can lead to various civil issues.

In addition, larvae from clothes moths can cause damage to stored garments and dermestids are also responsible for destroying and damaging furs, which result in lawsuits. There are some controversies and concerns that face forensic entomology on the post-colonization interval (PCI) and period of insect activity (PIA) with regard to the postmortem interval (PMI) based on the entomologist evidence. Letters that were sent to Dr. Wells with questions about the practical implications of PCI and PIA, which was defined by Tomberlin et al. (2011) in relation “to guides to basic research, which it was in agreement with is suggesting that no forensic entomologist should use those definitions unless he or she has fully explained in the report the exact meaning” (Carlo P.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

Campobasso, 2014). The letter states that although Campobasso et al. (2005) did not give a precise meaning for PIA the way in which the authors used the terms clarified the phrase and compared the age of the oldest larvae found on the corpse. The technique that was developed by the use of minimum PMI that is occurs after the onset of decomposition.

A documented protocol for the best practice in forensic entomology “warned experts that PIA is not the actual time of death and does not always correspond to PMI. The letter further goes on to say that the risk of controversial and unclear terminology used in forensic entomology was clearly argued” (Villet & Amendt, 2011). They discovered and showed illustrations with diagrams that explain a wide difference in the definition of ‘death’. Based on their demonstration, it showed that there is a large amount of variations in the meaning, which can be easily confused with research practice. They pointed out that the need for standardization and harmonization is mandatory when establishing standards and common language to practice research. Moreover, almost all areas of science have problems when technical phrases are used incorrectly and because of these findings, the scientific community periodically reviews several terms. Therefore, “the estimation of PMI by the forensic entomologist must be accomplished in a reliable and dependable method” (Carlo P. Campobasso, 2014). They state that when insects are associated with the body, the entomological method can introduce some more quantitative information to estimate the PMI based on the duration of insect development,

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

but PMI estimations from insect evidence must include considerations of number of factors affecting decomposition as well as insect colonization and development.

Because insects are found everywhere and attack dead matter that is deposited on the face of the Earth, it is absolutely clear that insects play a very important role in forensic entomology and crime fighting techniques. With continuous research and experiments, forensic insects will eventually become the leading tool in crime scene management.

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

- Anderson, D. G. (2006, May 24). *Nature*. Retrieved January 21, 2018, from Crime Scene Creatures: <http://www.pbs.org/wnet/nature/crime-scene-creatures-case-files/297>
- Benecke, Mark D. B. (1998). six Forensic Entomology Cases: Description and commentary. *ASTM International*.
- Campobasso, Carlo P., F. I. (2014, May 01). Influential article collection. *Journal of Medical Entomology*.
- Cherry, R. (2011). *Insects and Death*. Retrieved January 20, 2018, from MusingS: <https://academic.oup.com/ae/article-abstract/57/2/82/6492>
- Dadour, I. (2011, August 16). *Forensic entomology: the time of death is everything*. Retrieved January 21, 2018, from The Conversation: <http://thecoversation.com/forensic-entomology-the-time-of-death-is-everything-2037>
- Forensic Entomologist*. (2014). Retrieved 2018, from Purdue University, College of Agriculture, Department of Entomology: <https://www.extension.entm.purdue.edu/radicalbugs/index/index.php?page=forensic-entomologist>
- Gaines, Allison. (2014). *The Emerging Interface of Entomotoxicology, Forensic Entomology and Decomposition in Modern Crime Scene Investigation*. Retrieved January 27, 2018, from Medico- legal Death Investigator: <http://gaines/spring/2014>
- Gardner, R. M. (2005). *Practical Crime Scene Processing and Investigation*. Boca Raton, Florida, USA: CRC Press LLC.
- Goff, M. L. (2000). *A Fly for the Prosecution*. (New York Times) Retrieved January 27, 2018, from Havard University Press: <http://www.nytimes.com/books/first/g/goff-fly.html>
- Hall, R. D. (1995). *Encyclopedia of entomology*. Retrieved February 24, 2018, from Forensic entomology : applications in medicolegal investigations: <https://links.spinger.com>
- Issac Joseph, D. G. (2011, July-December). *The use of insects in forensic investigation: An overview on the scope of forensic entomology*. Retrieved January 23, 2018, from Journal of Forensic Dental Sciences: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3296382>
- Mangels, J. (2009, November 10). *At crime scenes such as the home of suspected serial killer Antony Sowell, bug expert Joe Keiper uses insects as clues*. Retrieved January 28, 2018, from http://blog.cleveland.com/metro/2009/11/post_111.html
- Mcmillan, C. (2014, November 19). *10 Ways Creepy-Crawlies Helped Solve Heinous Crimes*. (Connatix, Producer) Retrieved January 25, 2018, from <https://lisverse.com/2014/11/19/10-ways-creepy-crawlies-helped-solve-heinous-crimes>
- O'Connor, B. M. (2015, February 2015). *Forensic Entomology is more than just Blow Flies and Beetles*. Retrieved January 27, 2018, from Entomology Today:

Johnnie Erskine
Professor Bauer
August 1, 2018

Final Project
How do Entomologists use insects to determine PMI

- <https://entomologytoday.org/2015/01/22/forensic-entomology-is-more-than-just-blow-flies-and-beetles>
- Perry, W. (2011, November 11). *Live Science*. Retrieved January 27, 2018, from Bugs of Death May Help Solve Crime: <https://www.livescience.com/16987-blow-flies-csi-forensics.html>
- Ruchi Sharma, R. K. (2015, May 1-12). *Various Methods for estimation of post mortem interval from Calliphoridae: A review*. Retrieved January 20, 2018, from Egyptian Journal of Forensic Sciences: <http://www.journals.elsevier.com/egyptian-journal-of-forensic-science>
- Sanford, M. R. (2013-2016, January). *Plos*. Retrieved January 23, 2018, from Insects and associated arthropods analyzed during medicolegal death investigations in Harris County Texas USA: <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179404>
- Vass, A. A. (2001, November). Beyond the grave- understanding human decomposing. *Microbiology Today*, 28.
- Verma, K. (2013, March 25). *Entomology, Ornithology & Herpetology: Current Research*. Retrieved January 20, 2018, from Assessment of Post Mortem Interval, (PMI) from Forensic Entomotoxicological Studies of Larvae and Flies: <https://www.omicsonline.org/assessment-of-post-mortem-interval-pmi-from-forensic-entomotoxicological-studies-of-larvae-and-flies-2161-0983.10001>
- Whigham, N. (2013, August 13). *Australia's weidest job: How forensic entomologists use insect clues to assist crime investigation*. Retrieved January 27, 2018, from <http://www.news.com.au/technology/science/animals/australias-weidest-job-how-forensic-entomologists-use-insect-clues-to-assist-crime-investigation>
- Winley, L. (2015, January 10). *How Insects help solve murders*. Retrieved January 21, 2018, from <http://www.sandiegouniontribune.com/sdut-forensic-entomology-bugs-murders-2015jan10-story.html>
- Winter, D. B. (2010). *Forensic Entomology or the use of Insects in Death Investigations*. Retrieved January 26, 2018, from SFU Museum of Archeology Ethnology: virtualmuseum.ca