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Monika
Department of Veterinary Parasitology, College of Veterinary and Animal Science, Bikaner, Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan, India

Gayatri Gujar
Department of Veterinary Parasitology, College of Veterinary and Animal Science, Bikaner, Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan, India

Avinash Kumar Chouhan
Department of Veterinary Parasitology, College of Veterinary and Animal Science, Bikaner, Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan, India

Durga Bai Sodha
Department of Veterinary Parasitology, College of Veterinary and Animal Science, Bikaner, Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan, India

Bhavana Rathore
Department of Veterinary Parasitology, College of Veterinary and Animal Science, Bikaner, Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan, India

Corresponding Author:
Monika
Department of Veterinary Parasitology, College of Veterinary and Animal Science, Bikaner, Rajasthan University of Veterinary and Animal Sciences, Bikaner, Rajasthan, India

Forensic entomology: Insects as evidence

Monika, Gayatri Gujar, Avinash Kumar Chouhan, Durga Bai Sodha and Bhavana Rathore

Abstract
Forensic entomology is basically the use of necrophagous insects, and their arthropod relatives that inhabit decomposing remains to aid in legal investigations. Forensic entomology can be useful to the veterinary professionals in vetero-legal cases viz. animal cruelty or illegally killed wild animals. Forensic entomology is based on the principle of determining minimum postmortem interval (PMI) by estimating the time of insect colonization, based on knowledge of the rate of development of pioneer colonizers and on insect species succession during decomposition of animal remains. Time of death can often be ascertained based on the ambient temperature and other weather conditions over the preceding days at the crime site and by correlating this information with the developmental rates of key arthropod species present on, or in, the corpse. These arthropods are typically fly larvae, some of which are important primary and secondary decomposers of animal remains. By knowing developmental biology of decomposer species at different temperatures, it often is possible to quite accurately estimate the time of death.

Keywords: Forensic entomology, insects, legal veterinary medicine, postmortem index

Introduction
Forensic entomology is study of the succession pattern of developmental stages of different species of arthropods found on the decomposed cadavers and most commonly associated with use in death investigations. It is an instrumental tool to scientifically estimate the time elapsed since death. Although entomology has been used at crime scenes for centuries, research in recent decades has resulted in a significant advance of forensic entomological knowledge [1, 2, 3]. The use in legal veterinary medicine is however limited and the literature available from human death or abuse investigation is applicable to the veterinary arena [4]. Insect and arthropod evidence can assist in estimation of the postmortem interval (PMI) by the time of insect colonization, based on knowledge of the rate of development of pioneer colonizers and on insect species succession during decomposition of animal carcass [5, 6, 7, 8, 9]. Forensic entomology can serve as indicators of perimortem and postmortem treatment of remains, and demonstrate neglect in both humans and animals [10] and can be used to create associations between a suspect, a victim, and a crime scene. In some instances, it can aid in the detection of drugs or toxins within decomposed or skeletonized remains [11, 12]. While there is a bulk of forensic entomological applications in human death investigations, forensic entomology cases involving animals are limited but gaining momentum in recent years [13].

Insects as evidence: Most insects used in investigations are in two major orders:

1. Flies viz. Blowflies, Flesh Flies, House Flies, Cheese Skippers (Diptera)
2. Beetles viz. Carrion Beetles, Dermestids and Scarab Beetles (Coleoptera) [14]

After death: As the body decays, odors attract insects to the dead body. Levels of putrescine (decomposing enzyme), sulfur and methane compounds send up an "open for dinner" flare [15]. The flies (order Diptera) are the first to arrive. Blowflies (*F. calliphoridae*) and flesh flies (*F. sarcophagidae*) are flesh feeders and will be the first in line and arrive within minutes or up to a couple hours after death. There is tremendous competition among organisms, especially in the early stages of decomposition as cadaver is a very rich but ephemeral (short-lived) resource.

Succession: Different groups of arthropods are adapted to different decomposition stages of a investigators. Some species may prefer to feed on a fresh carcass, while another species may

prefer to feed on one that has been dead for two weeks. Investigators will also find other insect species that prey on the insects feeding on the corpse.

Table 1: Succession of different arthropod species

Succession wave	Principle insect fauna	State of corpse	Age of corpse
1	Flies (blow flies)	Fresh	First 3 months
2	Flies (blow flies and flesh flies)	Odour	
3	Dermestid beetles	Fats are rancid	3-6 months
4	Various flies		
5	Various flies and beetles	Ammonia fermentation	4-8 months
6	Mites		6-12 months
7	Dermestid beetles	Completely dry	1-3 years
8	Beetles		3+ years

Taken from Smith, K.G.V. 1986, A manual of forensic entomology. Cornell Univ. Press, Ithaca, NY.

Five Stages of Decomposition as described by Anderson (2011) [16]; Battan *et al.* (2010) [17] and Goff *et al.* (2010) [18].

A. **Fresh Stage (Days 1-2):** Commences at death, ends when bloating is first evident. Breakdown of protein and carbohydrates into simpler compounds. The larvae of the Calliphoridae are responsible for consuming most of the soft tissue on remains, in just few days [19].
B. **Bloated Stage (Day 2-6):** Cadaver begins to Putrefy and gasses produced by anaerobic bacteria inflate the abdomen. Flesh flies appears during this stage while Blowflies are still ovipositing.
C. **Decay Stage (Days 5-11):** Abdominal wall breaks allowing gasses to escape and decomposition fluids seep from body reducing carcass to about 20% of its original mass. Adult blowflies no longer attracted. Large masses of maggots can be observed feeding externally and internally. Predators and parasitoids of maggots arrive.
D. **Post-decay Stage (Days 10-25):** Cadaver begins to dry out and large maggots leave the carcass. Mite and predatory beetle populations increase. Hide beetles are dominant in dry environments. In dry habitats, remains are skin, cartilage, and bones whereas, in wet habitats, wet, viscous material in the soil under the remains can be found.
E. **Dry Stage (Days 25+):** Only skin and bones can be found at this stage. Insects with the ability to digest keratin (clothes moths and Dermestid beetles). However, in a wet region, maggots will stay longer and hide beetles will not appear. The corpse is reduced to at least ten percent of the original mass.

What do forensic entomologists do?

Forensic Entomologists apply their knowledge of entomology to provide information for criminal investigations.

A forensic entomologist's job may include:

- Identification of insects at various stages of their life cycle, such as eggs, larvae, and adults.
- Collection and preservation of insects as evidence.
- Determining an estimate for the postmortem interval or PMI (the time between death and the discovery of the body) using factors such as insect evidence, weather conditions, location and condition of the body, etc.
- Testifying in court to explain insect-related evidence found at a crime scene.

Post-Mortem Interval (PMI): PMI is elapsed time from a death to the discovery of a cadaver. In order to calculate the PMI accurately, first collect and identify the species of insect correctly and develop a lifecycle model of the fly and calculate the age of the insects. Most species are identified by using a classification key. They cannot be identified easily just by viewing a photograph of them. Fly development is structured into stages and each stage requires a certain amount of time to complete the development as it is temperature dependent. At warmer temperatures the rate of development is fast whereas, at cool temperatures it slows down [20].

The process of decomposition itself is highly dependent on degree day accumulation [21]. Using a simple formula to calculate degree-day accumulation for a species with a 10 °C threshold.

$$\frac{(DailyMax-10)+(DailyMin-10)}{2}$$

***If max or min is less than 10, then enter zero**

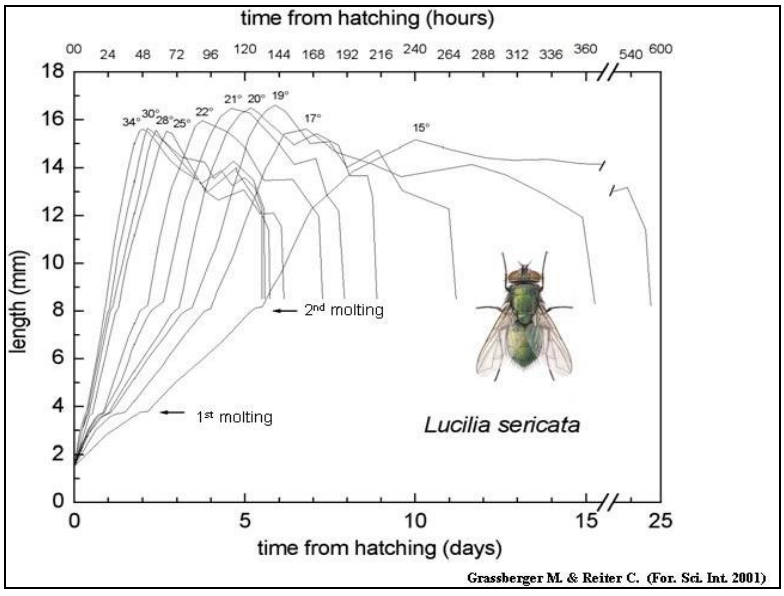

Fig 2: Temperature-Dependent Development of Flies

Conclusion

The future of forensic entomology depends on identification of the new insect species in various ecosystems. Entomotoxicology could also serve as an important tool for identification. The presence of toxins in the invertebrate decomposers can be detected and is used as a method of finding the cause of death. There is a need to enhance the awareness regarding forensic entomology among veterinarians by introducing teaching and specialized training and establishing systems and protocols, similar to those used in human forensic medicine.

Conflict of interest

We declare that we have no conflict of interest.

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