Insects: As a tool in forensic inquiries

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Introduction

With about two million of described species, insects comprise the largest metazoan class. They are found in almost all habitats. One such habitat providing an excellent food source for more or less specialized insect communities is vertebrate corpses. In addition to their ecological importance in decomposition, they also represent as an important tool in criminal investigations especially in estimating the time since death based on insect colonization on cadavers. Several flies, beetles, soil mites and other invertebrates are associated with cadavers, in particular, blowflies, Calliphoridae among the first to colonize on cadavers, which serve as a biological clock in measuring the time of death for two or more weeks. Such an entomologically-based estimate is more precise than the medical examiners, which is limited to the first 72 hours of death. Hence, utilization of naturally inhabiting insects and other arthropods in medico-criminal investigation is often termed as forensic entomology.

Blowflies are olfactorily attracted to remains within hours of death as both a source of protein for egg development and a site for oviposition. Insect succession patterns are also closely linked to the progression of carcass decomposition and as such, while a continuous process, decomposition can be defined into distinct stages which are linked to specific insect groups used as markers for the estimation of PMI. In addition it provides other valuable information concerning the circumstances surrounding the victim's demise, including the season of death, location of death, movement or storage of remains after death, specific sites of injury on the body, post mortem artefacts on the body, use of drugs, and can even crime, to a child neglect or sexual molestation case, as well as in the identification of suspects.

Stages of decomposition

Usually decomposition of human cadavers is classified into five stages in relation with the arthropod succession on the cadaver as fresh, bloated, decay, post decay and dry

stage. In fresh Stage, after the putrefaction, the body begins to smell, different types of insects are attracted to the dead body. The insect that usually arrives first is the Diptera, in particular the Calliphoridae. The females lay their eggs on the body, especially around the natural orifices such as the nose, eyes, ears, anus, penis and vagina. In a bloated Stage, cadaver begins to swell due to excess gas production by putrefying bacteria. Adult blowflies are no longer attracted but large masses of maggots feeding externally and internally and predators and parasitoids of maggots arrive at the site in decay stage. The cadaver starts drying and a large number of maggots left the cadaver for pupation in case of post-decay stage. In the final stage (dry Stage) of decomposition skins and bones left. During this stage the insects have the ability to digest keratin, like dermestid beetles that attend the cadaver.

Insect succession on buried corpse

Payne *et al.* (1968) reported that during the fresh stage, ants especially *Prenolepis imparis* feed actively on blood and exposed moist skin at the mouth, abdomen and ears. Ants followed by diptera (*Leptocera spp* and *Metopina subarcuata*) dominant during bloat stage and Psychodidae dominant by the end of bloating stage. In the deflation stage, numerous maggots' feeds on the corpse which attracts the predators and parasites that feed on the fly maggots. This is followed by the disintegration stage where the larvae of Psychodidae, phorid and sphaerocerid are active around the remaining soft tissue. Mites, springtails, cryptophagid beetles and millipedes also appeared. The colonies of fungi and bacteria now cover the corpse. The maggots migrate from the carcass at the end of this stage. At the time of 30-60 days, mites *Caloglyphus* spp. and collembolan, *Hypogastrura armata* are the main scavengers. Finally, ants, collembola and mites are dominant fauna during the skeletonization stage.

Insect succession on immersed corpse

Simpson (1985) reported that decomposition is retarded in water because body heat is lost twice as fast as in air. He also gave valuable information on the fate of ectoparasites of potential forensic value. Fleas are drowned in about 24 hours but if immersed for only 12 hours they require about an hour to revive and after 18-29 hours immersion a period of some four to five hours. Body lice usually die in 12 hours following immersion. Blow fly larvae if already present on a body when immersed will not survive for long and if still alive may thus indicate recent removal from another site.

Factors influencing the insect succession on carrion

The geographical region of the country and type of terrain within a given country will affect the composition of fauna and rate of decomposition. In Polar regions available carrion fauna is less. While in tropical regions we can find a richer number of carrion feeders. The major factor controlling the oviposition and rate of development of necrophagous insects are temperature and humidity. The cold weather and rain inhibit the fly activity. The thermal death points for most of the carrion insects ranges from -15 ^{0}C to 30 ^{0}C. Some insects prefer light *i.e.* positively phototropic or may avoid the light *i.e.* negatively phototropic. This may affect the particular insects present on the corpse. It is well known that the two commonest genera of blow flies associated with carrion, bluebottles (*Calliphora*) prefer shady conditions and greenbottles (*Lucilia*) prefers sunlight. Different insects occur at different times of the year or day and are said to have different flight periods. A corpse exposed in the spring and summer will have a richer and different fauna from the one exposed in the winter when the faunal succession is absent. Corpse exposed during the winter, when no blowflies are about, will have smaller fauna consisting of ground level insects such as beetles. The competition may be either intra or inter specific. Early arrivals ovipositing on a corpse, especially blow flies will have advantages over late arrivals such as *Sarcophaga* and *Chrysomya spp.* Some dipteran larvae may be carrion feeders at the first and become predators in the second and third instars

Application of insects in forensic investigation

Estimating the minimum post-mortem interval: Post-mortem interval (PMI) refers to the time between the death and discovery of a corpse. There are several natural processes associated with decomposition, such as rigor mortis or livor mortis, that can be used to estimate the PMI, but many of these are reciprocal functions and become inaccurate in application very quickly. Furthermore, they are limited to the first 72 h after death. However, during that 72 h and well beyond, insects can be a very powerful tool for estimating the minimum time since death. Usually the first taxa to arrive on a body are flies, mainly blow flies (Calliphoridae), which can locate an odor source with great spatial precision and deposit their eggs on a corpse within minutes–hours of death. Larvae (often called ‘‘maggots’’) hatch from the eggs and feed on the underlying tissues. Decomposition as a result of insect activity in and on the corpse is a continuous process that can be measured, allowing accurate minimum PMI estimates to be made up to several months after death depending on the circumstances. The estimation of PMI is done by two means one is that by calculating the age

of developing insects on a body, it is possible to calculate the time of colonization, which infers a minimum PMI ($PMI_{min.}$) *i.e.* the time when insects first colonized the body, rather than the actual time of death. Another important biological phenomenon that occurs on cadavers is a succession of organisms that thrive on the different parts.

Detection of drugs in insects (Entomo-toxicology): The potential use of insects as alternative samples for detecting drugs and toxins has been well studied. Fly larvae and pupae are often found on decomposing bodies. In such badly decomposed bodies, these immature stages and their remnants are not only useful for estimating the PMI_{min}. but they can also be used as a reliable substrate for toxicological analysis and can sometimes provide a more suitable bio sample without any decomposition interference. Most of the substances involved in drug-related deaths are detectable through analyses of maggot's opiates such as morphine and codeine, cocaine and benzoylecognine, amphetamines, tricyclic antidepressants, phenotiazines and benzodiazepines, steroids, barbiturates and several salicylates such as paracetamol. Drugs and toxins have also been detected through analyses of empty puparium cases and even beetle exuviae and fecal material.

Post mortem transfer: Post Mortem transfer refers to the movement of the body from one place to another after death. After death, a succession of fungi, bacteria and animals colonize the dead body. The substrate on which the body is lying also changes over time. Leakage of fluids from the dead body leads to the disappearance of certain insects, and other insects increase as the time goes. A forensic entomologist can then look for how long the body has been there by looking at the fauna at the body, and also estimate the time the body has been lying there by sampling soil insects underneath the dead body. If there is a difference in the estimates, and the analysis of the soil suggests a short PMI, and the analysis of the body fauna suggests a longer PMI, one can suspect that the body has been moved. One can also see that a body has been lying at a particular place long time after the body has been removed, both by botanical means, and by analysis of the soil fauna.

In investigation of contraband trafficking: Many arthropods are found together with stored products, even such products as narcotics and other drugs. Since illegal drugs are often made in one country, and sold in others, it can be important to find out where the drugs were produced. Sometimes, insects and other arthropods can be found together with the drugs. If these insects are determined, and the world distribution of the different insects are plotted on a map, one can by analyzing the degree of overlap, find out approximately where the drugs

came from. If one looks at the biology of the insect species found with the drugs, one can also often say something about the surroundings where the drugs were produced or packed.

Link between the suspect and the crime scene: Sometimes there will be no clues of crime during that time entomological evidence plays an important role in linking between the suspect or victim to the crime scene. For example, mosquitoes (Culicidae) are widespread insects and those found at the crime scene can be a useful source of human DNA. DNA derived from mosquitoes helped in solving a crime.

Limitations

1. Delay in insect colonization lead to an underestimate of PMI: Several parameters can lead to a delay in colonization (e.g. the wrapping of the corpse, low temperature, rain, burial, or the inactivity of most flies at night) which can lead to an underestimate of PMI $_{min}$.
2. Effects of drugs and toxins on the rate of insect development may lead to errors in PMI estimates.
3. Myiasis can be a significant point of confusion, because the period of insect activity could be far longer than the actual PMI. The possibility of a pre-mortem myiasis infestation must always be borne in mind by forensic entomologists. If the infestation on a body was initiated before death, then assuming incorrectly that it started after death would clearly lead to an inaccurate estimate of PMI $_{min}$.
4. Misleading of postmortem artifacts by insects as antemortem injuries, Campobasso *et al.*, (2009) explained that the injuries made by *Solenopsis geminata* Hymenoptera ant can be easily misinterpreted as antemortem abrasions.

Conclusions

The forensic entomology is an emerging field in the forensic sciences and have a new discipline which needs to be emphasized, since it has become an important tool in criminal investigations of homicide, suicide, and other violent crimes. Insect evidence collected from the body of a victim, when properly collected and analyzed by trained forensic investigators, can provide valuable information like determination of post mortem interval, the toxicological examination of insects found on corpses may reveal the cause of death, identity of victim and even linking the suspect to the crime. Insects' databases are still needed for many parts of the world. Therefore, study of succession should be conducted in many parts of the world and regional data should be created.

Common insects occurring on dead bodies

	
Fig 1: House Fly, Wikipedia	**Fig 2: Black Blow Fly, BugGuide.Net**
	
Fig 3: Green Bottle fly, Wikipedia	**Fig 4: Blue Bottle Fly, Wikipedia**
	
Fig 5: Flesh fly, Wikipedia	**Fig 6: Hairy Maggot Blowfly, Wikipedia**
	
Fig 7: Humpbacked fly, Britannica.com	**Fig 8: *Metopina subarcuata*, BugGuide.Net**
	
Fig 9: Sap Beetle, BugGuide.Net	**Fig 10: Carrion Beetle, BugGuide.Net**
	
Fig 11: *Prenolepis imparis*, AntWiki	**Fig 12: *Hypogastrura armata*, Collembola.org**

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