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Studies on incidence and succession of forensically important insects associated with decomposition of goat flesh

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Abstract
Studies on the incidence and succession pattern of forensically important insects associated with the decomposition of goat flesh was carried out in Bala village of Banjar, Distt. Kullu, Himachal Pradesh. In total, twelve insect species belonging to ten families under three orders were recorded, namely Diptera, Coleoptera and Hymenoptera. Order Diptera included families Calliphoridae, Muscidae, Sarcophagidae, Sepsidae and Piophilidae; order Coleoptera included families Silphidae, Histeridae, Staphylinidae and Dermestidae and order Hymenoptera represented by single family Formicidae. Flies were abundant in the early stages of decomposition while beetles attacked the flesh at later stages. Ants were recorded to be present in all the stages. Total decomposition of flesh took twenty-two days. This study on mammalian flesh provides a baseline data of forensically important insects of Banjar and also the succession pattern followed by them on goat flesh.

Keywords: Incidence, succession, forensically, insect, decomposition, flesh

1. Introduction
Insects are the largest group in phylum Arthropoda and are hexapods. They live in a variety of habitats and feed on a huge number of materials as roots, leaves, nectar, wood, seed etc. Some of them are predators and others parasites. Besides these, some of them also feed on carrions and hence play an important role in the decomposition of dead remains and thus in cleaning the environment. This concept of carrion eating insects is nowadays used in forensic sciences. Forensic entomology is a field that deals with use of insects for legal issues (Amendt *et al*., 2007) [1]. Its prime application is in calculating the minimum time after death in case of unnatural deaths (Catts, 1992) [10] and this minimum time is called as Post-Mortem Index (PMI). It can be done in two ways. One is to evaluate the age of mature necrophagous insect that has grown on the corpse (Catts, 1992) [10]. The other is to examine the insect species composition and succession pattern followed by them on carrion (Davies, 1990) [11]. An ample of work has been done on carrion associated forensically important insects around the world by various workers (Anderson and Van Laerhoven, 1996; Tullis and Goff, 1987; Watson and Carlton, 2003) [2, 21, 23]. From India, such studies were carried out by various workers from different regions (Bala and Kaur, 2015; Bharti and Singh, 2003) [5, 7]. In Himachal Pradesh, such work has been done in Gharakar, Distt. Kullu by Bala and Singh (2017) [6]. A thorough understanding regarding the carrion insects of a particular area is needed so as to use the entomological data in examination of illegal acts.

2. Materials and methods
2.1 Study site description
The study site chosen was a garden at Bala village of Banjar area of Distt. Kullu, Himachal Pradesh (31.63° N longitude, 77.35° E latitude and 1356 meters above sea level altitude). This site is rich in biodiversity and surrounding flora include *Malus*, *Pyrus*, *Pinus* and various types of herbs, shrubs and grasses. There is very less interference of animals and humans. Study was conducted during the spring season in 2019. The temperature ranges from 27-30˚C.

2.2 Experimental Carrion and its handling
For the purpose of experiment, flesh of a goat, *Capra aegagrus hircus*, belonging to the family Bovidae and order Artiodactyla was bought from a slaughter house.

The flesh was kept in a cage as a bait. Cage was made of steel and its dimensions were as 50 × 25 × 30 cm. Holes in the cage were large enough for the easy passage of the insects through it. The cage was positioned in a manner such that it remains under direct sunlight throughout the whole day. For the protection of experimental material from the scavengers as dogs, birds and jackals, the cage was tied to *a* nearby *Pinus* tree with the help of a metal wire. Many a times, there was a need to chase away the birds so as to keep the flesh safe from them as they were trying to pull out the flesh.

2.3 Sampling of specimens

The data such as the arrival time, the time period of insect remaining on flesh and the pattern of their arrival was noted from the study site. The set up was observed visually and very keenly without causing any disturbance to the fauna-carrion association. Collection of insects was done by the use of forceps and hand picking. Samples were identified in Regional Forensic Science Laboratory, Dharamshala, Himachal Pradesh. Sampling was done during the day time.

3. Results

In present investigations, total of 12 species of forensically important insects were collected and these species represented 10 families and 3 orders of class Insecta. 5 families namely, Calliphoridae, Sarcophagidae, Muscidae, Sepsidae and Piophilidae belonging to order Diptera; 4 families namely, Silphidae, Staphylinidae, Histeridae and Dermestidae belonging to the order Coleoptera and 1 species belonging to family Formicidae of the order Hymenoptera were recorded. Insects recorded in this study are shown in Plate 1.

These species were further investigated for abundance and succession pattern:

Total number of insects recorded were 839. Most abundant insects were ants, *Solenopsis* species (23.7%), followed by 3 species of blow flies, family Calliphoridae (20.7%) and least abundant were rove beetles, *Aleochara* species (2.9%). Abundance of insect species recorded on goat flesh is given in Table 1.

Succession pattern of insects on decomposing flesh is given in Table 2. It has been described as follows:

Week 1: During 1st week, 10 species of insects arrived on flesh. The first insect to visit the flesh were blow flies. 3 species of blow flies belonging to family Calliphoridae were recorded i.e., blue bottle fly (*Calliphora vicina*), *Calliphora vomitoria* and shiny blue bottle fly (*Cynomyopsis cadaverina*) on day 1st and they reached at the flesh within 5-10 minutes. In about half an hour, these were followed by flesh fly (*Sarcophaga bullata*, family Sarcophagidae), house fly (*Musca domestica*, family Muscidae) and ants (*Solenopsis* species, family Formicidae) on the same day. Within 4 hours, adult females blow fly started ovipositing on the flesh.

On day 2nd and 3rd, same species of insects were recorded on flesh. From day 1st -3rd, there was no physical change in the flesh, so it was in fresh stage.

On day 4th and day 5th, there was arrival of cheese fly (*Piophila casei*, family Piophilidae) and black scavenger fly (*Sepsis* species, family Sepsidae) respectively. These also feed on the flesh. Larval masses of blow fly and flesh fly were also present on the flesh on day 4th. On these two days, inflation was observed. It represented the bloat stage. Odour from the flesh was noticeable.

In the first 5 days, there was abundance of dipterans and ants on the flesh. Ants were seen to feed both on the flesh and the larvae of flies.

On day 6th, there was arrival of carrion beetle (*Silpha ramosa*, family Silphidae) and clown beetle (*Saprinus* species, family Histeridae) belonging to order Coleoptera. These beetles were attracted to presence of larvae. Day 7th was observed with already present species and no new specimen was observed. On these two days, there was deflation of flesh and also the upper layer of flesh started to separate. Strong putrefaction odour was also detectable. These are characteristics of the active decay stage.

Week 2: On day 8th, all old observations were made except that there were no larvae present on the flesh. Larvae may have found suitable places for pupa formation in area surrounding the flesh.

On day 9th, there was attendance of rove beetle (*Aleochara* species, family Staphylinidae) and hide beetle (*Dermestes maculatus*, family Dermestidae) on the flesh. Day 8th and 9th showed the advanced decay stage. Flesh had got totally blackened due to putrefaction and the odour was comparatively less than that of active decay stage. In this whole week, there was abundance of ants, belonging to family Formicidae and beetles, belonging to families Silphidae, Histeridae, Staphylinidae and Dermestidae. Number of flies was reduced.

Week 3: This was the last stage of decay process, i.e., dry stage. There was very less tissue remained and bone was visible. This stage was dominated by adults and larvae of hide beetle, *Dermestes maculatus* which feed on remaining dried tissue, skin and bones. Ants were irregularly visiting the flesh for small pieces of tissues.

4. Discussion

In the present study, twelve species of forensically important insects belonging to 10 families under 3 orders were collected on goat flesh. Earlier, other workers have recorded varying number of insects on different corpses (Islam *et al*., 2016; Tabor *et al*., 2004; Watson & Carlton, 2003) [14, 20, 23].

The pattern of insect's arrival on goat flesh noticed in the present study is similar to various studies done around the world as Shi *et al*. (2009) and Smith (1986) [18, 19]. Shi *et al*. (2009) recorded the same succession pattern as dipterans were the dominant species in early stages while beetles during the later stages of decomposition. Although, there have been noted differences in the insect species depending on the type of carcass, type of habitat and environmental conditions but the pattern of succession is almost same. Variations in the succession pattern have been observed among the different genera of same families.

Calliphorids were first to arrive after placement of fresh goat flesh and oviposit shortly. This finding is consistent with the studies of Wang *et al*. (2008) [22]. On the same day, these were followed by sarcophagids, muscids and ants within half an hour. These results are similar with those of Arnaldos *et al*. (2005) and Omar *et al*. (1994) [4, 16]. But Boulkenafet *et al*. (2015) have observed *Musca domestica* in decay stage on the carcass [8]. Richards & Goff (1997) also found ants on fresh carcasses [17].

On day 4th, *Piophila casei* noticed on flesh. This is same as observed in studies of Islam *et al*. (2016) [14]. But Easton and Smith (1970) observed these to be late colonizers [12]. *Sepsis* species arrived on day 5th. Abundance of dipteran species in

early stages is a common finding of various workers (Anderson & Van Laerhoven, 1996; Goddard *et al*., 2012; Wyss & Cherix, 2006) [2, 13, 24].

Silpha ramosa (family, Silphidae) and *Saprinus* species (family, Histeridae) belonging to order Coleoptera arrived on day 6th. This finding is similar to that of Anderson (2011) [3], but Tabor *et al*. (2004) recorded these beetles in both early and later stages [20]. Also, Braack (1987) recorded members of family Histeridae during the first stage of decay [9].

Aleochara species and *Dermestes maculatus* arrived on day 9th and were the last species to arrive. These feed on remaining tissue and bones. This is similar to studies of Miller *et al*. (1994) [15].

Table 1: % age of forensically important insects associated with decomposition of goat flesh

Sr. No.	Name of Species	Family	Order	No. of individuals			Total sample	% age
				1st Week	2nd Week	3rd Week		
1.	*Calliphora vicina* (Blue bottle fly)	Calliphoridae	Diptera	38	21	5	64	7.6281
2.	*Calliphora vomitoria*	Calliphoridae	Diptera	30	29	2	61	7.2705
3.	*Cynomyopsis cadaverine* (Shiny blue bottlefly)	Calliphoridae	Diptera	25	20	4	49	5.8402
4.	*Sarcophaga bullata* (Flesh fly)	Sarcophagidae	Diptera	24	14	3	41	4.8867
5.	*Musca domestica* (House fly)	Muscidae	Diptera	39	26	6	71	8.4624
6.	*Piophila casei* (Cheese skipper)	Piophilidae	Diptera	29	41	10	80	9.5351
7.	*Sepsis* species (Black scavenger fly)	Sepsidae	Diptera	25	36	5	66	7.8665
8.	*Solenopsis* species (Ants)	Formicidae	Hymenoptera	98	70	31	199	23.7187
9.	*Silpha ramosa* (Carrion beetle)	Silphidae	Coleoptera	19	29	20	68	8.1048
10.	*Saprinus* species (Clown beetle)	Histeridae	Coleoptera	10	23	15	48	5.7210
11.	*Aleochara* species (Rove beetle)	Staphylinidae	Coleoptera	-	10	14	24	2.8605
12.	*Dermestes maculatus* (Hide beetle)	Dermestidae	Coleoptera	-	30	38	68	8.1048
	Total Specimen						839	100

Table 2: Succession of forensically important insects on goat flesh

Scientific name	Family	Order	Arrival day	Arrival week	Stay in days
Calliphora vicina (Blue bottle fly)	Calliphoridae	Diptera	Day 1	Week 1	13-17
Calliphora vomitoria	Calliphoridae	Diptera	Day1		13-16
Cynomyopsis cadaverine (Shiny blue bottle fly)	Calliphoridae	Diptera	Day 1		13-14
Sarcophaga bullata (Flesh fly)	Sarcophagidae	Diptera	Day1		10-12
Musca domestica (House fly)	Muscidae	Diptera	Day 1		12-14
Solenopsis species (Ants)	Formicidae	Hymenoptera	Day 1		17-18
Piophila casei (Cheese fly)	Piophilidae	Diptera	Day 4		5-7
Sepsis species (Black Scavenger fly)	Sepsidae	Diptera	Day 5		9-10
Silpha ramose (Carrion beetle)	Silphidae	Coleoptera	Day 6		8-10
Saprinus species (Clown beetle)	Histeridae	Coleoptera	Day 6		8-11
Aleochara species (Rove beetle)	Staphylinidae	Coleoptera	Day 9	Week 2	7-8
Dermestes maculatus (Hide beetle)	Dermestidae	*Coleoptera*	Day 9	Week 2 & 3	11-13

Goat flesh (fresh stage).

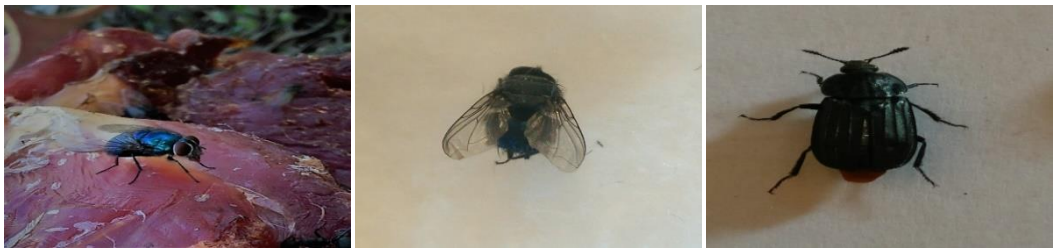
Solenopsis species.

Flesh (active decay stage).

Cynomyopsis cadaverina.

Sarcophaga bullata.

Musca domestica.



Calliphora vicina. *Calliphora vomitoria.* *Silpha ramosa.*

Saprinus species. *Aleochara* species. *Dermestes maculatus*.

Plate 1: Forensically important insect species associated with decomposition of goat flesh.

5. Conclusions

Based on the results, it can be concluded that goat flesh attracted diverse forensically important species of insects. 12 species belonging to 10 families under 3 orders were recorded which include *Calliphora vicina, Calliphora vomitoria, Cynomyopsis cadaverina, Sarcophaga bullata, Musca domestica, Piophila casei, Sepsis* species, *Solenopsis* species, *Silpha ramosa, Saprinus* species, *Aleochara* species and *Dermestes maculatus*. Dipterans were the first insects to arrive on the goat flesh, followed by hymenopterans and latter in turn followed by coleopterans. Initial stages of decomposition were colonised by flies and later by beetles. Ants were present in every stage of decomposition process. Flesh decomposed in about 22 days. Insect succession pattern on mammalian flesh can be useful in determining PMI. This study is first of its kind from Banjar area. Thus, the information obtained from this study will be helpful in providing basic data of forensically important insects of this area.

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