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Role of insects in environment with special reference to forensic science

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Abstract
Insects are the dominant group of animals on earth today. They occur practically everywhere and far outnumber all other terrestrial animals taken together. They create the biological foundation for all terrestrial ecosystems. They cycle nutrients, pollinate plants, disperse seeds, maintain soil structure and fertility, control populations of other organisms, provides food besides having great utility in the field of medicine and forensics. Forensic entomology is a science, which applies knowledge of insects (and other arthropods) to civil proceedings and criminal trials. The applications of Forensic Entomology are numerous, encompassing any situation that may involve an interaction between insects and other arthropods, and the law. Therefore, the utility of the field includes in the areas like; urban, stored product and medico legal. The principle underlying this science is to establish the time of death, known as postmortem interval (PMI) by knowing the life cycle of insect species and evaluating the insect succession waves present on the corpse at any given time *viz a viz* movement of the corpse, manner and cause of death and association of suspects at the death scene. The Forensic Entomology in India is in its infancy state and few workers are doing their research in this field. Despite the enormous usefulness, little work is done in our country as our court of justice didn't include use of Forensic Entomology as a legal proceeding under Article 138 of Evidence Act of IPC. Therefore, in this article we will briefly discuss the role of insects in environment with special focus on their application in forensic science in India.

Keywords: Insects, Pollination, Natural enemy, Forensic entomology, PMI, India

Introduction
Arthropods are by far the largest and most important biological group on Earth (they outnumber even plants), they occur everywhere and perform important biological functions that support the whole living system on our planet. They perform pollination (Dar *et al*. 2016) [13], recycle nutrients, maintain soil structure and fertility, control populations of other organisms, provides food besides having great utility in the field of medicine and forensics, thus their presence at crime scenes opens a wide range of applications for forensic entomology (Turchetto and vanin, 2004) [43].

Role of Insects
Insects are important because of their diverse roles they have in the environment (Scudder *et al*. 2017) [36]. The dominance of insects in the living world has been central curiosity to many fields of research. Insects create the biological foundation for all terrestrial ecosystems, however the major of them act as pests (Dar *et al*. 2015) [10] in agriculture. Insects have evolved unique features in the animal world that are a surprise to experts in biomechanics and bioengineering because many are recent inventions of humans. Insects have been in competition with humans for the products of our labor ever since cultivation of soil began.

The role of insects in environment is explained briefly under following heads
1) Insects as Natural enemies
Natural enemies are insects that eat other organisms that we consider as pests of crops and other commodities. Broadly the natural enemies are categorized as following:
a) Predators
b) Parasitoids

Predators consume their prey after killing, includes some well known members like lady beetles (lady bugs) as well as some lesser known insects such as lacewings. Parasitoids are like parasites because the feed off a host, but, unlike parasites, parasitoids kill their hosts. Many have parasitoids that attack them, for example, wasps or tachinid flies. They deposit their eggs near, on, or actually inside their hosts, larvae hatch and feed on the host, either inside or attached on the outside until they are ready to pupate. In a home or school garden, the parasitoids you are most likely to interact with are aphid parasitoids. These are tiny wasps that lay their eggs inside of aphids. The larvae eat the aphid from the inside out, then for a cocoon in the shell of the aphid. At this stage the aphid appears hard and is a different color from a healthy aphid; this is called a mummy.

2) Ecological balances

Ubiquity of insects means they are a foundational link in food webs and ecosystems. Researchers have showed that over 40% of insect species could go extinct in the next few decades, with butterflies, bees and dung beetles most affected. Insects' collective mass-the estimated weight of all insects on Earth combined-is dropping by an estimated 2.5% every year. Insect population collapses have recently been reported in Germany and Puerto Rico, but the literature strongly indicates the crisis is global. It is observed that four broad issues as the global problems leading to insect loss are: Habitat destruction (Dar *et al*. 2017a) [11]; expansion of agricultural pollution, extensive use of pesticides, fertilisers, and industrial waste; parasites and pathogens and climate change; that together had already caused other disturbances too; therefore world over thrust is given to organic farming using organic fertilisers and biopesticides and other botanicals (Dar *et al*. 2014) to save insect habitat and diversity. However, if nothing is done fast enough, the very foundations of our planet's ecology will be threatened, and with that, humans, too.

3) Pollinators

Bees are most recognized pollinators plainly adapted to pollination. Bees are typically are fuzzy creatures and carry an electrostatic charge, as the features to adhere pollen grains to their bodies, but they also have specialized pollen-carrying apparatus in the form of a structure known as the Scopa, on the hind legs of most bees, and/or the lower abdomen (for example, in megachilid bees), made up of thick, plumose setae. In most recognized pollinators, Honey bees and Bumblebees scopa is absent but a more specialized structure called corbicula, also known as pollen basket is present. Bees gather nectar, a concentrated energy source, and pollen, which is high protein food, to nurture their young and store some for dearth periods. The bee species *Euglossine* pollinate orchids, male bees collecting floral scents rather than females gathering nectar or pollen. Female orchid bees act as pollinators, but of flowers other than orchids. Eusocial bee such as honey bees need an abundant and steady pollen source to multiply and feed massive brood populations. Some insects other than bees accomplish pollination by visiting flowers for nectar or pollen, or commonly both. Many do so adventitiously, but the most important pollinators are specialists for at least parts of their lifecycles for at least certain functions. For example, males of many species of hymenoptera, including many hunting wasps or Jacket wasps, rely on freely flowering plants as sources of energy (in the form of nectar) and also as territories for meeting fertile females that visit the flowers, examples are Sphecidae, Vespidae, Pompilidae. The pollen wasps is solitary, belong to subfamily of the Vespidae, specialise in gathering pollen for feeding their larvae, carried internally and regurgitated into a mud chamber prior to oviposition. Bee flies, Tabanidae and Nemestrinidae pollinate fynbos and Karoo plants with narrow, deep corolla tubes through long probosces. Lepidoptera also pollinate plants to various degrees, having less abundance and less visitation (Dar *et al*. 2015; Dar *et al*. 2017b; Dar *et al*. 2018) [10, 14, 9] therefore are not major pollinators of food crops. However, various moths are important pollinators of other commercial crops such as tobacco. Pollination by certain moths may be important, however, or even crucial, for some wildflowers mutually adapted to specialist pollinators, examples include orchids dependent on a particular Hawk moth, Morgan's sphinx. Yacca exhibited an elaborate ecological interaction with particular species of Yacca moth for fertilization. Beetles visiting flowers for various resources and perform cross-pollinators of some plants species Araceae and Zamiaceae. Pollination by insects is an important function contributing 38% of the total food items sheared but management of diseases (Ullah *et al*. 2020) [44] and conservation of bees is very important (Dar *et al*. 2017c) [12] to sustain continues production of food crops.

4) Maintenance of Soil condition

Healthy soil perform the functions of nutrient cycling and pest suppression as an indication of its potential. The contributions of soil micro-arthropods to soil health through their intersecting roles in decomposition and nutrient cycling and direct and indirect suppression of plant pests are well known. Arthropods can impact soil and plant health directly by feeding on pest organisms or serving as alternate prey for larger predatory arthropods. Indirectly, micro-arthropods mediate the ability of crop plants to resist or tolerate insect pests and diseases by triggering induced resistance and/or contributing to optimal nutritional balance of plants. Soil fauna, including micro-arthropods, are key regulators of decomposition at local scales but their role at larger scales is unresolved. Further, dead insects incorporated into the soil, add organic matter in it and also improves its structure and fertility status.

Further, in addition to the role of insects for the soil health improvement; the agro climatic conditions are also play an important role in the soil health maintenance (Dar *et al*. 2014b, 2017d, 2018b) [46, 47, 45]

5) As food

Insects also act as food in many countries. Estimates of numbers of edible insect species consumed globally range from 1,000 to 2,000, including 235 butterflies and moths, 344 beetles, 313 ants, bees and wasps, 239 grasshoppers, crickets and cockroaches, 39 termites, and 20 dragonflies, as well as cicadas. The consumption of the insect species varies by region due to differences in environment, ecosystems, and climate and the culture. To increase consumer interest in Western markets such as Europe and North America, insects have been processed into a non-recognizable form, such as powders or flour. At the global level the large scale food products include: *Entomofarms* in Canada, *Aspire Food Group* in United States, *Protifarm* and Protix in Netherlands, and Buhler Group *in* Switzerland, focus on insects species suitable for human consumption as well as industrialized mass production.

Common insect (and other) species used as food items

a) Mealworms (*Tenebrio molitor*) as larvae
b) Lesser mealworm (*Alphitobius diaperinus*) larvae marketed under brand name Buffalo worms
c) House crickets (*Acheta domesticus*) as adult
d) European migratory locust (*L.migratoria*) as adult.

6) Medicine and forensics sciences

Forensic entomology is a science, which applies knowledge of insects (and other arthropods) to civil proceedings and criminal trials (Arnaldos *et al.*, 2005) [5]. Although it has come of age as a science only in the last 40 years, it is a field with a long history. Forensic entomology is now considered as a major component of forensic science. It deals primarily with determining the place, time and mode of death in homicide cases by analyzing the insects collected from and around corpses (Hall, 2001) [19]. Insects, along with bacteria and fungi, plays major role in the decomposition of dead animals. Insects use this decomposing material as a food source as well as a place to rear their young ones (egg, larva and pupa). Initially, the insects are attracted to body fluids like urine, saliva and faecal material oozing from natural openings and blood from wounds. Later on, the flesh and other tissues and bones also become attractive. As a body decays, it can be viewed as providing a succession of habitats, each attractive to and supporting a particular group of insects. The review is aimed to know about the history, role of different orders/families/species of insects *viz a viz;* Coeloptera, Diptera, Lepidoptera in criminal investigations throughout the globe with special emphasis on the status of Forensic entomology in India.

History of Forensic Entomology

The earliest case known to us was witnessed in 1235 A.D in China, a murder by slashing. The local investigator who was deputed to probe the crime inferred a sharp sickle as the weapon used. He asked the villagers to bring their sickles to one spot and lay them out before the crowd. To the surprise of the villagers, flies were attracted to only one, otherwise innocent-looking, sickle. On rigorous interrogation the owner of that sickle confessed to the gruesome crime. It was explained later that the attractants on the sickle were small traces of human flesh invisible to the naked eye (McKnight, 1981) [29].

The era between 1960s and 1980, forensic entomology was maintained primarily by medical doctor Marscel Leclecq (Belgium) (Hase, 1930: Hase, 1934) [22, 23] and professor of biology Pekka Nuorteva ((first, Helsinki Zoological Museum, later, professor at the Department of Environmental Protection and Conservation, University of Helsinki, Finland) (Nuorteva *et al.*, 1967; Nuorteva, *et al*., 1974) [33, 34] with a focus on case work.

Since then basic research and advanced application of forensic entomology in the US (Anon, 1943) [4], Russia (Anon *et al.*, 1912) [3], Canada (Abbott, 1937) [1], France and Japan (Anon *et al.*, 1883) [2] as well as case work in other countries like England and India has opened the way to routine casework.

By now, researchers worldwide use entomology in criminal investigations like in solving murders and high profile cases.

Applications of Forensic Entomology

The applications of forensic entomology are broadly categorized under three separate headings: urban, stored product and medico legal forensic entomology (Hall, 1990; Harvey, 2006) [20, 21].

The stored product aspect of forensic entomology involves the infestation of stored commodities by insects. Infestations may include the harvesting and storage of crops and subsequent invasion by an insect pest and domestic invasion of kitchen products. This aspect also encompasses the infestation of food sold by retailers to the public, which may result in prosecution and substantial fines (Hall, 1990) [20].

The most accepted aspect of forensic entomology is assuredly the medico legal aspect. Forensic entomology intends to establish the time of death, known as postmortem interval (PMI).

Principles of Forensic entomology

Forensic entomology intends to establish the time of death, known as postmortem interval (PMI), or more precisely, how long a carrion has been exposed in the environment. By analyzing the parameters like, body temperature or livor and rigor mortis, time since death can only be correctly estimated for the first two to three days after death. On the other hand, by calculating the age of insect immature stages feeding on a corpse and analyzing the necrophagous species present on a cadaver, PMI from the first day to many days can be calculated (Hall and Amendt, 2007) [18].

Forensic Entomology in India

The state of Forensic entomology in India is in its infancy stage and only few workers are doing their research in this field. The dipteran flies are most exclusively used for medical experiments, especially because of their fast attraction towards cadaver as lures and their fast nature of multiplication. Much of the dipteran fly species act as vagarious and devastative agricultural pest (For example, Family: Tephritidae Fruit flies, Mir *et al*. 2014; Mir *et al*. 2017), but a few species have medical importance and are used for various types and categories of medical experiments. The first observations on the life stage of different sarcophagous insects was done by Mackenzie in 1889, after that only a few handful of scientists has shown their interest in this particular field of science.

Several attempts has been made to study the life history and reproduction behavior of different blow flies *Chrysomya. megacephala*, *C. rufifacies* and *Luciliacuprina*, among them Subramanian and Mohan, 1980 [42]. Rao *et al*. 1984 [35] carried out experiments on the developmental stages of the maggots to estimate time since death. Kashyap and Pillay 1989 proved that entomological method is important than other methods for estimating post mortem interval by observing sixteen infested cadavers.

Dr. Pankaj Kulshrestha conducted several studies on the behaviour of flesh flies towards a corpse, so to evaluate post mortem interval. He was successful in studying the life cycle of different flesh flies and published several research papers related to it (Kulshrestha and Chandra, 1987; Kulshrestha and Satpathy, 2001) [28].

In 1998-2001 a research project funded by Department of Science and Technology, Government of India led by Dr. Devinder Singh has done tremendous amount of work on the use of insects in forensics. He was working with Dr. Bernard Greenberg, who is considered as father of modern forensic entomologist to identify and study the fauna of different flesh loving flies and identified five species of flesh flies on the basis of their egg morphology (Singh and Greenberg, 1994;

Greenberg and Singh, 1995) [41, 16].

Bharti and Singh, 2003 carried out insect faunal succession on decaying rabbit carcasses at Punjabi University, Patiala (Punjab), India, from March 1997 to December 1999. They recognized four stages of decomposition, i.e., fresh, bloated, decay and dry. A total of 38 insect species belonging to 4 orders and 13 families were recorded. Diptera, Coleoptera and Hymenoptera dominated the carrion fauna. Calliphorids were the first to arrive in all the seasons of the year. Five species of Calliphoridae, four of Sarcophagidae, ten of Muscidae, and one each from Anthomyiidae and Otitidae were observed on rabbit carcasses. Representatives of six Coleopteran families, *i.e.*, Staphylinidae, Histeridae, Cleridae, Dermestidae, Tenebrionidae, and Silphidae, were recorded. Eight species belonging to family Formicidae (Hymenoptera) and only one species of order Lepidoptera were recorded on carrion. Gupta and Setia, (2004) [17] described the past, present and future status of Forensic entomology in India. Singh and Bharti, (2000) [39] studied the nocturnal oviposition behavior of Indian species blow flies. Bharti and Singh, (2001) [40] demonstrated the succession pattern of insect species on rabbit carcasses. The identification of insect species by mitochondrial genes revolutionized and unraveled the phylogenetic relationship, by using the mitochondrial COI gene Sharma *et al. (*2014) analyzed and characterized ten forensically important flies from North India.

Conclusion

Forensic entomology may not be the last word in all death investigations. However, the evidence from insects, if investigated by the right person and with right techniques, can certainly complement and supplement other conventional procedures in forensics. Besides, at least in some cases, insects might be the only major sources of information regarding time and place of death. The accuracy of these methods, of course, largely depends on the expertise of the forensic entomologist and also the availability of all required data on the insects concerned. A wrong interpretation of the insect data may even mislead the investigators. The field and application of forensic entomology is growing at a steady pace around the world for the last two decades. As far as India is concerned the former judiciary allow any scientific evidence to prove a case, under article 138 of the Evidence Act. The incorporation of Forensic entomology is still yet to find a desired place in our legal proceeding system because of very less data available about the fauna of insects involved in it and also due to very less number of forensic entomologists present in our country. It is hoped that the scenario would change in favour of this important branch of forensic science in India with the initiatives of the scientists working in this field.

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