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Arthropod succession on pig carcasses in Southeastern Nigeria

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ABSTRACT

*The domestic pig (*Sus scrofa*) was used as a model to study arthropod succession on carcasses under tree shade and out of shade in southern Nigeria. Carcass decomposition took longer periods under tree shade than in exposed sites, at 24.5 and 16.5 days, respectively. Four decomposition stages – fresh, bloated, decay, and dry – were observed. No significant variabilities were recorded in the types and patterns of infestation of the carcasses by arthropods in both locations. Four classes of arthropods – Insecta, Arachnida, Diplopoda and Crustacea – were recorded. The class Insecta dominated the total arthropods collected with 24 families, and formed 94% of the catches. The other three classes each had one family represented, and contributed only 2% of the total catches. The calliphorids, a phorid, and sarcophagids arrived and bred on the carcasses only a few hours after death of the pigs. Families of coleopterans came during the bloated stage, and fed on the immature dipterous maggots and carrion materials. The ants (Hymenoptera) came in large numbers to eat the carcasses, and also preyed on all other fauna of the food resource. A muscid and a stratiomyiid, bred on the carcass as to the decay stage. Other insects and arthropods arrived mostly during the decay stage to feed on the carcasses. Species richness on the carcasses peaked during the decay stage.*

Keywords: Decomposition stages; Carcass; Arthropods; Insects.

INTRODUCTION

Insects are the most abundant animals on earth (Koptal, 2007), and are present in all ecological systems, especially terrestrial environments (Catts & Goff, 1992). Because of their ubiquity, they are usually present as silent witnesses at crime scences (Greenberg, 1991). Some sarcosaprophagous flies are very vagile (Hall, 1948), and are able to reach a carcass and oviposit within a few hours of death. Forensic entomology, the scientific discipline which uses the presence of insects at sites of felony, came to being from knowledge of this natural phenomenon.

Earliest recorded application of the science in criminal investigation dates to the 13th century in China, where according to Mcknight (1981), fly preference for a particular sickle in a farming community enabled the investigators in a murder case to identify the culprit.

Insects visiting carcasses usually exhibit a uniqueness in their pattern of succession on carcasses (Greenberg, 1991). This pattern usually correlates with stages

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of decomposition of the carcass (Catts & Goff, 1992; Carvalho *et al.,* 2000; Wolff *et al.,* 2001). Thus there are usually the early invaders which arrive as soon as the animal falls dead (Hall, 1948), to be followed by latter groups as the corpse decomposition progresses (Schoenly & Reed, 1987). It is from this predictable behaviour of carrion insects on carcasses that estimation of the post mortem intervals (PMI) are made. Accurate PMI estimates can only be made when the species involved are recognised, and information on their pattern of succession and subsequent emergence of immature stages (eggs, larvae, and pupae) are obtained.

In tropical Africa, cases of application of insects in criminal investigations are rare. One reason for this may be a paucity of information on carcass decomposition, and insect succession on it in the area. This study therefore sets out to record the entomofauna of the pig carcass as a model for human corpses in the southeastern part of Nigeria, and also to describe carcass decomposition under shade and out of shade in the area.

MATERIAL AND METHODS

Arthropod succession on pig carcasses in the southeastern part of Nigeria was studied in Uyo, a metropolitan town in the area (Fig. 1). There are two seasons: the dry and rainy or wet seasons in the area. The dry season is between November and March, while the wet season is from April to October. This study was conducted at the end of the dry season i.e. from March to early April. Two sites, shaded and unshaded, were selected. The shaded site was in a forest reserve along a ravine at one end of the town. Besides the plantation of *Gmelina arborea* and *Acacia* sp. to control soil erosion, the ravine is thickly forested with native flora, such as *Costus afer, Chromolaena adorata, Smilax kraussiana, Ipomoea* sp. *Elaeis quineensis,* and many others. At the base of the ravine is a stream which runs for the entire length of the ravine into a river some four or five kilometers away. The unshaded site was at an abandoned vegetable garden, about one kilometer away from the ravine site.

At each site, two young and healthy pigs, *Sus scrofa,* weighing between 23.6-23.85 kg each, were killed according to Tantawi *et al.* (1996) at 06:00 hrs, and placed on sacks on the ground at least 2 meters apart, but not more than 3 meters. This was to observe any variabilities that might occur in the decomposition rates of the two carcasses due to physiological differences (Tantawi *et al.,* 1996). A Scavenger exclusion enclosure (4 × 4 × 4.5 m) which kept out all vertebrates, but permitted the entry of all arthropods, was erected over each pair of carcasses. Daily observations and specimen collections, were done at intervals of three hours, from 06:00 to 21:00, until complete decomposition of the carcasses. Before each collection, the decomposition state of each carcass was noted. Specimens collected were adults and immature arthropods on the ground beside each carcass. Flying insects were caught with two sweeps of an insect net, while the immature insects and other arthropods were picked with forceps. All adult arthropods were killed with ethyl acetate and preserved either dry, or in 70% ethyl alcohol for subsequent taxonomic determination. Operational time at each carcass did not exceed 18 minutes to ensure a uniform and limited disturbance at each site. Samples of eggs and larvae were reared and identified (Greenberg & George, 1985), while the adults were sent off for identification at the Insects Museum, Institute of Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. The air temperature and relative humidity at each site were recorded using a uniscope thermometer and a Gallenkamp before each sampling.

TABLE 1: Average daily air temperatures and relative humidity records during experimental periods at the site in Uyo.

Sites	Ambient air temp °C			Ambient RH %
	Min ± SD	Max ± SD	Av.	
Exposed	24.7 ± 1.8	32.4 ± 2.1	28.6	75
Shaded	23.2 ± 1.3	29.7 ± 1.2	26.5	85

RESULTS

During the working periods, average air temperature and relative humidity were recorded as shown in Table 1. Figs. 2-3 are lists of the arthropods collected from both sites. Decomposition phases were more prolonged under shade (26.5 days) than at the exposed sites (16.5 days) (Figs. 4-5).

Four carrion decomposition phases – fresh, bloated, decay, and dry – as classified by Reed (1958) were recorded (Figs. 4-5). The fresh stage lasted less than 24 hours at the exposed sites, while under shade it was about 27 hours. Bloating of the exposed carcasses was characterised by a distention of the abdomen early on day 2, and the phase continued until day 5 (4 days) at the exposed site. Under shade, bloating was noted around mid-morning (09:00 hrs) of day 2, and lasted till end of day 6 (4½ days). The decay stage commenced with the breaking open of the abdomen to expose the internal tissues, releasing a lot of fluid and a strong foul odour. At this period, many insects were attracted to the sites, particularly at the

exposed site. Dipterous maggots were numerous on the soft tissue of the carcasses. Carcasses at the exposed site were overcrowded with maggots and adult insects. Under shade, such heavy presence of insects as recorded at the exposed site was not observed, but there was still a large assemblage of both immature and adult insects on the carcasses. The dry stage was recorded from the point at which drying up of the soft tissue was first noted until the point at which only bones and fur remained. At the exposed site, drying up was observed on the 9th day, and was completed in about 8 days, while under shade, drying commenced as from the 13th day and lasted for more than 13 days (Figs. 4-5). A total of 50 species from four classes of arthropods were collected from the carcasses. The classes were Insecta, Arachnida, Diplopoda, and Crustacea (Figs. 2-3). Of these, insects formed 94%, and each of the other classes contributed 2%. Each carrion was initially invaded by calliphorids, sarcophagids phorids, and hymenopterans (Figs. 4-5). This invasion was followed by those of coleopterans, muscids, other insects, and other arthropods.

Six species of calliphorids (Fig. 2) were recorded on the carcasses, but only three species were observed breeding on them. The breeding species were: *Hemipyrellia fernandica* (Macquart) *Chrysomya chloropyga*

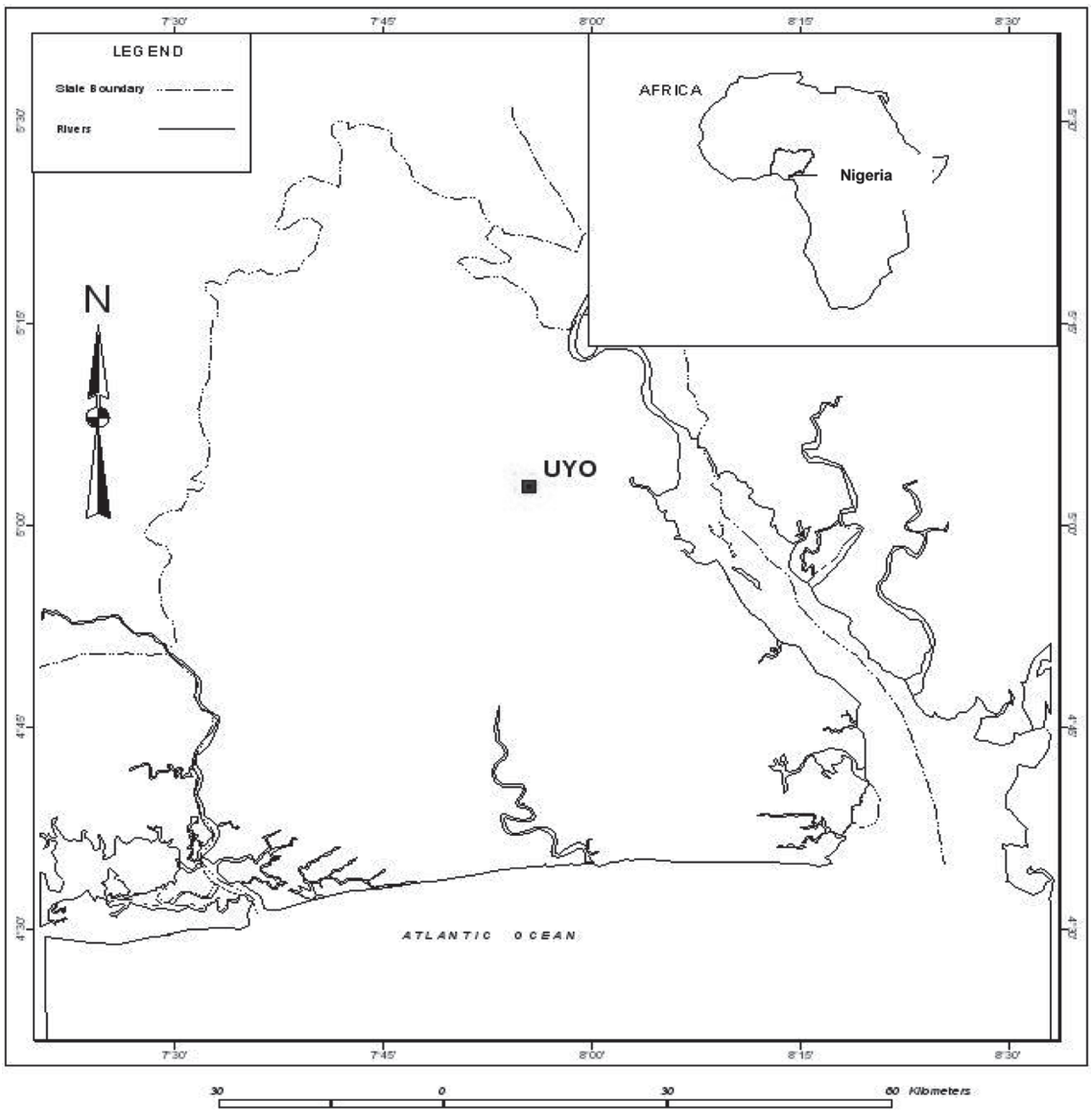

FIGURE 1: Map of Southeastern Nigeria showing position of Uyo.

(Wiedemann), and *C. albiceps* (Wiedemann). Calliphorid eggs were observed around the nostrils, mouth, and wound site around the neck of the pig carcasses as from day one, during the fresh stage. Maggots of these three calliphorids were numerous on the carcasses, especially during the decay stage, and the 1st and 2nd instars of *C. chloropyga* and *C. albiceps* continued to be available on the carcasses up until the early phases of the dry stage of the carcasses (Fig. 2). The other three calliphorids, particularly *Rhyncomya* sp., were collected only during the later decomposition stages of the carcasses (Fig. 2).

Adults of three sarcophagids, *Sarcophaga nodosa* (Engel), *S. inequalis* (Austen), and *S. exuberans* (Pandélle), were collected from the carcasses. Second instars of sarcophagids were collected from the wound sites on the carcasses on day 2 (Fig. 2). Due to logistical problems, these larvae were not reared to adults to ascertain their identities.

Three species of muscids, *Musca* sp., *Morellia nilotica* (Loew), and *Confiscata* sp., were collected in the study. Of these, only *M. nilotica* was noted breeding on the carcasses. Muscids appeared on the carcasses during the bloated stage (Fig. 2). *M. nilotica* oviposited at this period, and its larval instars were recorded on the carcasses during the decay stage (Fig. 2).

Pupae of a phorid, *Megaselia* sp., were recorded on the fur of the carcasses as of day 3 (Fig. 2).

Sagaricera analis (Grunberg), a Brachycera (Stratiomyidae) also bred on the carcasses (Fig. 2). Its eggs and larvae were numerous during the decay and dry stages of the carcasses. The eggs and larvae were reared to adults and identified.

Fifteen species of coleopterans were recorded in this study (Fig. 3). The earliest coleopterans on the carcasses were the scarabids, staphilinids, chrysomelids, and clerids, which arrived during the bloated stage of the carcasses (Figs. 4-5). More coleopterans were noted during the decay stage of the carcasses. No coleopteran was observed to breed on the carcasses.

The ants (Formicidae) arrived on the carcasses within the first three hours since death of the pigs (Figs. 4-5), and continued to be present till exhaustion of the carcasses. Their population increased up to the decay stage of the carcasses, and then decreased as the carcasses dried up. Seven species of ants (Fig. 3) were recorded.

Other insect orders recorded on the carcasses were orthopterans, hemipterans, dictyopterans, and a termite. Other arthropods were spiders, millipedes, and a crustacean (Fig. 3). Full identification of the non-insects were not done.

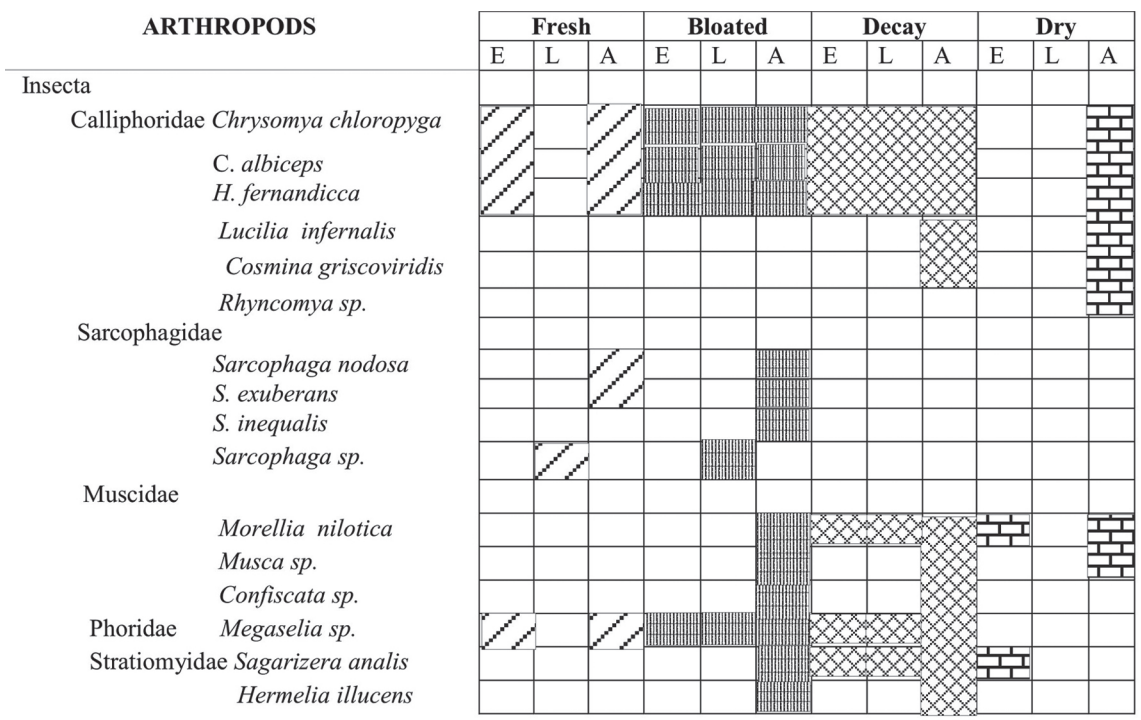

FIGURE 2: Succession pattern of the breeding arthropods on decomposing pig carcasses in Akwa Ibom, Nigeria.
E = eggs, L = larval instars and pupae, A = adults.

DISCUSSION

The two sets of pig carcasses were studied under differing environmental conditions. The result affirms the observations by Galloway *et al.* (1989) as regards the effect of air temperatures, relative humidity, and insect abundance. Average daily air temperatures and relative humidity at the exposed site were 28.6°C and 75%, respectively, while at the shaded site, air temperature and relative humidity were 26.5°C and 85%, respectively (Table 1). The higher air temperature and lower relative humidity at the exposed site led to faster chemical reactions, thus leading to faster decomposition of the carcasses at this site than at the shaded site.

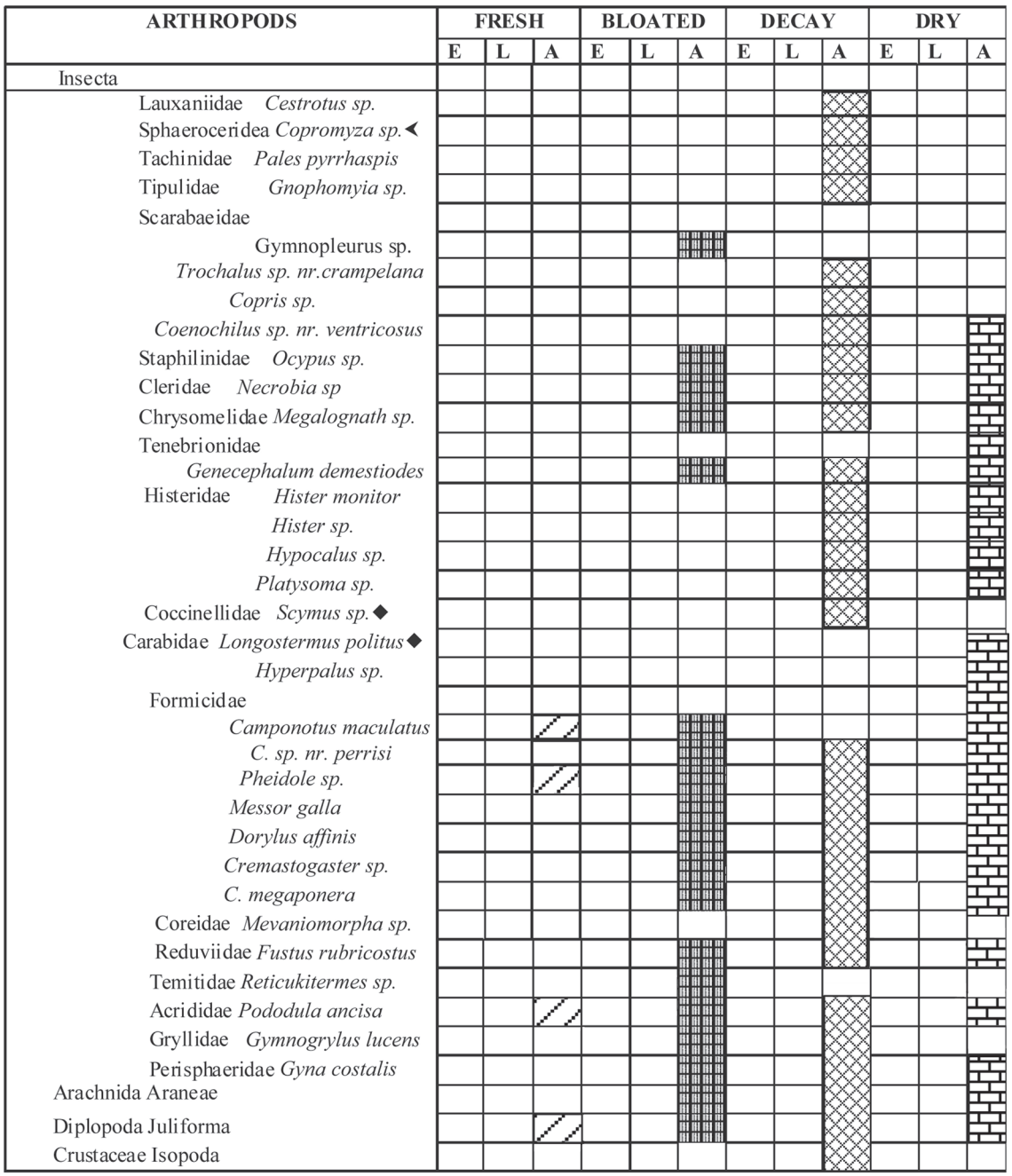

FIGURE 3: Succession pattern of the non-breeding arthropods on decomposing pig carcasses to under shade and out of shade in Akwa Ibom, Nigeria. ◄ species taken only from carcasses out shade, ♦ species taken only from carcasses under shade.

Also, the larger number of insects and other arthropods attracted to carcasses at the exposed site led to a more rapid consumption of the carcass tissues at the exposed site than at the shaded site. Following the rapid consumption of carcass tissues and the higher air temperature and lower relative humidity, the carcasses at the exposed site were able to decompose at a faster rate than those under shade. Environmental conditions in the afro-tropical region are mostly characterised by high air temperatures and insect abundance. These environmental factors led to the faster rate of carcass decomposition in this study than at temperate zones where many workers have recorded a decomposition rate of more days, such as 118 days (Wolff *et al.,* 2001), over 36 days (Fielder *et al.* 2008), and many other examples.

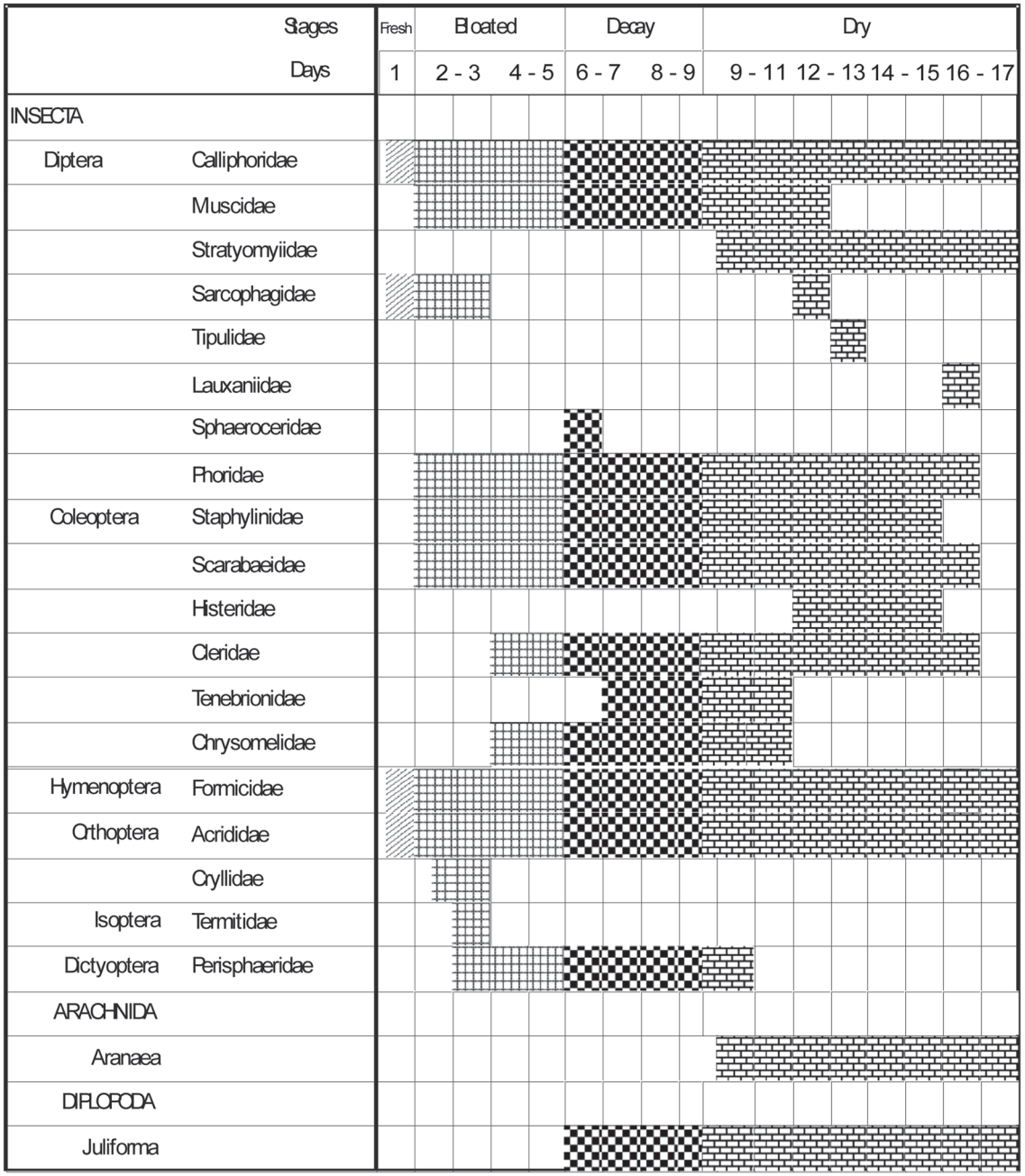

FIGURE 4: Arthropod succession on exposed pig carcass.

Tantawi *et al.* (1996) in a seasonal study of decomposition rates of rabbit carcasses in Alexandria, Egypt, recorded 12 days in summer and 92 days in winter. The influence of external factors, such as environmental factors, in the rate of carcass decomposition is therefore of great significance, since attraction

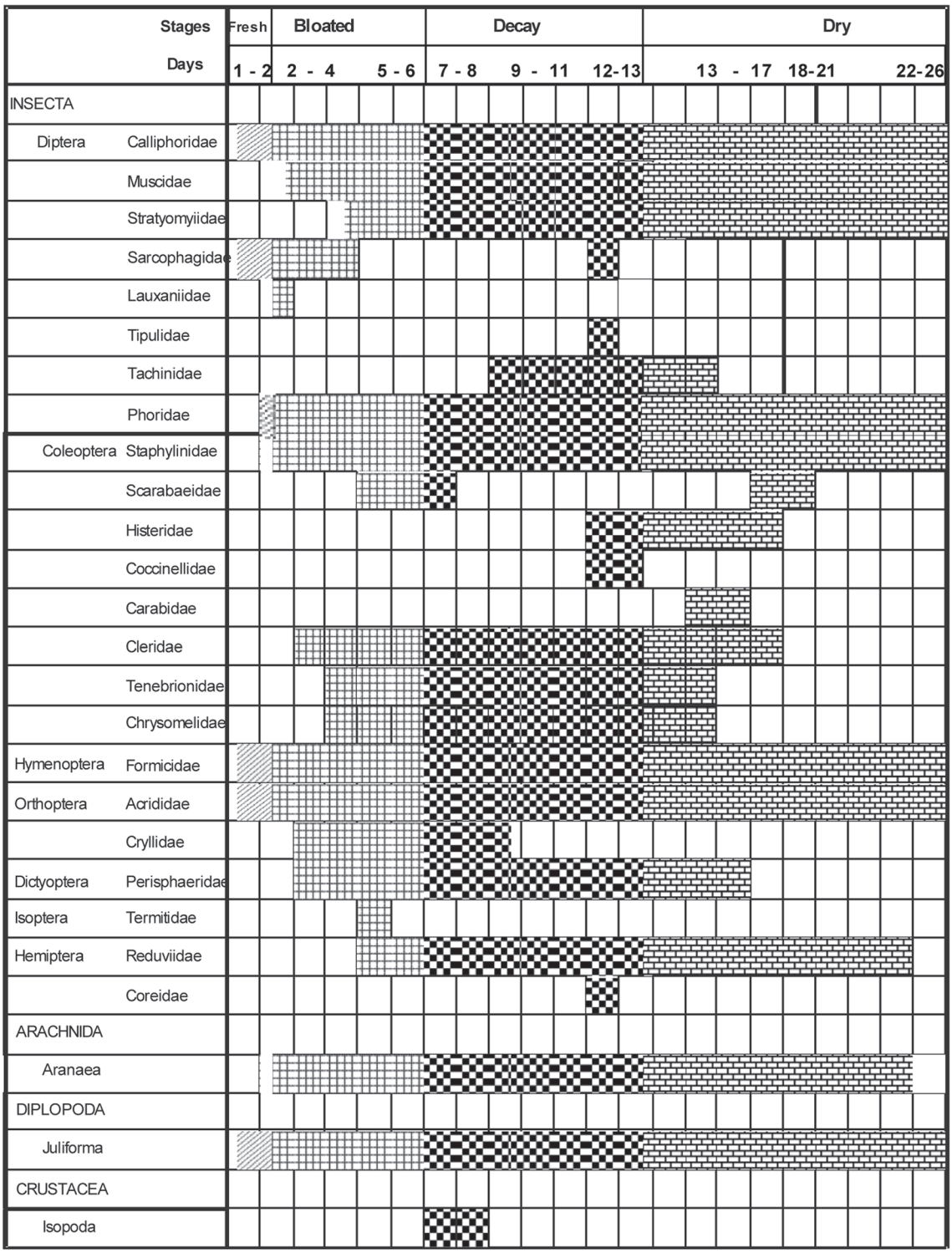

FIGURE 5: Arthropod succession on carcass under shade.

of insects to carcasses will depend on the stage of the carcass decomposition (Benecke, 2004). Also of importance in rate of decomposition is the size and type of cadaver (Wolff *et al.* 2001). In Ekanem & Usua (2005) rabbit carcasses weighing 2.5 kg each were used, and the total decomposition during the wet season, which is the cool season in the area, lasted for 8 days only.

In the study, insect species had dominated the arthropod populations on the carcasses. Similar domination by insects on terrestrial habitats have been reported by several authors, including Catts & Goff (1992), Wolff *et al.* (2001).

The succession pattern of arthropod invasion of the carcasses began with ants (Formicidae), Calliphoridae, Sarcophagidae, and Phoridae as the initial or 'Primary' invaders (Fuller, 1934). They were followed by the muscids and coleopterans. Other insects, e.g. grasshoppers and other arthropods such as millipedes, found on the carcasses were part of the local entomofauna. A slight difference in this succession pattern from reports by others, such as Carvalho *et al.* (2000), Wolff *et al.* (2001), and Clery (2010), is the appearance of sarcophagids before muscids. We consider sarcophagids as primary carcass flies of this area. First instars of sarcaphagids can usually be obtained after a brief exposure of fresh meat outdoors. Leccese (2004) working in Northern Italy had made a similar observation. Sarcophagidae (*Sarcophaga africana*) as well as calliphorid flies, were attracted to fresh meat. A comparable occurence was seen in this study. Calliphorids and a phorid (*Megaselia* sp.) oviposited eggs while the sacrcophagids gave birth to first instar larvae in the body openings and wound sites of the pigs. Their larval instars have mouth hooks with which they chewed, burrowed, and fed internally in the decomposing animal tissues.

The ants (Formicidae) also have strong mandibles which enabled them to chew off pieces of the decomposing carcasses, as well as prey on dipterous eggs and larvae, and any other accessible arthropods on the carcasses. Their invasion, especially as they came in colonies, may have affected the carcass decomposition rate, either by predation on immature stages of dipterous flies, or by removal of portions of the carcasses.

The earliest coleopterans consisting of staphylinids, scarabaids, clerids and chrysomelids during the bloated stage (Fig. 3) consumed soft tissues of the decomposing carcasses, as well as preyed on the abundant dipterous larvae present on the carcasses. Presence of these predatory beetles, as well as ants, may substantially have affected the decomposition rate of the carcasses. The latter coleopteran arrivals, e.g. the histerids, fed on the drying carcass tissues. Coleopterans came either to feed on the carcasses or prey on other participants of the food resource.

Muscids arrived at the carcasses during the bloated stage when the odour of decomposition had become noticeable. Their arrival at this stage suggests a preference for animal tissue at a more advanced stage of decomposition. Adults of *Musca* sp. and immature stages and adults of *M. nilotica* were very abundant during the decay stage.

Observation of the pupal stage of the *Megaselia* sp. on day 3 (bloated stage) of decomposition, suggests an earlier arrival of the fly on the carcasses during the fresh stage. They were abundant and, as noted by Leccese (2004), in conjunction with *Sarcophaga* sp. they could contribute to the estimation of post mortem interval (PMI).

Adults of *Sagaricera analis* were also attracted to the carcasses during the bloated stage. Their immature stages were also very abundant during the decay and early dry stages of the carcasses (Fig. 2).

Seven species (*C. chloropyga, C. albiceps, H. fernandica, Sarcophaga* sp., *Megaselia* sp., *M. nilotica* and *S. analis*) bred on the carcasses (Fig. 2). Of these seven, the breeding biology of three calliphorids, *C. chloropyga, C. albiceps* and *H. fernandica* was clearly noted, as they had primarily invaded the carcasses. Together with the ants, they were responsible for tearing apart the carcasses. Larvae of the three flies were present on the carcasses in great numbers. The sarcophagids were few and the phorid was small in size. These may not have played a very significant role in the break-up of the carcasses within those first few days. Similarly, *M. nilotica* and *S. analis,* although numerous, only appeared on the carcasses after the carcass tissue had broken down.

Several other insects, including the breeding species and other arthropods, fed on the rotting carcasses. These included the hemipterans, dictyopterans, termites, orthopterans, millipedes (Diplopoda), and the wood louse (Crustacea) (Fig. 3). These formed part of the local entomofauna. For instance, the hemipterans and the wood louse in this study were only encountered at the shaded sites (Figs. 4-5), which also had a thick topsoil cover of rotting plant materials. Such a forest environment is a preferred habitat for this crustacean as well as bugs, rather than the uncovered eusynanthropic environment of the exposed site.

The pattern of arthropods succession on carcasses is determined by the roles of each species on the carcasses. According to Smith (1986) four major groups of arthropods occur on carcasses. Foremost

and classified as necrophagous are the primary invaders, made up of flies which breed and feed on the carcasses, as well all the carcass feeding coleopterans and hymenopterans. The hymenopterans, coleopterans, and the spiders which prey on dipterous eggs, larvae, and other insects on the carcasses are grouped as predators/parasitoids. A third group, the omnivores, made up of both predatory and necrophagous insects include the hymenopterans, the dipterans, and coleopterans. Lastly, are the incidentals or adventitious species which include all other insects and arthropods found on or close to the carcasses. Being a part of the local entomofuna, the carcasses become an extension of their ecological niches. Included here were millipedes, termites, grasshoppers, wood louse, bugs, and cockroaches.

CONCLUSION

The decomposition rate of carcasses is affected by environmental factors such as air temperatures and relative humidity of the area. Also affecting decomposition rate is the body weight of the carcass and insect abundance. In this study, four distinct stages of carcass decomposition were observed. The decomposing carcasses attracted a succession of arthropods, particularly insects, and formed a pattern of succession. In this pattern of succession, dipterous insects of the families Calliphoridae, Sarcophagidae, Phoridae, Muscidae, and a stratiomyidae (Brachycera) oviposited and fed on the carcasses. Their breeding biology led to the breakdown and exposure of the carcasses' soft tissue to other groups of arthropods. This second group included both predators and omnivorous species.

Aside from preying on defenseless, immature dipterous and other insects on the carcasses, the hymenopterans, coleopterans and spiders also fed on the carcass material. The orthopterans, dictyopterans, isopterans, diplopods, hemipterans and crustaceans were on the carrion only as incidentals, since they were part of the entomofauna of the area.

RESUMO

*O porco branco (*Sus scrofa*) foi usado como modelo para o estudo da sucessão de Artrópodes em cadáveres em zonas sombreadas e não sombreadas por árvores no sul da Nigéria. Nos cadáveres em decomposição em zonas sombreadas observou-se um processo de decomposição mais lento que nos expostos ao sol; 24,5 e 16,5 dias, respectivamente. Foram observadas quatro etapas de decomposição; fresco (autólise), intumescido (putrefação), deteriorado e seco (diagênese). Não foram observadas diferenças significativas de tipo e padrão nas infestações dos cadáveres por Artrópodes em ambas as condições. Foram registradas quatro classes de Artrópodes: insetos, aranhas (Arachnida), Diplópodes e Crustáceos. Os insetos foram a classe predominante representada por 24 famílias no total de 94% das coletas. Para cada uma das três classes restantes registrou-se apenas uma família no total de 2% das coletas. As moscas das famílias Calliphoridae, Phoridae e Sarcophagidae tomaram lugar e desenvolveram-se nos cadáveres apenas algumas horas após a morte dos animais. As famílias de coleópteros surgiram na fase de putrefação e alimentaram-se de insetos dípteros jovens e dos próprios cadáveres. As formigas (Hymenoptera) ocorreram em grande número para se alimentar dos cadáveres e usurpar, à restante fauna presente, a fonte de alimento. Na fase de deterioração desenvolveram-se nos cadáveres uma espécie de Diptera da família Muscidae e uma de Stratiomydae. Outros insetos dípteros e artrópodes surgiram para se alimentar dos cadáveres sobretudo na fase de deterioração. O ponto de maior riqueza de espécies (S) foi registrado na fase de deterioração dos cadáveres.*

Palavras-chave: Fases de decomposição; Cadáver; Artrópodes; Insetos.

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