VOL. 8, NO. 11, NOVEMBER 2013 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

DECOMPOSITION AND INSECT SUCCESSION PATTERN OF EXPOSED DOMESTIC PIG (*Sus scrofa* L.) CARRION

Rosina A. K. Kyerematen[1, 3], Bernard A. Boateng[2], Michael Haruna[3] and Vincent Y. Eziah[2, 3]
[1]Department of Animal Biology and Conservation Science, University of Ghana, Legon, Accra, Ghana
[2]Department of Crop Science, College of Agriculture and Consumer Sciences, University of Ghana, Legon, Accra, Ghana
[3]African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon, Accra, Ghana
E-mail: baboateng@gmail.com

ABSTRACT

Pig carrion decomposition and insect succession patterns were monitored in the dry and wet seasons at the University of Ghana, Legon in the Greater Accra Region. The sequence and composition of the local carrion visiting fauna, as well as, the rate of decomposition of the carrion and their determinant climatic factors were measured. The complete decomposition of the carrion lasted 16 and 24 days for dry and wet season, respectively. Five stages of decomposition of the cadaver namely the fresh, bloated, active decay, advanced decay and dry remains were observed. In total, 19 species of insects from 14 families: Calliphoridae, Muscidae, Dolichopodidae, Gasterophilidae, Formicidae, Histeridae, Dermestidae, Cleridae, Lycidae, Staphilinidae, Pyrrhocoridae, Saturniidae and Therevidae were collected. A few species from the family Ixodidae (Arachnidae) were also collected during the decomposition of the carrion. On account of their activity and frequency, the Calliphorid species, *Lucilia rufifacies* were the insects of greatest forensic importance. These blowflies were the early colonizers of the carrion in both seasons and remained throughout the decomposition process. Temperature, though important in controlling decomposition rates of carrion, could not account for the differences in decomposition rates observed between the two seasons. Rainfall delayed colonization of carrion during both seasons and this might have played a major role in the delayed rate of degradation observed during the wet season. The succession patterns were typical for the seasonal periods and provide data on baseline fauna important for estimating postmortem interval in cases of human death in Ghana.

Keywords: pig carrion, insect succession, animal decomposition, forensic entomology, Ghana.

INTRODUCTION

In forensic entomology, insects are used as a potential source of evidence in cases of murder or suspicious death. This is because many insects are associated with human body after death and their pattern of colonization of carrion occurs in a predictable sequence (Payne, 1965). Forensically significant insects will colonize the carrion at a specific period because they get attracted to specific products of decomposition or are predators on other necrophagous insects. Species of necrophilous flies in the families' Calliphoridae and Sarcophagidae are the first forensic insects to arrive at and oviposit on a corpse or carrion (Watson and Carlton, 2003; Kyerematen *et al.*, 2012). Predators of fly maggots, including beetles in the families; Silphidae, Staphylinidae, and Histeridae arrive later to feed on the maggots (Goff, 1993). Beetle species in the family Dermestidae are late arrivers that invade a corpse in the dry stages of decomposition after early colonizing taxa have already left the remains (Rodriguez and Bass, 1982; Watson and Carlton, 2003). This information can be beneficially exploited to yield the Postmortem Interval (PMI) (time elapsed since death) by comparing a known sequence of insect succession on carrion for a given geographical region against collected species from bodies of unknown time of death provided the circumstances are similar (Anderson, 2001).

Studies on the successional patterns of arthropods have been conducted in different climatic areas in the world (Payne, 1965; Rodriguez and Bass, 1982; Anderson and VanLaerhoven, 1996; Watson and Carlton, 2003; Kyerematen *et al.*, 2012). Insect species that colonize carrion vary widely with geographic regions, and factors such as ambient temperature, humidity, rainfall and microclimate of the postmortem habitat play major roles in the determination of the invertebrate assemblage on carrion and the rate of carrion decomposition (Smith, 1986; Mann *et al.*, 1990). In countries such as Ghana where decomposed human cadavers are repeatedly found in backyards and bushes in the cities and suburbs of the country, not much baseline succession data are available on forensically important arthropods. The purpose of this study was to describe the composition and sequence of local carrion-insect succession as influenced by seasons at the University of Ghana, Legon Campus in the Greater Accra Region of Ghana, which could be used for estimating PMI in cases of human death. The domestic pig (*Sus scrofa* L.) was used as surrogate model because many studies have shown that it possesses a pattern of decomposition that is similar to that of human (Catts and Goff, 1992).

MATERIALS AND METHODS

Study site

The studies were conducted in the wet season (July 10 - August 2, 2009) and dry season (February 8 - February 23, 2010) at the University of Ghana main campus at Legon. The study site (05º 39′ N, 000º 11′W) was located near the University Research Farms at an altitude of about 129 m above mean sea level. Vegetation at the study site and the surroundings were predominantly

composed of the grass, *Andropogon gayanus*, with young teak (*Tectona grandis)* and *Cassia nodusa* trees evenly scattered all over. Shrubs and herbs found at the site were *Waltheria indica*, *Tiliacora sp*., *Leucaena leucocephela*, *Tridax procumbens* and *Mimosa pudica*. Other trees occasionally encountered at the site included the neem tree (*Azadirachta indica* L.). The identification of these plants was done at the Herbarium of the Department of Botany of the University of Ghana, Legon, Accra, Ghana.

Experimental animals and cages

A total of six 3- month old domestic pigs, *Sus scrofa* L., weighing between 10.5 and 11.3 kg were used as surrogate models. Three pigs were used as replicates in each season. Each pig was euthanized by electrical shock. After death was confirmed, each pig was immediately double-bagged to prevent arthropod colonization and then transported to the study site. At the study site, the pig carcasses were placed at three prepared locations set at >100 m apart; representing three different replicates of the same study. Because decomposition and colonization of a carcass by insects is affected by the placement of the carcass (Shean *et al.*, 1993), the cages were positioned so that both carcasses received direct sunlight until mid-day, although, one carcass usually was slightly shaded during the afternoon. The carcasses were protected from large scavenging animals with metal cages. The cages measured 90 x 60 x 75 cm with 4 cm^2 mesh. Each cage had a hinged, lockable lid and an open base which allowed the pig carcasses to be in direct contact with the ground. Cages were staked to the ground to prevent disturbance of the carrion by vertebrate scavengers.

Each pig carcass was placed inside a wire cage with its legs pointing toward the hinged door on the front of the cage. Observations were made using the stage criteria set by Anderson and VanLaerhoven (1996) namely, the Fresh, Bloat, Active Decay, Advanced Decay, and Dry/Remains).

Sampling protocol

Each carcass was visited at least twice a day. Because the decomposition of carrion progressed at different rates during the two studies, the sampling protocol was adjusted accordingly for each period. Sampling was conducted daily (between 0800 - 1000 hrs and 1400 - 1600 hrs) until the carcasses reached advanced decay stage. Internal temperature, ambient temperature, maximum/minimum temperature, soil temperature, pig/soil interface temperature and relative humidity were recorded at 1500 hrs every day throughout the whole experiment. Internal, ambient, soil and pig/soil inter-phase temperature were recorded on every visit using a calibrated mercury thermometer after 5 minutes exposure time. Internal temperatures were taken through the anus. Ambient air temperatures were taken in shaded locations. Maximum/minimum temperatures and relative humidity were also recorded on each visit using a thermo-hygrometer. Maggot mass temperatures were recorded during the Active and Advanced Decay stage of decomposition using a mercury thermometer. For comparison with data from the experimental site, daily weather data were also acquired from the Local Meteorological Station situated about 3 km from the study site. The carcasses were weighed in the field every day with a spring scale. Before examining the carcasses on each visit photographs were taken with an Olympus® FE-160 digital camera.

Sampling of adult insects was done with aerial net sweeps above and around the carrion, pitfall traps, and by taking specimens directly off the carrion to qualitatively assess species occurrence. Adult flies collected were transferred to a 'killing' jar containing ethyl acetate. Fly eggs and maggots were collected, when they were present, and one part was reared to the adult stage for species identification. The other part was killed immediately in warm water and transferred to vials containing 70% ethyl alcohol for preservation. When the carcass was being weighed, specimens were sampled from the litter under the carrion and the underside of the carrion themselves. This was done by taking a sample of the litter under the carrion and sorting it out in a tray to separate the insects from the debris. Only small numbers of representatives of every life stage of each species were collected to minimize effect of sampling on the outcome of the study. On each visit, the carcasses were thoroughly examined visually for decomposition changes without being disturbed. Observations were recorded and photographed.

On arrival at the laboratory, all specimens were transferred to vials with fresh 70% ethyl alcohol and any fur, soil or plant material adhering to the specimens were removed. Adult insects were prepared and mounted on pinning boards. Larvae to be identified were reared to adult on beef liver in jars covered with a net mesh. All collected samples were identified to the lowest taxonomic rank. Most of the specimens were identified to generic or specific levels and all identified specimens were placed in the Entomological Museum of the Department of Animal Biology and Conservation Science of the University of Ghana, Legon. Care was taken to protect the data collectors from any pathogens, pollutants or contaminants by wearing protective clothing. Signposts warning passersby about the potential hazards of the experiment were erected at all locations, about five meters from the experimental set-up (Kyerematen *et al.*, 2012).

RESULTS

Decomposition

A summary of the daily physical parameters recorded during the study periods in both seasons is presented in Table-1. The mean ambient temperature, relative humidity, soil temperature and maggot mass temperature recorded did not differ significantly ($p>0.05$) between the two seasons. However, internal carrion temperature was significantly higher ($p<0.05$) during the dry season than the wet season. The fresh stage began at the moment of death and continued until bloat was obvious, with no odour emanating from the carrion. There were no changes in the weights of the carcasses at this

stage. The fresh stage lasted two days in the wet season (Days 0-2) and a day in the dry season (Day 0-1). The defining characteristics for each stage of decomposition, corresponding temperature and precipitation levels for both seasons, are summarized in Tables 2 and 3.

Table-1. Summary of average daily physical parameter recorded during the study periods.

	Seasons	
Parameters	**Wet season**	**Dry season**
	Mean ± S.E	Mean ± S.E
Ambient temperature (ºC)	27.07 ± 0.11	26.94 ± 0.12
Relative humidity (%)	80.21 ± 0.70	83.56 ± 0.58
Rainfall (mm)	0.14 ± 0.06	4.63 ± 3.60
Carrion/soil interface (ºC)	28.03 ± 0.26	28.50 ± 0.12
Soil temperature (ºC)	28.39 ± 0.24	28.13 ± 0.12
Internal temperature (ºC)	30.07 ± 0.50	32.13 ± 0.41
Maggot mass temperature (ºC)	32.67 ± 0.25	32.83 ± 0.31

The bloat stage, which began on day 3 for the wet season and day 2 for the dry, was marked by the accumulation of gases in the abdominal region of the carrion. This was accompanied by color changes as well as the onset of marbling with bubbles of blood forming at the nostrils. Odour became noticeable. Body temperatures remained low during this stage. The loss of biomass in the carrion ranged from 9.7% to 11.4% (mean 10.73%, ± 0.56 %) and 7.9% to 8.3% (mean 7.93%, ± 0.40%) of total body weights during the wet and dry seasons, respectively. This stage lasted two days in the wet season and a day in the dry season (Tables 2 and 3).

The carrion entered the active decay stage on day 5 during the wet season and day 3 during the dry season. The stage was marked by the complete deflation of the carrion because of feeding Calliphoridae larvae breaking the skin, and strong putrefaction odour associated with tissue liquefaction. During the active decay, the edges of broken skin blackened from putrefaction and started to flake from maggot activity. There was a continuous deflation of the pig carrion and separation of the carrion bones from the skin. The carrion, at this stage, attracted the largest diversity of insects. During this stage, the carcass became infested with maggots in all stages of development. Maggot masses began devouring extremities such as the heads, anal regions and limbs, and left the remaining skin perforated. The odour of decay increased dramatically and became putrid and offensive. The ground surrounding the carcass became wet as the gaseous pressure finally forced fluids out of natural orifices. The temperatures of the carrion began to rise during this stage as a result of insect activity and the putrefaction process. There were also sharp and rapid losses of biomass in the carrion. For example, the wet season saw weight losses between 63.7% and 65.7% (mean 64.40%, ± 0.66%) of the total body weight. Biomass losses for the same stage of decomposition during the dry season were between 80.6% and 85.8% (mean 84.03%, ± 1.72%) of the total body weight (Figure-1).

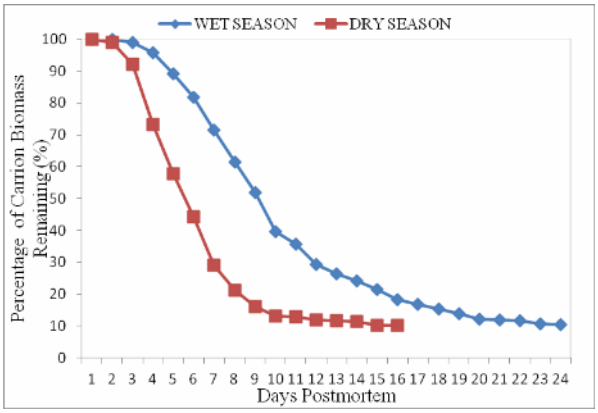

Figure-1. Trend of biomass loss in the two sets of carcasses during the wet and dry seasons.

By the end of advanced decay (days 11-15 and days 9-12 for the wet and dry seasons, respectively) (Tables 2 and 3), the carrion in the wet season had lost between 80.5% and 81.9% (mean 81.60%, ± 0.57%) and those of the dry season had also lost between 87.0% and 89.3% (mean 88.33%, ± 0.69%) of their initial weights. Mucilaginous materials were found on and around all the carrion. This by-product of decomposition (BOD) consisted of some internal tissues with insect material and other products of decomposition. Larval activity on the carrion was notably reduced although it continued to be dominated by Calliphoridae. The majority of the larval masses were concentrated in the muddy ground under the body. Several dead larvae were found on the body, underneath it and in the immediate vicinity. Pre-pupal larvae and pupal cases were scattered in the muddy ground under the body. The number of adult flies dropped considerably. The process of skeletonization began at this stage.

The dry stage began on Day 16 during the wet season and Day 13 in the dry season (Tables 2 and 3). The

last collections were made during this stage. By the end of this stage, the carrion had lost between 88.5% and 90.5% (mean 89.60%, ± 0.59%) and between 88.9% and 91.1% (mean 89.87%, ± 0.65%) of their initial body weights. At this stage, skeletonization was almost complete. The loss of skin on the head, limbs, and posterior section was common to all carrion. However, carrion retained most skin in the abdominal area. Remaining hair and skin rapidly dehydrated in the advanced decay stage. The BOD had dried up and some of this had mixed with the soil. The small numbers of larvae found were concentrated in the extremities (hooves), places providing shelter and where small amounts of soft tissue remained.

Table-2. Summary of decomposition characteristics by stage of decay and associated ambient and internal carcass temperatures and precipitation in the wet season

Stage	**Defining characteristics of decomposition stages**	**Days postmortem**	**Temperatures** (ºC)				**Precipitation** (mm)
			Ambient temp. (range)	**Ambient temp. (mean)**	**Internal temp. (range)**	**Internal temp. (mean)**	
Fresh	No odour; fresh appearance	0 to 2	26-27	26.33	27-33	29.83	1.1
Bloated	Bloating initiating in abdomen; discoloration; maggots developing inside body openings; moderate odour	3 to 4	27-28	27.17	27-28	27.67	0
Active	Release of gases, associated with maggot infestation outside of body; liquefaction of tissues; strong odour of decay; black putrefaction; continual deflation; Skin separation from bone.	5 to 10	25-28	27	27-35	31.22	0.9
Advance	Removal of flesh at extremities (head, limbs, anus); odour moderate; bone exposure evident at extremities	11 to 15	26-28	27.07	33-35	34.33	0.2
Dry	Little to no odour; hardened, dried, and wrinkled skin; exposed bone.	16 to 24	26-28	26.89			1.1

Table-3. Decomposition characteristics of pig carrion by stage of decay and associated ambient and internal carcass temperatures and precipitation in the dry season

Stage	**Defining characteristics of decomposition stages**	**Days post-mortem**	**Temperatures** (ºC)				**Precipitation** (mm)
			Ambient. temp. (range)	**Ambient. temp. (mean)**	**Internal. temp. (range)**	**Internal. temp. (mean)**	
Fresh	No odour; fresh appearance	0 to 1	27	27.00	32	32.00	0
Bloated	Bloating initiating in abdomen; discoloration; maggots developing inside body openings; moderate odour	1 to 2	28	28.00	28	28.00	0
Active	Release of gases, associated with maggot infestation outside of body; liquefaction of tissues; strong odour of decay; black putrefaction; continual deflation; Skin separation from bone.	3 to 8	25-28	26.67	30-35	32.83	74.1
Advance	Removal of flesh at extremities (head, limbs, anus); odour moderate; bone exposure evident at extremities	9 to 12	26-28	27.25	-	-	0
Dry	Little to no odour; hardened, dried, and wrinkled skin; exposed bone.	13 to 16	26-27	26.75	-	-	0

Insect succession

Diverse insect species visited the decomposing carrion during the experimental period. The succession tables for forensically significant insects for the wet and dry seasons are shown in Tables 4 and 5, respectively. Sixteen species of insects from 12 families and 5 orders were collected in the wet season as opposed to 18 insect species from 13 families and 4 orders that visited the carrion during the period of decomposition in the dry season. In total therefore 19 insect species, representing 5 orders and 14 families were collected in the two studies. The insect species encountered were from the following families; Calliphoridae, Muscidae, Dolichopodidae, Gasterophilidae, Formicidae, Histeridae, Dermestidae, Cleridae, Lycidae, Staphylinidae, Pyrrhocoridae, Saturniidae, Paussidae and Therevidae. Three other arthropod species found were not insects; *Rhipicephalus* sp. (Ixodida: Ixodidae) and two other unidentified arachnids.

Table-4. Succession of insect species visiting the domestic pig carrion during wet season on the University of Ghana campus.

Decomposition stage	Order	Family	Genus and species	Live stage	Carrion		
					1	2	3
Fresh	Diptera	Calliphoridae	*Chrysomyia rufifacies*	A, L, E	×	×	×
		Calliphoridae	*Austropha sp.*	A	×	×	×
		Muscidae	*Musca domestica*	A	×	×	×
		Dolichopodidae	*Dolichopus sp.*	A	×	×	×
		Gasterophilidae	*Gasterophilus intestinalis*	A	×	×	×
	Hymenoptera	Formicidae	*Atta sp.*	A	×	×	×
		Formicidae	*Dolylus sp.*	A	×	×	×
		Formicidae	*Pheidole sp*	A	×	×	×
		Formicidae	*Crematogaster sp.*	A	×	×	×
Bloated	Diptera	Calliphoridae	*Chrysomyia rufifacies*	A, L, E	×	×	×
		Calliphoridae	*Austropha sp.*	A	×	×	×
		Muscidae	*Musca domestica*	A	×	×	×
		Gasterophilidae	*Gasterphilus intestinalis*	A	×	×	×
	Coleoptera	Cleridae	*Necrobius violacea*	A	×	×	×
		Histeridae	*Saprinus sp.*	A	×	×	×
		Lycidae	*Lycus sp.*	A	×	×	×
		Staphylinidae	*Philonthus longicornis*	A	×	×	×
	Hymenoptera	Formicidae	*Atta sp.*	A	×	×	×
		Formicidae	*Dolylus sp.*	A	×	×	×
		Formicidae	*Pheidole sp.*	A	×	×	×
		Formicidae	*Crematogaster sp.*	A	×	×	×
	Hemiptera	Pyrrhocoridae	*Dysdercus sp.*	A	×	×	×
	Lepidoptera	Saturniidae		A			
Active	Diptera	Calliphoridae	*Chrysomyia rufifacies*	A, L, E	×	×	×
		Calliphoridae	*Austropha sp.*	A	×	×	×
		Muscidae	*Musca domestica*	A	×	×	×
		Therevidae	*Ozodiceromya nigrimana*	A	×	×	×
		Dolichopodidae	*Dolichopus sp.*	A	×	×	×
		Gasterophilidae	*Gasterphilus intestinalis*	A	×	×	×
	Coleoptera	Cleridae	*Necrobius violacea*	A	×	×	×
		Cleridae	*Necrobia rufipes*	A	×	×	×
		Histeridae	*Saprinus sp.*	A	×	×	×
		Lycidae	*Lycus sp.*	A	×	×	×
		Staphylinidae	*Philonthus longicornis*	A	×	×	×

A = Adult L = Larva E = Egg

Table-5. Succession of insect species visiting the domestic pig carrion during dry season at the University of Ghana

Decomp. stage	Order	Family	Genus and species	Live stage	Carrion		
					1	2	3
Fresh	Diptera	Calliphoridae	*Chrysomyia rufifacies*	A, L, E	×	×	×
		Muscidae	*Musca domestica*	A	×	×	×
		Dolichopodidae	*Dolichopus sp.*	A	×	×	×
		Therevidae	*Ozodiceromya nigrimana*	A	×	×	×
	Hymenoptera	Formicidae	*Atta sp.*	A	×	×	×
		Formicidae	*Dolylus sp.*	A	×	×	×
		Formicidae	*Pheidole sp.*	A	×	×	×
		Formicidae	*Crematogaster sp.*	A	×	×	×
Bloated	Diptera	Calliphoridae	*Chrysomyia rufifacies*	A, L, E	×	×	×
		Dolichopodidae	*Dolichopus sp.*	A	×	×	×
		Muscidae	*Musca domestica*	A	×	×	×
		Gasterophilidae	*Gasterphilus intestinalis*	A	×	×	×
	Coleoptera	Cleridae	*Necrobius violacea*	A	×	×	×
		Cleridae	*Necrobia rufipes*	A	×	×	×
		Histeridae	*Saprinus sp.*	A	×	×	×
		Lycidae	*Lycus sp.*	A	×	×	×
		Staphylinidae	*Philonthus longicornis*	A	×	×	×
	Hymenoptera	Formicidae	*Atta sp.*	A	×	×	×
		Formicidae	*Dolylus sp.*	A	×	×	×
		Formicidae	*Pheidole sp.*	A	×	×	×
		Formicidae	*Crematogaster sp.*	A	×	×	×
	Hemiptera	Pyrrhocoridae	*Dysdercus sp.*	A	×	×	×
Active	Diptera	Calliphoridae	*Lucilia rufifacies*	A, L, E	×	×	×
		Muscidae	*Musca domestica*	A	×	×	×
		Therevidae	*Ozodiceromya nigrimana*	A	×	×	×
		Dolichopodidae	*Dolichopus sp.*	A	×	×	×
	Coleoptera	Dermestidae	*Dermestis maculatus*	A	×	×	×
		Staphylinidae	*Philonthus longicornis*	A	×	×	×
		Paussidae	*Spinicorpaussus*	A	×	×	×
	Hymenoptera	Formicidae	*Atta sp.*	A	×	×	×
		Formicidae	*Dolylus sp.*	A	×	×	×
		Formicidae	*Pheidole sp.*	A	×	×	×
		Formicidae	*Crematogaster sp.*	A	×	×	×
	Hemiptera	Pyrrhocoridae	*Dysdercus sp.*	A	×	×	×

Fly activity was observed immediately after placement of the carrion in both seasons. The colonizers to arrive during the fresh stage of decomposition included the calliphorid species, *Chrysomyia rufifacies*. These were followed by the domestic houseflies *Musca domestica*. After several hours the predatory ants *Pheidole sp.* and *Atta sp*. (Hymenoptera; Formicidae) were also attracted to the pig carrion. Oviposition was not observed

immediately. The first egg batches were observed the next day in and around the natural orifices of the heads, as well as, around the neck wounds. Hatching of the blow fly eggs occurred after 24 hours, at which time the emerging larvae began feeding on the fluids seeping from the natural orifices. By noon of the second day, a few adult Therevidae, Dolichopodidae and Gasterophilida*e* were also observed on the carrion and surrounding vegetation (Tables 3 and 4).

The colonizers that arrived on the carrion during the bloat stage were adults of the dipteran families; Calliphoridae, Muscidae, Drosophilidae, Therevidae, and Gasterophilidae. Adults of *Chrysomyia rufifacies* were reared from larvae collected during days 3-6 in the wet seasons and days 2-5 in the dry seasons. Among the hymenopterans, *Atta sp*., *Dorylus sp*., *Pheidole sp*., *Crematogaster sp.* all belonging to the family Formicidae, as well as *Apis sp.* (Hymenoptera: Apidae) were collected. *Apis sp.* was, however, only collected during the wet season. Ants (*Pheidole sp.*) continuously removed eggs and larvae from the carrion during the first 2 weeks of the study. *Atta sp.* made holes in the ground around the natural orifices of carrion to trap adult flies. Beetles of the families Cleridae, Histeridae, Lycidae and Staphylinidae were observed regularly from days 4-8 and days 3-6 in the wet and dry seasons, respectively. Those of the families Dermestidae and Paussidae were observed from day 7 onward in both seasons. Pyrrhocorid bugs and a Saturniid moth were collected on day 4. No Saturniid moth was encountered in the dry season (Tables 3 and 4).

In the active decay stage, the heads of all carrion were entirely infested with calliphorid larvae in varying stages of development. Although *C. rufifacies* was first collected in the fresh stage, their numbers increased dramatically in the active decay on all carrion. New maggot masses formed around eyes, mouthparts and anuses. The number of ants visiting the carrion was also greatest during this stage. By the end of the active decay stage, huge maggot masses were evident in several areas of the exposed carrion. The first day that pupae were observed on the carrion was on day 11and 9 for the wet and dry seasons, respectively. In all carrion, active decay was driven by Calliphoridae larvae (mainly larvae of *C. rufifacies*). The number of coleopterans increased considerably during the advanced decay stage.

The onset of the dry/remains stage (between days 16-24 for wet season and 13-16 for dry season) was more difficult to define than the previous stages because of the lack of events marking the beginning of this stage. Coleopterans and hymenopterans were the dominant insects during the dry/ remains stage. Cleridae made another appearance on day 16 in the wet season. During the dry stage, a few adult Calliphoridae were still attracted to the remains, but did not lay eggs. The small numbers of larvae found were concentrated in the extremities (hooves), places providing shelter and where small amounts of soft tissue remained. Decomposition from the Fresh to the Dry stages took 24 days in the Wet season and 16 days in the Dry season

DISCUSSION

Changes in climatic factors, mainly temperature, relative humidity and rainfall affect carrion decomposition rates (De Carvalho and Linhares, 2001; Kočárek, 2003; Shi *et al*., 2009) and subsequently the number of days to complete decomposition. In this study, the carrion completely decomposed in 16 and 24 days for the dry and wet seasons, respectively. The number of days recorded for both seasons were fewer relative to reported cases elsewhere; Hawaii, 25 days (Payne, 1965), Western Australia, 40 days (Bornemissza, 1957), Brazil, 40 days (De Carvalho and Linhares, 2001), and Columbia, 83 days (Martinez *et al.*, 2007). However, Chin *et al.* (2007) reported relatively fewer days to complete decomposition in Malaysia, where it took only 14 days for the complete decomposition of pig carrion weighing approximately 10kg. These differences are usually attributed to the differences in changes in climatic conditions unique to each geographic region for each predefined stage of decomposition outlined by the researchers (Sharanowski *et al.*, 2008). In this study, however, there were not much seasonal differences between the mean ambient temperatures and relative humidity (Table 1) and these might not readily explain the differences observed.

The decomposition changes and the pattern of insect (and other arthropods) succession observed in the dry season were therefore, very similar to those of the wet season. Although the warmer weather played a major role in the overall decomposition process, it did not account for the difference in the rates of decomposition. The warmer temperatures experienced in both seasons, however, increased the number and diversity of carrion insects visiting the carcasses, which in turn accelerated the growth and development of maggots. This explained the observed faster rate of decomposition as compared to the cited studies conducted in Europe and the Americas.

The relatively higher humidity observed during the dry season than the wet season, which was not typical (as humidity values tend to be generally low in dry seasons across Ghana), might have helped to keep the carrion in a favorable state for optimum microbe and dipteran development and therefore, contributing to the faster rate of degradation observed in the dry season. According to Gunn (2008) and Shi *et al.* (2009) humid atmosphere promotes decay while a dry one delays it. A humid environment contains enough moisture suitable for growth of microbes and blowfly maggots during the early stages of decomposition which result in accelerated decomposition. A dry environment, on the other hand, dries the skin and underlining tissues of the carrion making it relatively unsuitable for growth of microbes and dipteran larvae. This subsequently leads to low external maggot activity during the early stages of decomposition.

Access of the insects to carrion, according to Mann *et al.* (1990), is the second most important variable affecting the decomposition rate of human body, after temperature. If given access, the female adult insects will oviposit on carrion within the first few hours (Hall, 1948). In this study, all three carrion were placed on the ground and exposed without clothes, shade or too much rain. All

the natural orifices (mouths, eyes, ears and anal regions) were well exposed and accessible to insects. In addition, they had open neck wounds. Odours from fluids oozing out of these openings attracted adult blowflies and houseflies which reached the carrion within minutes after exposure. This led to early oviposition in the natural orifices and the open wound. The emergent larvae were, therefore, guaranteed sufficient food, warmth, moisture, oxygen and internal tissues. This led to the formation of massive larval masses resulting in the accelerated decomposition of the pig carrion.

The general patterns of insect succession were similar in both wet and dry seasons. Dipteran flies were always the first to visit the carrion; they arrived a few moments after carrion exposure. These were followed several minutes later by the ants. Coleopterans and hemipterans were not observed until the bloated stage. On account of their activity and frequency, the Calliphorid species, *Lucilia rufifacies* were the insects of greatest forensic importance. These blowflies were the initial colonize of the carrion in both seasons and remained throughout the decomposition process. The larvae subsequently fed vigorously on the carrion tissues leading to rapid removal of biomass and accelerated decomposition. This observation is in line with other carrion decomposition studies (Payne, 1965; Anderson and VanLaerhoven, 1996) and demonstrates that there may be no significant delay in colonization of carcasses even in urban habitats. Ants were collected from all carrion throughout the decomposition period, feeding on both carrion and insects. In some areas, the removal of eggs by ants can have a major effect on decomposition rates (Reed, 1958; Payne, 1965; Greenberg, 1991), and some authors have found that other species of ants can also have a significant effect on decreasing the decay rates (Cornaby, 1974; Lord and Burger, 1984). Beetle activity was essentially associated with the advanced stages of the degradation process causing the drying out of semi-liquid soft tissues. Other insect orders such as Lepidoptera and non-insect orders such as Arachnida were either adventitious species or predators of necrophagous species.

Our study demonstrated that rate of decomposition and pattern of insect succession do not vary across different seasons, or tend to be small, if climatic conditions prevailing during these seasons are not very different. The dry season study might not have yielded significant information since conditions prevailing at the time of study were not characteristic of the usual dry season pattern experienced in Ghana. The greatest forensically useful indicator species were the calliphorid species, *Lucilia rufifacies* and ants. Coleoptera and Hemiptera were observed until the bloated stage. Future research would look at the biological and ecological characteristics of the particular species associated with carrion in the different core habitat types within a geographic area.

ACKNOWLEDGEMENTS

We are grateful to Mr. Ekow Davis of the Entomology Museum of the Department of Animal Biology and Conservation Science and Mr. J. Y. Amponsah of the Department of Botany for their enormous assistance in identifying the various insect and plant species, respectively.

REFERENCES

Anderson G. and VanLaerhoven S. 1996. Initial studies on insect succession on carrion in southwestern. British Columbia. Journal of Forensic Sciences. 41: 617-625.

Anderson G.S. 2001. Insect succession on carrion and its relationship to determining time of death. Forensic entomology: the utility of arthropods in legal investigations. G.S., Anderson, J.H. Byrd and J.L. Castner (Eds.). CRC Press, Boca Raton, FL. pp. 143-175.

Bornemissza G. 1957. An analysis of Arthropod succession in Carrion and the effect of its decomposiion on the soil fauna. Australian Journal of Zoology. 5: 1-12.

Catts E. and Goff M.L. 1992. Forensic entomology in criminal investigations. Annual Review of Entomology. 37: 253-272.

Chin H.C., Marwi M.A., Salleh A.M., Jeffery J. and Omar B. 2007. A preliminary study of insect succession on a pig carcass in a palm oil plantation in Malaysia. Tropical Biomedicine. 24: 23-27.

Cornaby B.W. 1974. Carrion reduction by animals in contrasting tropical habitats. Biotropica. 51-63.

De Carvalho L.M.L. and Linhares A.X. 2001. Seasonality of insect succession and pig carcass decomposition in a natural forest area in southeastern Brazil. Journal of Forensic Sciences. 46: 604-608.

Goff M.L. 1993. Estimation of post mortem interval using arthropod development and succession patterns. Forensic Science Review. 5: 82-94.

Greenberg B. 1991. Flies as forensic indicators. Journal of Medical Entomology. 28: 565-577.

Gunn A. 2008. Essential forensic biology. John Wiley and Sons Ltd, England.

Hall D. 1948. The blowflies of North America. Thomas Say Foundation, Lafayette, Louisiana.

Kočárek P. 2003. Decomposition and Coleoptera succession on exposed carrion of small mammal in Opava, the Czech Republic. European Journal of Soil Biology. 39: 31-45.

Kyerematen R.A.K., Boateng B.A. and Twumasi E. 2012. Insect diversity and succession pattern on different carrion types. Journal of Research in Biology. 2: 683-690.

Lord W. and Burger J. 1984. Arthropods associated with harbor seal (Phoca vitulina) carcasses stranded on islands along the New England coast. International Journal of Entomology. p. 26.

Mann R.W., Bass W.M. and Meadows L. 1990. Time since death and decomposition of the human body: variables and observations in case and experimental field studies. Journal of Forensic Sciences. 35: 103-111.

Martinez E., Duque P. and Wolff M. 2007. Succession pattern of carrion-feeding insects in Paramo, Colombia. Forensic Science International. 166: 182-189.

Payne J.A. 1965. A summer carrion study of the baby pig Sus scrofa Linnaeus. Ecology. pp. 592-602.

Reed Jr H. 1958. A study of dog carcass communities in Tennessee, with special reference to the insects. American Midland Naturalist. pp. 213-245.

Rodriguez W.C. and Bass W. 1982. Insect activity and its relationship to decay rates of human cadavers in East Tennessee. University of Tennessee, Knoxville, Tennessee, USA.

Sharanowski B.J., Walker E.G. and Anderson G.S. 2008. Insect succession and decomposition patterns on shaded and sunlit carrion in Saskatchewan in three different seasons. Forensic Science International. 179: 219.

Shean B.S., Messinger L. and Papworth M. 1993. Observations of differential decomposition on sun exposed vs. shaded pig carrion in coastal Washington State. Journal of Forensic Sciences. 38: 938-938.

Shi Y-W., Liu X-S. Wang H-Y. and Zhang R-J. 2009 Seasonality of insect succession on exposed rabbit carrion in Guangzhou, China. Insect Science. 16: 425-439.

Smith K.G. 1986. A manual of forensic entomology. The Trustees of the British Museum (Natural History), London, UK.

Watson E. and Carlton C. 2003. Spring succession of necrophilous insects on wildlife carcasses in Louisiana. Journal of Medical Entomology. 40: 338-347.