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The Influence of Clothing and Wrapping on Carcass Decomposition and Arthropod Succession During the Warmer Seasons in Central South Africa*

ABSTRACT: The influence of clothing and wrapping on carcass decomposition and arthropod succession was investigated to provide data to enable estimated postmortem interval in homicide investigations. Six pig carcasses, *Sus scrofa,* were divided into three sample groups, each with a clothed carcass wrapped and a carcass wrapped with no clothes. Two more carcasses, one with no clothes or wrapping, the other with clothes and no wrapping were used as controls. The clothed or wrapped carcasses had larger visible maggot masses, which moved more freely and these carcasses took longer to dry out. The blow fly maggot masses were dominated by *Chrysomya marginalis* and *Chrysomya albiceps.* Oviposition occurred simultaneously on all carcasses. High temperatures in one case caused significant maggot mortality. The Coleoptera community was dominated by Silphidae, *Thanathopilus micans* larvae, Dermestidae, *Dermestes maculatus* adults and larvae, and Cleridae, *Necrobia rufipes.*

KEYWORDS: forensic science, forensic entomology, clothing and wrapping, blow fly succession, South Africa

Forensic entomology is commonly used in many criminal investigations, for example; Greenberg (1), Goff and Odom (2), Goff and Flynn (3), and many others (4–7). Its primary use is to determine the period of arthropod activity which can contribute to an estimated minimum postmortem interval, in other words, an estimated time of death. In some cases, this estimation can be calculated to within minutes of death as some arthropods may respond immediately. This is done by analysis of the insect composition found at the crime scene and on the victim's body. Victims of crime can be found in many different environments and circumstance. Arthropods respond directly to their environment (8). There are many studies done to determine the effects different environments and circumstance may have on the carrion-associated arthropods (9–21). These studies are done on insect succession on pig (*Sus scrofa* Linneaus) or human remains, (9–21), under a number of different circumstances, for example; contrasting habitats (12), arid habitat (13), intertidal habitat (14), in water (15, 16), burnt carrion (17), refrigerated carrion (18), exposed versus shaded carrion (19), inside dwellings (20), and buried (21). There are very few reports of cases or studies in which the remains were wrapped (22). Wrapping may firstly restrict the insect access to the remains and then when the insects or maggot mass has established, the clothes and the wrapping may provide shelter and microclimate in which the insects can develop. This may be more significant than the natural shelter proved by the exposed carcasses. This study aimed to test the influence of (i) clothing, (ii) wrapping of a carcass, (iii) combination of both clothing and wrapping. A 5- and 10-day rotation was included to determine if there was any influence or effect of daily disturbances.

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Materials and Methods

Location

The field trials were conducted in an open field which was located at the west campus of the University of the Free State, Bloemfontein, South Africa. (29°05′S; 26°10′E, 1443 m above sea level). The field was 26 ha of grassland interspersed with trees. The grass species were dominated by *Themeda triandra* Forsk., with scattered tufts of *Aristida congesta* Roem. *et* Schult., *Eragrostis lehmanniana* Nees, *Eragrostis capensis* (Thumb.), *Sporobolus pyramidalis* Beauv., *Heteropogon contortus* (Linnaeus) Beauv., and *Chloris virgata* Sw. The tree species were *Acacia karoo* Hayne, and *Rhus rehmanniana* Engl. Due to difficulty defining the beginning of the seasons in South Africa, the trials were begun on the closest practical day to the autumn equinox and summer solstice. As a result, the autumn trial began on 18 March 2003 (equinox—22 March). The summer trial unfortunately was delayed due to the availability of the pigs and qualified personnel to inject them. Therefore, the trial began on 7 January 2004 (solstice—21 December). Both trials were conducted over a 50-day period.

Experimental Design

Eight freshly killed pig carcasses (*S. scrofa*) were used, as they are an internationally accepted substitute for human bodies (23). The use of carcasses >23 kg was recommended by Catts and

Goff (23). The autumn carcasses were between 23.2 and 28.5 kg, and the summer ones were between 36.5 and 39 kg, and thus, in an acceptable range as not to limit the decomposition and arthropod succession (24). The animals were killed by a single euthanasia injection (Euthapent®; Kyron Laboratories (Pty) Ltd., Johannesburg, South Africa—pentobarbitone 200 mg/mL) at the animal research housing, located next to the field in which the trials were to be conducted. The carcasses were placed in the field minutes after they were killed. The date of death was designated as day 0. The carcasses were placed in full sunlight, with the abdomen facing north, in a north–south orientation and at least 50 m apart. Each carcass was placed in a welded cage of 1.6 by 0.9 by 0.9 m, covered with a fine wire mesh. The mesh on the base of the cage was larger with a 5 cm grid. The carcasses were thus in direct contact with the ground. The cages provided protection from depredation by stray dogs and other scavengers, and facilitated weighing.

The eight pig carcasses were divided into seven experimental carcasses. One carcass had clothes but no wrapping. The remaining six carcasses were divided into three sample groups, each with a clothed carcass wrapped and a carcass wrapped with no clothes. These groups were sampled (i) frequently, (ii) after 5 days, and (iii) after 10 days. The carcass with clothes but no wrapping was sampled frequently. The last carcass with no clothes or wrapping was also sampled frequently as a control. The frequent sampling took place twice a day (morning and mid-day), for the first 2 weeks, then once a day for the next 2 weeks, and finally three times a week for the remainder of the trial. The carcasses that were sampled every 5 and 10 days were sampled only on the applicable day. The clothed carcasses were simply dressed in the same weight/thickness and colored T-shirts, shorts, and underwear (male briefs). The wrapping used was medium weight cotton sheeting, the size of a standard double bed sheet (i.e., 1.5×2 m). The sheet was not secured by pegs or rope. However, care was taken to wrap the carcasses in a similar fashion and after each sampling visit to restore the sheet to the position in which it was found. Data Loggers (MCS 120-02 EX, Mike Cotton Systems, Cape Town, South Africa), in waterproof casing were attached to an upright pole placed approximately a meter from the cage. The data loggers were programmed to record the average temperatures during every hour. Data loggers were placed at the control carcass, the wrapped clothed carcass sampled every day, and the wrapped carcass with no clothes sampled every 5 days. The probes were inserted into the head via the mouth, into the center of the carcass via a thoracic incision, and in the abdomen via the anus. Another probe was placed under the carcass and lastly a free hanging probe was placed in the cage to record ambient temperature. In the summer trial, three additional data loggers in the form of Dallas Thermochron iButtons DS1921G (Maxim Integrated Products Inc., Sunnyvale, CA) (−40 to 85°C) were used to record the ambient temperature.

Sampling Methods

During each sample time the carcasses were described in detail in terms of physical appearance (e.g., bloated, smell, visibility of bones and internal organs, amount of skin) and all arthropods were visually identified and recorded. Only specimens that were not recorded previously were collected, and added to the reference collection, which was established during an introductory trial done in November 2002. Maggot mass locations were drawn. A photographic record of all the carcasses was maintained. The Diptera larvae (maggots) and eggs, when present, were collected and preserved in 70% ethanol, and sub-samples were raised to adulthood (for identification purposes) from every second day's samples. The preserved maggots were classed into instar and age and identified where possible. Both maggots and adults were identified using keys compiled by Zumpt (25). During the sampling, care was taken not to disturb the maggot masses more than necessary. Only a small sample of *c.* 50–100 maggots (depending on the maggot mass size) was taken from each mass so as not to disrupt the natural decomposition process. The carcasses were weighed to determine mass loss during the decomposition process. This was restricted to daily weighing of the control carcass and the clothed carcass and alternate day weighing of the two wrapped carcasses sampled every day and the two wrapped carcasses sampled every 5 days. The alternate weighing used on the wrapped carcasses was designed to minimize the disturbance caused by lifting the cage. The other two carcasses (sampled every 10 days) were only weighed on day 0 and again at the termination of the trial.

Results

Decomposition Stages

Some forensic entomological studies describe the decomposition process (e.g., 9, 11). Physical characteristics of various decomposition stages were selected for this study and are summarized in Table 1. These characters were taken from a number of sources, for example Payne (9) and Anderson and VanLaerhoven (11). Decomposition is an ongoing process and the differences between the stages may not always be clear. Thus, there are transitional stages in which characteristics from the adjoining decomposition stages may be present. This sort of classification can be rather subjective to individual observation, but it did provide some base comparison with other available information.

In both trials, the carcasses began to bloat within hours of being placed in the field. Skin breakage and gut distension was also observed in both trials. There was no delay in oviposition by the adult female Diptera on the wrapped carcasses. They oviposited on all carcasses simultaneously regardless of the experimental status of the carcass. The carcasses then entered the active stage simultaneously. The active decay stage lasted *c.* 8–10 days in the autumn and 6–7 days in the summer. The carcasses also entered the advanced decay stage simultaneously. In both seasons, none of the wrapped carcasses dried out to the same extent as the exposed clothed carcass and the control (no clothes nor wrapped). These carcasses therefore remained in the advanced decay stages for the remainder of the trials. Both the control carcasses and the exposed clothed carcass from the summer trial reached the dry remains stage after 29–30 days, with the exposed clothed carcasses of the autumn trial reaching the same point after 19–20 days (Fig. 1A,B).

Arthropod Succession on the Carcasses

In both seasons, the first arthropods to detect the presence of the carcasses were the Muscidae (common house flies) followed closely by the adult members of the Calliphoridae. The adult Calliphoridae (*Chrysomya marginalis* and *Chrysomya albiceps*), were no longer recorded at the carcasses in numbers of more than five after the maggot masses became well established. This occurred from the afternoon of day 11 to the afternoon of day 13 in the autumn and from day 4 in the summer. Muscidae, *Hydrotea capensis* (Wiedemann) and Piophillidae spp. adults were frequently recorded in low numbers throughout the trial.

The *C. albiceps* maggots appeared to have a longer development time than the other Calliphoridae species, rather than a delay in oviposition by the adults of this species. This was confirmed by the

TABLE 1—*Summary of the physical characteristics of decomposition and the dominant arthropods present during the warmer seasons.*

Fresh	Diptera
Commenced when the animal was killed	Muscidae
The torso (thorax and abdomen) was soft and the limbs were flexible	Muscidae spp. (adults)
No odor associated with the carcass	
Very short duration	
Bloat	Diptera
Commenced when the torso began to harden and the abdomen in particular became inflated, due to the buildup of gasses	Calliphoridae *Chrysomya marginalis* (adults) *Chrysomya albiceps* (adults)
Bubbles of blood formed at the nose, creating small puddles or saturating the sheet on the wrapped carcass	*Lucilia* spp. (adults)* Sarcophagidae†
Carcass appeared ''balloon''-like	*Sarcophaga cruentata* (adults)
Body color changed	Muscidae
Oviposition took place during this stage	*Hydrotea capensis* Muscidae spp.
Active decay	Diptera
Carcass deflated, as the maggots actively fed on the carcass tissues and allowed the gasses to escape	Calliphoridae *Chrysomya marginalis* (adults and maggots)
Odor of decay was prominent	*Chrysomya albiceps* (adults and maggots)
The limbs collapsed back into the ''resting'' position, and in some cases the clothing had moved	*Chrysomya chloropyga* (maggots)
The skin began to peel allowing maggots to feed underneath it	*Lucilia* spp. Sarcophagidae: *Sarcophaga cruentata* (adults and maggots)
The carcass mass was halved during this stage	Coleoptera
The maggots were the most dominant insects	Dermestidae *Dermestes maculatus* (adults)
Areas surrounding the maggots and the tissue on which the maggots were feeding became liquefied	Cleridae *Necrobia rufipes* (adults)
Plenty of decomposition liquids were present	Silphidae *Thanatophilus micans* (adults)
Advanced decay	Diptera
There was little tissue remaining on the carcass	Piophilidae (adults and maggots)
Fewer odors were associated with the carcass	Coleoptera
Puddles of decomposition fluids were common along the backs and upper surfaces of the carcass	Dermestidae *Dermestes maculatus* (adults and larvae)
The carcass was still moist but often the head was dried out	Cleridae: *Necrobia rufipes* (adults)
Bones of the skull, ribs and legs were often visible	Siphidae *Thanatophilus micans* (larvae)
The majority of the maggots moved off the carcass to pupate (i.e., <20 individuals remaining)	
Coleoptera became the most dominant group	
Dry remains	Coleoptera
The carcass had little to no moisture	Dermestidae
Gut content had dried out, although there may have been some fluids present when it was very hot	*Dermestes maculatus* (adults and larvae) Cleridae
Only hair and small patches of skin remaining	*Necrobia rufipes* (adults)

*Two species of *Lucilia* have been identified, *Lucilia sericata* (Meigen) and *Lucilia cuprina* (Wiedemann), but they were difficult to distinguish in the field without collection of all the specimens and thus were referred to as *Lucilia* spp.

†*Sarcophaga cruentata* Meigen has been identified, but as with *Lucilia* species, field species identification was difficult and thus they were referred to by family.

presence of *C. albiceps* and *C. marginals* in the sub-samples of maggots raised to adulthood collected just after the eggs hatched. The development time of the maggots was similar during both seasons. In the autumn, *C. marginalis* maggots migrated 10–12 days after hatching, while *C. albiceps* maggots migrated after 13–17 days. And in the summer, *C. marginalis* maggots migrated after 8–11 days and *C. albiceps* migrated after 13 days (Fig. 2A,B).

The Coleoptera community in both seasons was dominated by Dermestidae, *D. maculates*, which successfully bred on the carcasses from the end of the second week. Cleridae, *Necrobia rufipes* were also present on the carcasses from the middle of the first week. Both species numbers increased as the decomposition progressed.

Ambient Temperatures

The daily maximum, minimum, and average ambient temperatures were calculated for each season. In the autumn trial, the probes measuring the ambient temperature in the field were averaged to eliminate some of the variation between the readings of the various probes. The maximum temperatures recorded by the probes at the study site were substantially and unrealistically higher than the temperatures provided by the South African Weather Services (SAWS) data. The weather station was a mere 13 km from the study site; this led to the conclusion that there was a malfunction with the probes used. Therefore, the airport maximum ambient temperature dataset was used. The minimum ambient temperatures recorded at the study site and the SAWS data also varied a little from each other, however, never more than 4°C. Therefore, the minimum ambient temperatures recorded from the study site were used. The ambient temperature recorded at the study site during the summer by the iButtons were very similar to the temperatures recorded at the Bloemfontein airport according to the SAWS data, and thus only the temperatures recoded at the study site were used.

The seasons were warm to hot during the day, with a maximum temperature of 30.3 and 36.1°C for the autumn and summer trials, respectively. It was cooler at night with minimum temperatures of 2.8 and 11.4°C, respectively. The region experienced summer rainfall with 123.2 and 45.8 mm recorded for the autumn and summer months respectively (SAWS data). The projected mean relative humidity for both trials was 62–64% (26). The summer trial minimum ambient temperatures ranged between 11 and 20°C. The maximum ambient temperatures varied from 25 to 32°C. There was less variability in these temperatures than those recorded in the autumn trial, where the minimum ambient temperatures ranged from 0 to 16°C, and the maximum ambient temperatures ranged from 15 to 30°C.

In both trials, the internal temperatures of the carcasses were higher than the ambient temperature most of the time. However, the minimum temperatures of the head and thorax more closely tracked the ambient temperatures during the advanced decay stage. The temperatures recorded underneath the carcasses and abdomen temperatures fluctuated the least. These regions were the least sensitive to the ambient temperature changes.

Mass Loss

In both seasons, the mass loss was faster for the exposed carcasses. Their overall mass was 11% and 14% (in autumn) and 16% and 19% (in summer) versus the wrapped carcasses with 27% to 32% (in autumn) and 31% to 41% (in summer). The two carcasses in the 10-day sample group were only weighed at the beginning of the trial and again at termination. Their remaining end mass loss was similar to the other wrapped carcasses, at 32% and

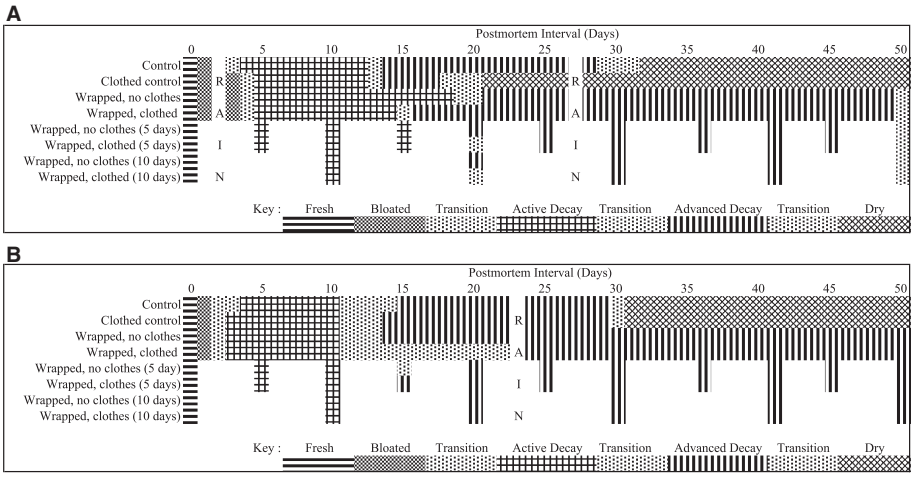

FIG. 1—*(A) Decomposition stages of the carcasses in the autumn wrapped trial. (B) Decomposition stages of the carcasses in the summer wrapped trial.*

37% for the autumn and 31% and 33% for the summer trial (Fig. 3A,B).

Maggot Mass Distribution

All the wrapped carcasses showed a similar pattern, in that the visible maggot masses (underneath the sheet) covered a larger area than those visible on the exposed carcasses. The maggots on the exposed clothed carcass were most prominent in the shorts and along the waistband of the shorts. When the maggot mass got to its largest, the carcass surface was covered almost entirely under the shirt and the shorts. The clothed and wrapped carcasses also had large maggot masses on the outside of the clothing under the sheet, whereas on the exposed clothed carcass, the maggot mass remained under the clothes and was seldom seen outside. The wrapping also appeared to allow the maggot masses great freedom of movement, migrating all over the carcass from tail to snout, at times covering the entire carcass surface under the protection of the sheet, compared with the exposed carcasses, where the visible maggot mass never completely covered the carcasses.

Maggot Mortality

On day 12 of the autumn trial, extensive maggot mortality along the back of a carcass was observed (carcass 4, clothed and wrapped, sampled frequently). The maggot mass concerned was almost completely made up of third instar *C. marginalis*. In the summer trial, both wrapped carcasses that were sampled daily were affected. Maggot mortality was recorded on day 5 in the afternoon. Sampling on day 10 showed that both wrapped carcasses sampled every 5 days were also affected; however, it must have occurred after sampling on day 5. The maggot mortality in these cases affected up to half the maggot masses. However, the wrapped carcasses only sampled every 10 days showed no evidence of extensive maggot mortality. These and other wrapped carcasses experienced some mortality, but only a few individuals were involved, often also found along the back of the carcass.

Maggot Predation

On the 13th day of the autumn trial, *C. albiceps* maggots were observed predating on *C. marginalis* maggots. The carcass they were associated with was not wrapped or clothed, with almost no tissue remaining. The *C. albiceps* were all third instars, but about half the size of well fed *C. albiceps* maggots seen on the other carcasses. They were on the ground below the carcass. Predation only occurred as the postfeeding *C. marginalis* moved off the carcass during maggot dispersal.

Discussion

One of the most significant results, in terms of postmortem interval estimation, was that oviposition by the adult female flies was recorded simultaneously at all the carcasses regardless of whether the carcass was wrapped or not, for both seasons. In the autumn trial, oviposition began on the afternoon of the 4th day after placement, this was due to heavy rainfall, from the afternoon of placement until it cleared in the afternoon of the 3rd day. In the summer trial, eggs were present by the morning of the first day after placement. All of the carcasses in all sample groups showed maggots of the same age and in most cases of the same species during the first 13 days. This was contrary to the work published by Goff (22), who estimated a 2.5-day delay on wrapped remains. However, it should be noted that in the study Goff (22) published, the remains were wrapped in two layers of blankets and securely tied. In the current study, the carcasses were only wrapped in a sheet and were not tied, and under these conditions there was no delay in oviposition.

It is also suggested that warm temperatures experienced during the trials resulted in a large number of adult flies, who would be competing for access to the carcasses. In the autumn, the average number of individual Calliphorid flies counted during the afternoon sampling during the days when eggs were laid (days 4–6) was an average of 52–144 per carcass and an average of 58–78 individuals per carcass in the summer trial (days 1–3). The actual number of flies to visit the carcass overall could be much higher than this estimate as sampling was done in a certain time frame and not according to the daily climatic changes which may result in more flies being attracted to the carcasses at another time. These flies can be fiercely competitive for carrion resources (e.g., [27]). Thus, the numbers of flies competing for the resource could have been significant enough to cause the flies to actively pursue access to the carcass. The flies were observed to push through the smallest gaps and folds of the sheet to the point of damaging their wings. Dead flies were sometimes found on the wrapped carcasses after they

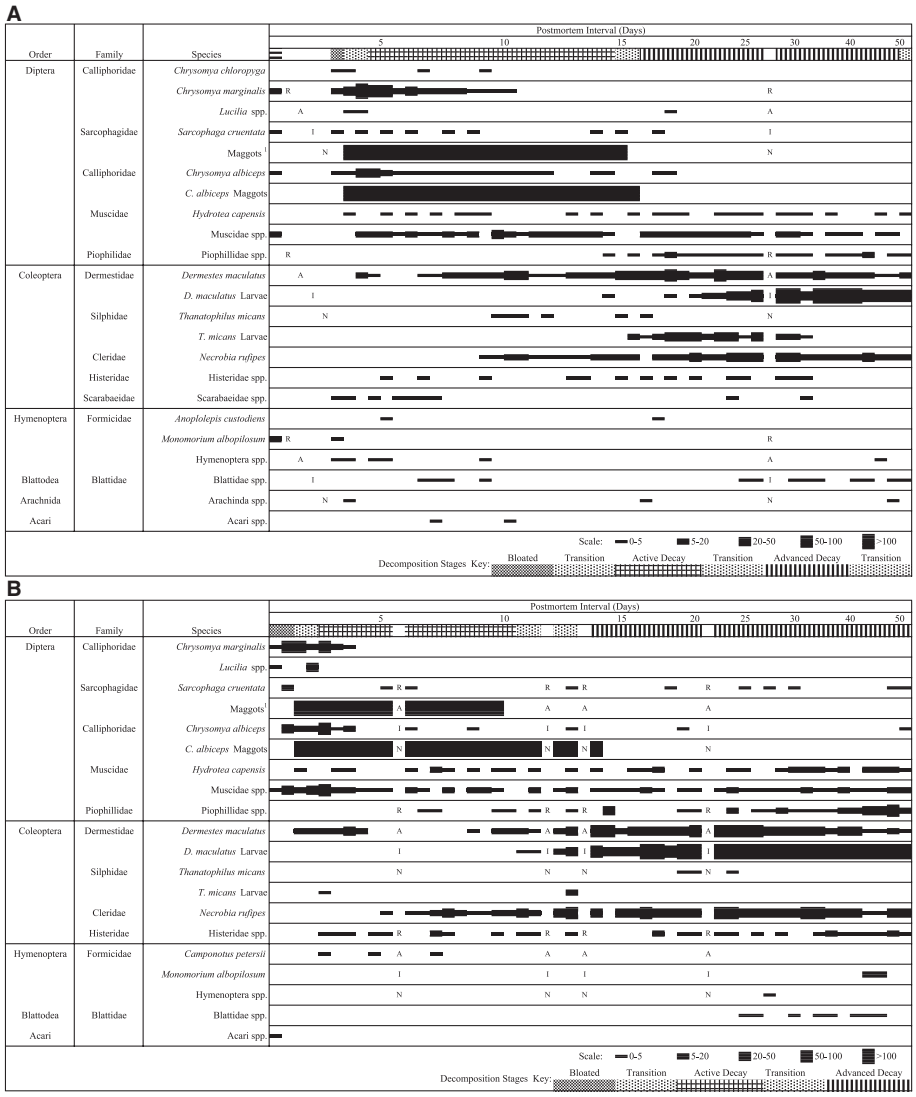

FIG. 2—*(A) Arthropod succession on the wrapped clothed carcass during the autumn wrapped trial, Maggots Chrysomya marginalis, and* Sarcophaga *spp. (B) Arthropod succession on the wrapped, clothed carcass during the summer wrapped trial, Maggots C. marginalis, and* Sarcophaga *spp.*

were unable to find a way out of the sheet. Thus, in a criminal investigation where a body has been wrapped and the wrapping has not been secured in any way, it may be assumed that there would be no delay in oviposition by adult *C. marginalis* and *C. albiceps* during the autumn and summer seasons in this region of South Africa. This assumption could be strengthened by the fact that the sheets were full double bed sized and an adult human would be of a larger body size than the pig carcasses. When a human body bloats, the gaps created in the folds of the sheet may be larger allowing the flies easier access. This was also the case in an experiment done by T.C. van der Linde in January–February 2002 (pers. com. Forensic Entomology Report, 03/25/2002).

The carcasses in this study remained fresh for only 1 day at most, which was shorter than reported elsewhere (11,12), but similar to Payne (9) in South Carolina. The bloat stage lasted only 3 days in autumn and less than a day in summer, whereas Anderson and VanLaerhoven (11) reported 10 days in western Canada. These time changes in the decomposition process are to be expected due to the geographic and climatic differences of the studies as Payne (9) and Anderson and VanLaerhoven (11) were conducted in the northern hemisphere.

Anderson and VanLaerhoven (11) also stated that all their seven exposed carcasses entered each stage synchronously. In this study, the advanced decay stage in both the exposed carcasses of each trial was considerably shorter than for any of the wrapped carcasses. This suggested that the wrapping allows little evaporation and thereby keeps the carcasses moist, causing the wrapped carcasses to remain in the advanced decay stage for significantly longer. This observation would need to be taken into consideration when dealing with human remains in cases where those remains are in the advanced decay stage. The arthropod succession did not change although the physical appearance of the carcass may be different. In other words, there was no delay in oviposition, the maggots' development was similar, and the Coleoptera species occurred on the carcasses simultaneously. Therefore, when remains are wrapped as described in these trials, the age and composition of the invertebrate community should given priority, over the physical appearance of the remains, in the determination of time intervals.

The succession of the arthropods at the family level, i.e., Diptera (Calliphoridae) and the Coleoptera (Dermestidae) was similar to most publications on arthropod succession on pig carcasses in other geographic regions (9–11), although the species composition of the

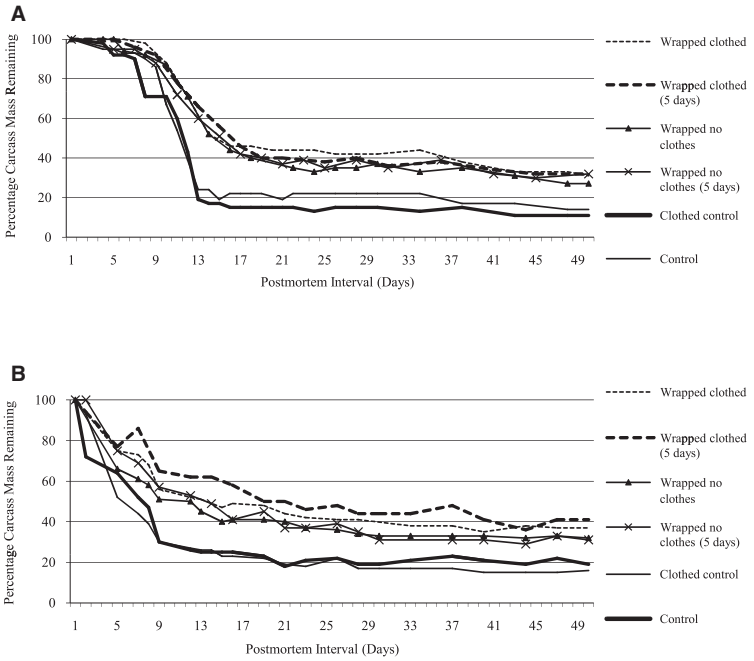

FIG. 3—*(A) Percentage body mass remaining of the carcasses during the autumn wrapped trial. (B) Percentage body mass remaining of the carcasses during the summer wrapped trial.*

arthropods were different to those in the northern hemisphere. The species composition did however correspond with those found in other African and South African studies albeit the source of the carcasses in these other studies were impala *Aepyceros melampus melampus* (Lichtenstein) (28,29) or African elephants, *Loxodonta africana* (Blumenbach) (30). This suggests that the data recorded from pig (*S. scrofa*) studies may be applicable to poaching cases.

During the summer trial, there was not a noticeable peak in the internal temperatures when the maggot masses were present. This suggested that the maggot masses were not in one region of the carcasses to cause a spike in the daily temperatures. The maggot mass effect on the internal temperatures may be reflected in a finer time scale. It is also suggested that the maggot mass may have regulated the internal temperatures, as the maggot masses were very large during the trials and were distributed throughout the carcass.

The mass loss was slower for the wrapped carcasses than for the exposed carcasses. Payne (9) showed a mass loss, which was very similar for all his exposed carcasses. This suggested that the wrapped carcasses maintain higher moisture content for longer, as the visible tissue loss was somewhat similar.

The free movement of the maggots under the sheets could be a result of the sheets providing some protection from the surrounding environmental and climatic conditions. The buildup of heat under the wrapping may have caused the extensive maggot mass movement. This would have been a result of a thermoregulation response as arthropods are susceptible to surrounding temperatures (8). This was supported by the temperatures recorded both externally (surface) and internally for the wrapped carcasses. During the hottest part of the day, the surface temperatures of the carcasses were in excess of 35°C. The internal carcass temperatures recorded approximately when mortality occurred ranged from 44 to 50°C. An *ad hoc* temperature recorded in the dead maggot mass itself during sampling was 56°C. These temperatures are well in excess of the highest maximum temperature at which most maggots can live, for example Grassberger and Reiter (31) showed no data at 40°C for *Lucilia sericata* (Meigen) and Byrd and Allen (32) raised the black blow fly, *Phormia regina* (Meigen) 40°C but they failed to develop.

All the maggot movement under the sheets was similar and the maggots moved into the folds of the sheet in the afternoons as the surrounding ambient temperature had increased. This movement was more distinctive in the summer trial. It should not be concluded from the visual increase in the maggot mass size that the maggot mass was larger in overall volume, but rather that the maggots on the wrapped carcasses are more visible by their position on the surface of the carcass. The consumption of the carcass tissue was not significantly altered other than in some cases where more skin was consumed by the maggots. There was no change in the succession of the Coleoptera after the maggots had migrated. The clothes, specifically the underwear and shorts, were pushed down the limbs, and almost off one carcass during the autumn trial. This was similar and supports results found by Komar and Beattie (33). But in the present study, the carcasses were less than 27 kg and were protected from carnivore predation, both of which reasons Komar and Beattie (33) gave for these observations not being seen in previous studies. This observation was recorded when the maggot masses were established and not during the bloat stage. Therefore, maggot mass movement and distribution under the sheet may explain the greater degree of clothing displacement, which may need to be considered when assumptions are made about sexual abuse in human investigations. However, some consideration should be taken of the physical differences between human and pig legs, when applying these observations to case studies. Added to this is the practical constraint of using human clothing to dress pig carcasses, although the clothes used in these trials were chosen to fit the carcasses snugly.

Some of the maggots on the wrapped carcasses completed their entire life cycle externally to the carcass on the sheet's surface. They were observed in the folds of the sheet and ground along the back of the carcasses. The sheets showed no signs of damage and although the maggots moved towards the head and then back towards the abdomen, their movement appeared to be restricted to

the length of the fold. There was no fluid trail from the maggot movement (the maggots were covered in decomposition fluids) out of the fold and no other evidence to suggest that they ever had direct access to the carcasses. They appeared to feed on the liquefied tissues seeping through the sheet. Nuorteva (34) recorded a similar occurrence of maggots feeding on a blood stain in a decaying shirt, in the absence of a carcass. However, the species in that study were *Muscina stabulans*, *Fannia canicularis*, and *Hydrotaea dentipes* and not Calliphoridae. The observations made in this study suggest that there is a possibility for Calliphoridae to complete their life cycles in the absence of a carcass and more detailed research would need to be conducted to confirm this.

All dead maggots, associated with the maggot mortality observed, were found only on the wrapped carcasses. The dead maggot mass occurred under a sheet soaked with fluids, which did not allow the free flow of air. It was possible that excessive heat, generated by the sun and the maggot mass, was trapped under the wet sheet which may have resulted in the mortality. It is also suggested that there was a buildup of noxious gasses, which may also have resulted in the mortality. The maggot mortality seemed to have little effect on arthropod succession, even in cases where large portions of the maggot masses were affected. The adult Diptera did not return to the carcass to utilize the remaining tissue. This could lead to the conclusion that the tissues were decomposed to a point that they were no longer attractive to the adult Diptera for oviposition (35). As a result the only differences observed in these cases were slightly more decomposed tissues remaining on the carcasses, and thus an overall higher carcass mass, through the later stages of decay. This did not appear to influence the Coleoptera species composition either, whose numbers and community structure followed the exposed and unaffected carcasses.

C. albiceps is known to be a facultative predator of other maggots (36). It was observed that more often than not, *C. albiceps* maggots were in the same maggot mass as *C. marginalis* maggots with no predation occurring. However, in the summer trial there were a few observations when the maggots formed distinct groups of *C. albiceps* within the *C. marginalis* dominant maggot mass, but this was not always the case. The predation was only observed in the autumn trial and occurred during maggot dispersal, similar to laboratory experiments done by de Andrade et al. (36), where *C. albiceps* were observed to predate on *Cochliomyia macellaria* (Fabricius) during dispersal. The number of *C. marginalis* observed at the carcass during emergence did not appear to be significantly impacted; however, this is only based on *ad hoc* observation in the field. The occurrence of predation of the *C. albiceps* on the *C. marginalis* did not appear to affect the overall succession of the arthropods, as the predation occurred only during maggot dispersal as a result of a resource limitation. This predation behavior occurred on the clothed carcass with no wrapping. This carcass had very little to no tissue remaining, in other words the carcass was dry and only the skeleton, hair, and some dried-out skin remained. The presence of *C. marginalis* was not completely eliminated. However, the predatory behavior of *C. albiceps* should be noted in South Africa.

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