The Effect of Clothing and Carrion Biomass Load on Decomposition and Scavenging in a Forensically Significant Thicketed Habitat in Cape Town, South Africa

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Thesis Presented for the Degree of
DOCTOR OF PHILOSOPHY – Biological Anthropology
in the Department of Human Biology
Faculty of Health Sciences
UNIVERSITY OF CAPE TOWN
2022

UNIVERSITY OF CAPE TOWN
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The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

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Abstract

Estimating the post-mortem interval is important to help identify the deceased in forensic death investigations and requires biogeographically specific knowledge of the rate of decay. Decomposition is influenced by numerous variables, including clothing, climate, and vertebrate scavenging guilds, requiring local studies. Conflicting results have been reported for clothing's effect on decomposition from various international habitats, with no data for Cape Town, South Africa, despite most local forensic cases involving single, clothed decedents. Most taphonomic research uses large samples of unclothed human/animal remains to increase statistical reliability, despite this design not simulating common forensic scenarios. This study examined the effect of seasonally appropriate clothing and carrion biomass load on decomposition and scavenging in the thicketed Cape Flats Dune Strandveld, a forensically significant local habitat. Clothing was identified from forensic case files and tailored to ensure an appropriate fit, preventing unrealistic scavenger access. The decay of ten ~60 kg porcine carcasses, as proxies for human decomposition, was quantitatively examined using daily weight loss. This occurred over two consecutive summers and winters between 2018 and 2020, initially comparing clothed versus unclothed carcasses, then examining single clothed carcasses to ascertain the effect of carrion biomass load. On average, double-layer cool-weather clothing notably delayed decomposition in winter, but single-layer warm-weather clothing had a comparatively negligible impact in summer. Weight loss correlated with scavenging activity by the Cape grey mongoose (*Galerella pulverulenta*), which displaced clothing to feed on the abdomen, more so during winter. Scavenging was hindered by the denim trousers, altering feeding patterns and causing preferential scavenging on unclothed carcasses. Single carcasses received more, longer mongoose visits and decomposed quicker than multi-carcass deployments. These results suggest that clothing delays decomposition locally by modulating the effect of seasonal weather and scavenging behaviour. Additionally, research forgoing forensic realism, with large, unclothed samples deployed simultaneously, will inadvertently alter the decay rate, creating inaccurate decomposition models for post-mortem interval estimation. Future studies should balance statistical robusticity and forensic realism, especially in environments where scavenging is prevalent. Single carcasses clothed in forensically realistic season-specific appropriately tailored clothing should be considered with statistical replication obtained via temporally separated repeat deployments.

Dedication

For Taro.

Acknowledgements

I would like to give my heartfelt thanks to my supervisor, Associate Professor Victoria Gibbon, and co-supervisors Dr Devin Finaughty and Associate Professor Jacqui Friedling for their continued guidance and encouragement; they have taught me so much. I would like to thank my three anonymous examiners for their insightful comments and suggestions. I am grateful to John Morris (Farm Manager: Mariendahl Experimental Farm, Stellenbosch University) for providing the pig carcasses used in this study. This research would not have been possible without the valuable support of Dr Charon de Villers (Research Director: Medical Research Council Animal Unit, Delft, Cape Town) and her assistant staff, who granted access to the facilities at the Medical Research Council Animal Unit and assisted with the experimental setup. I am grateful to Associate Professor Trevor McIntyre (Department of Life and Consumer Sciences, University of South Africa) for the generous loan of four of the cameras used. I owe a great thank you to Charles Harris (Principal Technical Officer: Mechanical Workshops and Operations, Department of Human Biology, UCT), Tyron de Wet (Mechanical Workshop/Laboratory Assistant: Department of Human Biology, UCT), and Abdul Samuels (Laboratory Assistant: Department of Human Biology, UCT) for their assistance with constructing and assembling the steel tripods, grids, and automated weighing system used in this research, as well as with transporting the pigs. I thank Justin Pead (Principal Technical Officer: Department of Electrical Engineering) for his continued assistance with the automated system's development and troubleshooting. I also thank Professor Edward Boje (Department of Electrical Engineering) for our initial consultation and for putting me in touch with Justin. I thank Noëlle van Biljon for guidance using R. I was supported by the University of Cape Town Vice Chancellor’s Doctoral Research Scholarship, the Postgraduate Merit Award, the National Research Foundation (NRF) Thuthuka Grantholder-linked Student Support grant via Prof Friedling (grant: 107010), and the NRF-DAAD Doctoral Scholarship directly (grant: 123254). The research costs were supported by Prof Gibbon’s University of Cape Town internal research grant, Health Sciences Faculty Research Council grant, and NRF grant (115357). Their financial contribution towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and not necessarily to be attributed to the funders. Finally, I am incredibly grateful to my parents and my partner, Kelly, for the endless support and motivation.

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List of Abbreviations

ADD = Accumulated degree days

FACT = Forensic Anthropology Cape Town

FHS AEC = Faculty of Health Sciences Animal Ethics Committee

PMI = Post-mortem interval

TBS = Total body score

UCT = University of Cape Town

Chapter 1: Introduction and Literature Review

1.1 Background

Anthropology is divided into four disciplines, all dealing with the study of human beings: archaeology, cultural anthropology, linguistic anthropology, and biological anthropology. Forensic anthropology is a comparatively recent subdiscipline of biological anthropology and was developed when skeletal biology was applied in the medico-legal system (Işcan, 1988). Although beginning purely with the identification of the deceased via osteological measurement and examination, the field has since expanded to include evidence recovery, skeletal trauma analysis, forensic archaeology and forensic taphonomy (Dirkmaat et al., 2008). Taphonomy (derived from the Greek for "burial law") is the study of how organisms decay, including all processes that occur between death and discovery. The term was first coined by palaeontologist Efremov (1940) with a historical focus on the processes of fossilisation but has since seen the inclusion of factors influencing decomposition and the dispersal of remains on the surface. In a forensic context, taphonomy frequently takes the form of analysing the conditions and circumstances surrounding the death, discovery and recovery of human remains from approximately the last 50 years, beyond which lies the purview of archaeology. Forensic taphonomy research involves decomposition studies using either donated human cadavers or animal analogues to investigate the host of variables that affect the rate and process of decomposition in various habitats. Research into these topics can help forensic taphonomists and anthropologists better understand the rate of decay in a given environment, and therefore produce more accurate estimates of the time elapsed since death, otherwise known as the post-mortem interval (PMI). This can provide insight into the occurrences since death, and crucially help to reduce the potential pool of decedents, as well as corroborate witness or suspect testimony in the event of a homicide investigation, ultimately, to assist with identifying the deceased.

Due to the incredible complexity of the decomposition process and the numerous variables that impact it, there is a great need for taphonomic research in relevant habitats to improve the understanding of local decomposition (terrestrial and oceanic) and facilitate better forensic identification. The study into terrestrial decomposition in Cape Town, South Africa, has aided local forensic casework from mortuaries in the Western Cape Province, especially the results of mummification, decomposition rates, scavenging, and scattering (Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018; Finaughty, 2019; Finaughty & Morris, 2019).

In 2021, the South African Police Service released the national crime statistics for the previous fiscal year. Despite a slight decrease during 2020, there is an increasing annual trend in violent crimes, with 54 people murdered daily (South African Police Service, 2021). This trend will result in already over-burdened state mortuaries struggling further to process the considerable number of existing dead bodies. Despite the best efforts of its members, such an overworked system will invariably fail, with people remaining unidentified and unclaimed. The issue of unidentified human remains in South Africa was highlighted as far back as 1998, when on average 3% of remains admitted to the Salt River Medico-legal Laboratory from 1980 to 1995 were unidentified (Lerer & Kugel, 1998). The mortuary in Salt River still serves the greater Cape Town metropolitan zone, with the trend of unidentified and unclaimed human remains continuing to increase; currently, approximately 9% of the annual 3500 cases go unidentified (Reid, Martin & Heathfield, 2019, 2020). Unidentified bodies can profoundly affect local government, the social and criminal justice system, and of course, the deceased's family. All people have the right to honour and mourn the death of a loved one, and without an identity, these personal grieving processes are hampered. Many civil procedures also cannot be completed (funeral, insurance, and inheritance matters, among others). Therefore, identifying human remains is crucial for social, ethical, criminal, and civil reasons (Naidoo, 2007; Cattaneo et al., 2010; Evert, 2012; Krysztofiak, 2016; Finaughty, 2019).

The task of establishing the identity of human remains requires the police to collate the evidence gathered from a post-mortem investigation and match it to antemortem information about a reported missing individual. Identification can be challenging for several reasons, as antemortem medical and dental records may be missing or absent, especially in rural disadvantaged populations with limited access to health care. Missing individuals may also go unreported, particularly in the case of legal or illegal immigrants and migrant workers. Post-mortem data for comparison may also be difficult to attain during an investigation, especially when the recovered remains are highly decomposed, skeletonised or burnt (Evert, 2012; Finaughty, 2019). This is where forensic anthropologists, as experts in biological anthropology and skeletal anatomy, primarily focus their efforts; helping identify skeletonised, burnt, or decomposed human remains by using specialised osteological measurement and visual morphological assessment techniques to extract as much information as possible from the skeleton. The generated biological profile includes estimations of age, sex, ancestry, stature, and any pathology or other identifying features of the deceased (Dirkmaat et al., 2008; Ousley, Jantz & Freid, 2009). This information is passed on to the police to assist in the identification process – by matching the information to that of a known missing person. If anthropologists provide more useful information, the potential pool of decedents can be reduced. Currently, in South Africa, any unnatural death must undergo a medico-legal investigation to ascertain the cause and date of death, determine whether the death was due to an act of omission or commission, and establish the deceased's identity (*Inquests Act, Act No. 58 of 1959, as amended*, 1996). These investigations are jointly conducted by the Forensic Pathology Service (FPS) and the South African Police Service (SAPS), with FPS only collecting and examining the remains once SAPS has concluded an examination of the scene. Either FPS or SAPS may consult forensic anthropologists to provide expertise in the case of decomposed or burnt remains, but in the Western Cape, FPS pathologists usually make contact at their discretion. Forensic Anthropology Cape Town (FACT) is a local service provider of academics and students at the University of Cape Town who frequently assist in such cases from across the Western Cape (Baliso, Finaughty & Gibbon, 2019).

1.2 Decomposition and the post-mortem interval

Along with the biological profile, which forensic anthropologists conduct when the remains are skeletonised or decomposed beyond recognition, an additional task is estimating the time elapsed since death, otherwise known as the post-mortem interval (PMI). The PMI can be a crucial component of the forensic death investigation, as an accurate PMI may reduce the potential pool of decedents the remains belong to, increasing the chances of correct identification of the remains (Sutherland et al., 2013). PMI estimates can also be used to corroborate witness testimony or exclude possible perpetrators in the case of a homicide, thereby further narrowing the police search (Megyesi, Nawrocki & Haskell, 2005).

The estimation of the PMI is based on the observed preservation state of the remains, compared to the known rate of decay in the environment. Early taphonomic research into PMI estimation focused on retrospectively analysing case reports to identify sequential patterns and stages of decomposition (Galloway et al., 1989; Megyesi, Nawrocki & Haskell, 2005; Sincerbox & DiGangi, 2018). Although these researchers and others completed foundational work using retrospective studies, the decomposition process was soon known to be exceedingly complex, with many intrinsic and environmental variables at play. Many of these variables have since been investigated by actualistic research using animal and human decomposition in various habitats around the world; these are examined in a following section of this chapter. The development of forensic entomology, the science of analysing insect evidence for medico-legal investigations, has enabled accurate estimations of the minimum time since death by using knowledge of the specific populations and lifecycles of the insects associated with carrion (Amendt et al., 2011). Estimating the PMI is challenging and requires foundational knowledge of the underlying processes of decay. Despite decomposition being a complex, continuous process, beginning at the moment of death and only ending once the skeleton is broken down, it is common to segregate this process into defined stages (Goff, 2009). Although previous researchers have divided decomposition into as many as nine stages, most studies have settled on four or five; fresh, bloat, active decay (both bloat and active are at times combined into early decomposition), and advanced decay, which is occasionally followed by dry remains or skeletonisation (Reed, 1958; Payne, 1965; Rodriguez & Bass, 1983; Galloway et al., 1989; Anderson & VanLaerhoven, 1996; Megyesi, Nawrocki & Haskell, 2005; Goff, 2009). The practice of dividing a continuous, mosaic process into separate qualitative and subjective stages is inherently limited (Matuszewski et al., 2010). However, it may be valuable for a layperson to understand the process and for clear comparison, organisation, and discussion of research (Goff, 2009).

The fresh stage of decomposition does not begin after somatic death when a person becomes unconscious and cannot initiate voluntary movement or respond to sensory stimuli, as in this state, artificial support can keep most tissues alive and functional (Saukko & Knight, 2015). Instead, decomposition begins after cellular death when tissues and cells are no longer metabolically active following the cessation of heart function and the consequent lack of oxygen (Saukko & Knight, 2015). What follows is a process, with different tissues dying at different rates – the cerebral cortex is the most vulnerable to a lack of oxygen, but connective and muscle tissue may survive much longer (Saukko & Knight, 2015). As oxygen supplies run out and waste products accumulate, the cells are poisoned and undergo autolysis, a self-destructive aseptic process of internal chemical breakdown via cellular enzymes, resulting in the rupture of cellular walls and the release of nutrient-rich fluids (Vass et al., 2002; Pinheiro, 2006). Prior to this, there are a series of observable changes that occur to the body. These include *livor mortis* (hypostasis or skin discolouration), *algor mortis* (body cooling), and *rigor mortis* (muscle stiffening), among others (Goff, 2009; Saukko & Knight, 2015).

Hypostasis results in blotchy patches of bluish-red staining due to gravity acting upon stagnant blood that is no longer being propelled through the capillary bed (Saukko & Knight, 2015). The pattern of pseudo-bruising is dependent on the body position after death, as although gravity acts to pull the blood down, the areas of support, such as the shoulders, buttocks, and calves if the body is lying on its back, are compressed, resulting in the skin in those areas remaining comparatively pale (Saukko & Knight, 2015). The body begins to approximate the ambient environmental temperature as soon it ceases to circulate blood and regulate internal temperature, but multiple factors influence the rate of cooling, and therefore it can be an unreliable indicator of time since death (Goff, 2009). Muscle stiffening or *rigor mortis* is caused by the anaerobic conversion of adenosine triphosphate into adenosine diphosphate, resulting in a build-up of lactic acid and the locking of myofibril chemical bridges and resultant contraction of muscle tissue (Goff, 2009; Saukko & Knight, 2015). Stiffening can occur from three to eight hours after death and usually subsides after 36 hours as muscle cells undergo autolysis, but is highly variable depending on the temperature, activity level before death, and other factors (Saukko & Knight, 2015).

Elsewhere on the body, autolysis presents as fluid-filled blisters on the skin after a few days – the epidermis separates from the dermis and can slough off in large sheets, often as “gloves” at the hands and feet (Vass et al., 2002; Pinheiro, 2006). Insect colonisation begins during this early stage, usually at the natural body openings and any present wounds. Calliphoridae (blowflies) and Sarcophagidae (flesh flies) are typically the first insects to explore for oviposition or larviposition sites, most often in openings of the head due to accessibility and the emission of chemical attractants (Goff, 2009). Once sufficient cells throughout the body have ruptured, the necessary amount of nutrient-rich fluid is available for the putrefaction process to begin (Vass et al., 2002).

Putrefaction is the breakdown of soft tissues into simple liquid and gas compounds caused by bacteria, fungi, and protozoa (Vass et al., 2002), and ultimately results in the balloon-like appearance giving the bloat stage its name. Putrefaction is usually first evident externally as a discolouration of the lower right abdominal wall due to the proximity of the bacteria-rich coecum, or as “marbling” – the discolouration of superficial blood vessels as blood cells are haemolysed by the colonising bacteria, converting haemoglobin and other compounds into pigmented products like sulfheamoglobin when reacting with gaseous sulfur, staining the blood vessels (Vass et al., 2002; Pinheiro, 2006; Goff, 2009; Saukko & Knight, 2015). The metabolic activity of the bacteria and maggots within the body causes the temperature of the body to increase significantly (Goff, 2009). Fluids begin to seep out of the body orifices due to increased internal pressure as various gasses are formed, predominantly in the bowels (Vass et al., 2002; Goff, 2009); the increased pressure, although rare, may even rupture the skin (Vass et al., 2002). The body deflates at this point, and strong odours are released, attracting mammalian vertebrate scavengers, which locate carrion via olfaction (Selva et al., 2019). The purging of gasses and liquids increases the pH, electrolyte and other nutrient content of the underlying soil, attracting prominent insect colonies of Diptera larvae and various beetles (Staphylinidae and Histeridae) (Vass et al., 2002; Goff, 2009). The rapid change in the composition of the surrounding soil results in a distinct habitat independent of the surrounding environment often termed a cadaver decomposition island (Carter, Yellowlees & Tibbett, 2007).

Once bloating has ceased, when the activity of the insects, scavengers, bacteria, and enzymes break the outer layer of skin, the active decomposition stage is said to begin. Aerobic protein degradation can now occur (Reed, 1958; Rodriguez & Bass, 1983), and body temperatures can remain high due to continued bacterial and maggot activity and latent heat (Anderson & VanLaerhoven, 1996). Most of the mass of the carrion is lost during this stage, with some bone exposure possible.

Advanced decomposition or skeletonisation begins as the body is reduced to skin, cartilage and bone (Anderson & VanLaerhoven, 1996). The number and diversity of invertebrate scavengers and parasites increases at this stage, and Dermestidae beetle species slowly remove the dried flesh and cartilage (Campobasso, Di Vella & Introna, 2001; Goff, 2009). This stage has no clear endpoint, as pH and soil fauna gradually return to normal with the presence of dry bones remaining for months or years (Goff, 2009).

The stages of decomposition outlined above are descriptions of recognisable states that decaying carrion will likely undergo. However, they are not objectively defined individual events, as decomposition is a continuous process with a large amount of variability. Mosaic decomposition, with certain regions decaying differently from others, occurs often and is one of the reasons the system of stages has been criticised (Carter, Yellowlees & Tibbett, 2007; Matuszewski et al., 2010; Michaud, Schoenly & Moreau, 2015). States of preservation are also possible, such as mummification in dry, hot or cold environments, or saponification, the development of adipocere or "grave wax", typically in moist environments (Pinheiro, 2006; Saukko & Knight, 2015). Ultimately, the decay process is influenced by numerous factors that can work to accelerate or delay decomposition, or even cause a state of preservation.

1.3 Influences on decomposition

The decomposition of a human body, like all carrion, forms part of a complex ecosystem as a rich resource utilised by various organisms, both micro-and macroscopic. As well as being a food source, carrion can provide shelter, a breeding ground, and a nursery (Putman, 1978; Carter, Yellowlees & Tibbett, 2007; Parmenter & MacMahon, 2009). Organisms that feed on carrion are separated into two types of decomposers: holozoic scavengers (invertebrates and vertebrates), which remove, ingest, and digest whole pieces of another organism, and true decomposers (microorganisms like saprophytes and saprozoic organisms), which release digestive enzymes to externally break down a food source before absorbing the resulting nutrients (Olea, Mateo-Tomás & Sánchez-Zapata, 2019). Both groups of decomposers are crucial for recycling the carbon and other nutrients trapped in the remains, and they drive the process of decomposition (Goff, 2009).

Decomposers are influenced by various intrinsic and extrinsic factors that can modulate the rate at which carrion decays and is recycled. Intrinsic variables include factors that are inherently linked to the carrion source before death (antemortem), such as the age-at-death, size and weight, and body fat content, or around the time of death (perimortem) such as health status, trauma, and integrity of the remains (Campobasso, Di Vella & Introna, 2001; Wescott, 2018; Alfsdotter & Petaros, 2021).

Some researchers have suggested that newborn infants are resistant to the onset of decomposition (Campobasso, Di Vella & Introna, 2001; Pinheiro, 2006). However, once begun, the process should progress quickly; smaller carrion sources undergo less putrefaction, have less for decomposers to consume, and will decompose quicker than larger sources (Sutherland et al., 2013; Matuszewski et al., 2014; Pereira, Owen-Smith & Moleón, 2014; Moleón et al., 2015, 2019; Baruzzi et al., 2018). Very large carcasses see reduced competition between vertebrate scavengers (Moleón et al., 2015). Although larger bodies decay more slowly, a high body fat content may accelerate decomposition due to the relative increase in tissue water content, facilitating the microbial and enzymatic breakdown (Campobasso, Di Vella & Introna, 2001; Pinheiro, 2006). Infection or other health imbalances may result in existing large bacterial colonies, which could accelerate the decay process (Campobasso, Di Vella & Introna, 2001; Pinheiro, 2006). Any injury or trauma to the body can also impact decomposition, as blood loss may attract insects and vertebrates, and wounds are an easy access point for both insects and bacteria (Campobasso, Di Vella & Introna, 2001; Pinheiro, 2006).

The many extrinsic variables can be separated into cultural and environmental factors and are not directly associated with the carrion source itself but rather the context in which it is found (Finaughty, 2019). Typical cultural factors associated with human remains include methods of preserving the body after death and the depth and method of burial (Campobasso, Di Vella & Introna, 2001; Wescott, 2018; Alfsdotter & Petaros, 2021). Preserving the body via embalming, smoking, pickling, or mummifying acts to delay or cease the decomposition process, and a similar delaying effect may occur due to burial, the use of a coffin or the wrapping and clothing of the remains (Mann, Bass & Meadows, 1990; Goff, 1992; Kelly, van der Linde & Anderson, 2008, 2009; Marais-Werner et al., 2017, 2018). These cultural practices all act as deterrents or barriers for the microscopic, invertebrate, and vertebrate agents of decay, delaying decomposition (Mann, Bass & Meadows, 1990; Goff, 1992, 2009; Kelly, van der Linde & Anderson, 2008, 2009; Marais-Werner et al., 2017, 2018).

The remaining extrinsic variables are environmental in nature and include both biotic and abiotic factors. Abiotic factors are weather and climate, such as temperature, humidity, rainfall, and sun exposure, as well as other factors like pH and soil composition (Campobasso, Di Vella & Introna, 2001; Wescott, 2018; Alfsdotter & Petaros, 2021). Biotic factors include the vegetation, surrounding environment, and access by insect and vertebrate decomposers in the local guild (Micozzi, 1986; Mann, Bass & Meadows, 1990; Campobasso, Di Vella & Introna, 2001; Megyesi, Nawrocki & Haskell, 2005; Adlam & Simmons, 2007; O'Brien et al., 2010; Simmons, Adlam & Moffatt, 2010; Cameron & Oxenham, 2012; Sutherland et al., 2013; Roberts & Dabbs, 2015). Maggots, which secrete proteinases to digest tissues externally, are one of the most significant contributors to decomposition. They feed in dense masses pooling enzyme production, which along with mechanical damage from their constant movement, act to break down carrion tissue rapidly (Archer, 2004). Necrophagous activity by other insects like multiple species of ants and beetles can not only cause superficial skin damage but also remove flesh and expose blood and other fluids, which may attract other insects (Ventura, Gallo & De Stefano, 2010; Goddard et al., 2012; Heath & Byard, 2014; Bonacci & Vercillo, 2015; Meyer et al., 2020; Souza et al., 2020).

All the factors identified above can influence the decay process to varying degrees and are highly interrelated and therefore cannot be viewed alone: "to isolate one variable would, in reality, give us only a tiny piece of a biased puzzle" (Mann, Bass & Meadows, 1990:104). This makes researching taphonomy, rates of decomposition, and PMI challenging (Roberts & Dabbs, 2015). Many of the contributing factors are also geographically specific, necessitating the development of locally relevant data (O'Brien et al., 2010; O'Brien et al., 2017). The most pertinent variables are examined in more detail in the following subsections of this chapter.

1.3.1 The effect of clothing

The effect of clothing as an extrinsic cultural variable on decomposition remains unclear in the international literature, with most taphonomic research conducted using unclothed samples. However, this is not necessarily the most appropriate model for decomposition, given that most recovered individuals in forensic cases are clothed (Galloway et al., 1989; Komar, 1998, 2003; Miller, 2002; Steadman, 2015; Juglan et al., 2016; Alfsdotter & Petaros, 2021). In a local context, case records from FACT, a local service provider, also indicate that the majority (58%) of human decedents recovered from the Western Cape Province are clothed to some degree (Baliso, 2020). Therefore, assessing how clothing affects decomposition is essential for accurate PMI estimates.

Previous research has shown that the presence of clothing may slow or accelerate terrestrial surface decomposition, depending upon other factors. These include trapping moisture, increasing temperature, inhibiting scavenging and entomological processes essential in the natural decomposition cycle, and allowing for new areas of increased oviposition for insects (Cahoon, 1992; Miller, 2002; Card et al., 2015). Some researchers have maintained that although the effect of clothing is measurable, it is only statistically significant when comparing winter and summer months or simply that the statistical significance does not equate to a practical effect (Kelly, 2006; Matuszewski et al., 2014; Card et al., 2015). A review of the relevant literature is outlined below, focusing on international studies due to the relative lack of such studies in South Africa. The climatic differences are described using the Köppen-Geiger climate type symbols (Peel, Finlayson & McMahon, 2007), as climate, season, and weather also play a role and are discussed in section 1.3.2. Definitions are available in Table A.1 and a colour-coded world map of the various climates across the globe is available in Figure A.1 in Appendix A.

Analysing 189 forensic cases across the deserts of Arizona, USA (BWh – arid, desert, hot), Galloway et al. (1989) found that when clothing covered the body and was not displaced during bloating, the decomposition process was delayed, especially during the advanced stage. Assessing scavenging of porcine carcases on the cold prairies of Alberta, Canada (Dfb – cold, without dry season, warm summer), Kjorlien et al. (2009) found coyotes preferred unclothed carcases, with the first scavenging event occurring on average 21 days earlier than clothed carcases. Looking at human decomposition in the humid subtropical climate of Tennessee, USA (Cfa – temperate, without dry season, hot summer), Cahoon (1992) concluded that clothing accelerates the decomposition process by facilitating insect activity. Later research in the same state by Miller (2002) indicated that clothing limits decomposition of the dermis and promotes mummification, resulting in the decomposition process taking approximately twice as long as an unclothed cadaver in the summer. However, she added that clothed and unclothed cadavers decomposed at similar rates in winter. In the Mediterranean climate of the coast of Western Australia (Csb – temperate, dry and warm summer), Voss et al. (2011) found clothing to prolong the wet decay stage in clothed pigs and to allow a greater abundance and distribution of maggot masses, but that clothing did not delay the onset of oviposition. This partially supports Kelly (2006), who found clothing to facilitate maggot movement in the Free State, South Africa, but the wrapping of pig carcasses caused a delay in decomposition. The Free State is climate type BSk – arid, steppe, hot. Matuszewksi et al. (2014), studying porcine decomposition in the grasslands of Western Poland (Dfb – cold, without dry season, warm summer), stated that clothing had little effect on the decomposition process. Similarly, in North West England (Cfb – temperate, without dry season, warm summer), Card et al. (2015) found clothing to have no practical difference on PMI estimation when a 95% confidence interval is applied, despite clothing causing a statistically significant delay in the rate of decomposition. Brown & Peckmann (2013) also found clothing to have a negligible impact on decay rates in Nova Scotia, Canada (Dfb – cold, without dry season, warm summer), and recorded variability in the clothed pig sample possibly due to differences in the degree of shade. This review highlights the inconsistencies observed concerning the effect of clothing on decomposition, as well as the importance of regional data due to the considerable effect of the local climate and environment on the decay process.

1.3.2 The effect of season, weather, and geography

The influence of weather variables on the rate of carcass decomposition has been thoroughly investigated. Seasonality has a large impact on decomposition in general, predominantly due to changes in temperature and other weather variables, and how these influence microbes, insects, and vertebrate scavengers (Mann, Bass & Meadows, 1990; Archer, 2004). Higher temperatures are well documented to increase the rate of decay, primarily caused by increased microbial activity and chemical reaction rate as temperatures rise (Gill-King, 1997; Archer, 2004; Carter, Yellowlees & Tibbett, 2007; Moleón et al., 2019). High temperatures are conversely known to limit the utilisation of carrion by vertebrate scavengers, presumably due to the increased microbial activity (DeVault, Brisbin & Rhodes, 2004; Selva et al., 2005; Parmenter & MacMahon, 2009; Moleón et al., 2019). Temperatures ranging from 25˚C to 35˚C are optimal for bacterial development, but extreme high or low temperatures may retard the decay of organic matter and inhibit bacterial growth (Campobasso, Di Vella & Introna, 2001). Invertebrate activity and growth are also impacted by temperature; warmer temperatures increase the number and variety of insects present on carrion, subsequently accelerating decomposition (Campobasso, Di Vella & Introna, 2001). Maggot infestation can occur rapidly within an hour in the warmer months but be delayed substantially over several days in the cooler months (Archer, 2004). Temperatures between 0˚C to 5˚C reduce invertebrate activity and kill maggots, although they may be protected from the cold in body cavities and generate sufficient heat to survive and continue to feed (Mann, Bass & Meadows, 1990; Campobasso, Di Vella & Introna, 2001). Therefore, warm temperatures have often been described as the most significant contributor to decomposition (Galloway et al., 1989; Mann, Bass & Meadows, 1990; Campobasso, Di Vella & Introna, 2001; Megyesi, Nawrocki & Haskell, 2005; Cockle & Bell, 2017).

Related to temperature, thermal energy in the form of sun exposure has been described to accelerate decomposition compared to shaded porcine remains in the same environment, with notably different ambient air temperatures (Shean, Messinger & Papworth, 1993). Greater maggot mass development was the primary cause for the increased decay rate (Shean, Messinger & Papworth, 1993). Sun exposure on human cadavers has also been investigated by Srnka (2003), indicating similar results; the sun-exposed cadavers decayed rapidly in the early stages of decomposition but then plateaued. Shaded subjects were exposed to lower temperatures with notably less variation between high and low extremes (Srnka, 2003).

Humidity also critically influences decomposition (Vass, 2011; Giles et al., 2020), with a general increase in relative ambient humidity accelerating the decomposition process and promoting maggot activity (Mann, Bass & Meadows, 1990; Pinheiro, 2006). Sufficient moisture is also necessary for the process of putrefaction and autolysis (Cockle & Bell, 2017). Increased humidity and moisture, such as in a damp environment, promote the development of adipocere via saponification, although these conditions are not essential (Pinheiro, 2006; Saukko & Knight, 2015). This process is the hydrolysis and hydrogenation of adipose tissue, chemically altering it to form a waxy, fatty, off-white substance – adipocere (Pinheiro, 2006; Ubelaker & Zarenko, 2011). Initially greasy and waxy, the substance becomes brittle with time (Saukko & Knight, 2015). Adipocere formation acts as a state of preservation, lasting for decades or even centuries and may conserve structures to assist in the death investigation (Pinheiro, 2006; Ubelaker & Zarenko, 2011; Saukko & Knight, 2015). On the other hand, a combination of prolonged low humidity and extremely high or low temperatures can result in rapid desiccation or mummification of available tissue (Galloway et al., 1989; Campobasso et al., 2009). Mummification is also viewed as a state of preservation or stasis in the decomposition process and is characterised by dry, brittle skin adhering to underlying bony prominences with tough, fixed creases and folds, usually brown in colour with possible patches of fungus (Pinheiro, 2006; Saukko & Knight, 2015; Finaughty & Morris, 2019). Depending on the time since death, the internal organs may be partially mummified, putrefied, with adipocere, or absent (Pinheiro, 2006; Finaughty, 2019). Mummification occurs most commonly in hot, arid, windy environments such as the deserts of North Africa, the

Middle East and Australia, or regions of North and South America, but it may also occur in cold environments like high altitude polar regions due to the dryness of the air and the inhibition of bacterial growth (Micozzi, 1986; Galloway et al., 1989; Marella et al., 2013; Saukko & Knight, 2015; Connor, Baigent & Hansen, 2019; Finaughty, 2019). Mummification has also been reported in more temperate regions, usually in warm, dry, enclosed spaces, like rooms, cupboards or lofts (Campobasso et al., 2009). However, more recently, Finaughty & Morris (2019) reported precocious natural mummification occurring rapidly in the early stages of decomposition outside under specific drought-like (hot and dry) conditions in a temperate climate in Cape Town.

The influence of rain on decomposition is evident but less pronounced than temperature or humidity, with even severe rainfall having little effect on maggot activity as body cavities act as shelter allowing for continued feeding (Mann, Bass & Meadows, 1990). Lopes de Carvalho & Linhares (2001) reported that substantial rainfall may have contributed to the increased summer decomposition observed, but that adult fly activity and abundance were decreased, as ovi- and larviposition may be affected or halted by moderate to heavy rainfall (Mann, Bass & Meadows, 1990; Lopes de Carvalho & Linhares, 2001). Rainfall may delay decomposition by reducing the temperature via evaporative cooling or by the remains becoming waterlogged (Archer, 2004). However, it may also increase the rate of decay by leeching body contents and keeping the surrounding soil moist, encouraging bacterial and maggot action (Archer, 2004). Rehydration of desiccated tissues by rainfall may also renew decomposition, as well as maggot, fly, and scavenging activity (Suckling, Spradley & Godde, 2016; Spies, Gibbon & Finaughty, 2018; Collins, 2019).

Many environmental variables fluctuate with the changing of the seasons and geography, as certain regions consistently experience higher temperatures or more rainfall, for example, compared to other areas. This variability in weather makes regionally specific data crucial for accurate estimations of the PMI. Cape Town, South Africa, is characterised by a temperate climate with dry and warm summers and winter rainfall, type Csb on the Köppen-Geiger climate type classification (Peel, Finlayson & McMahon, 2007). In local forensic anthropology investigations, most human remains are fully exposed terrestrial cases in areas covered with vegetation (Baliso, 2020). Human remains are recovered from two primary locations within the Cape Town metropolitan zone; bushy areas of the Cape Flats region and Table Mountain National Park (Baliso, Finaughty & Gibbon, 2019). The Cape Flats is a region of the Cape Town metropolitan zone with a high population density and multiple police precincts recording some of the highest murder rates in the country. This region coincides with two of the most populated vegetation subtypes in Cape Town – the Cape Flats Dune Strandveld and Cape Flats Sand Fynbos. Both habitats are readily colonised by the invasive tree species Port Jackson (*Acacia saligna*) and Rooikrans (*Acacia cyclops*), which grow into dense thickets and dominate areas of undeveloped land (Rebelo et al., 2006). These dense thickets provide significant cover for hiding human remains. As a result of this environment, and the high murder rate in the area, a large proportion of the forensic cases conducted by FACT come from this area.

Previous research has established the base rate of terrestrial decomposition for the locally relevant Cape Flats area using unclothed pigs (Finaughty, 2019). The Cape grey or small grey mongoose (*Galerella pulverulenta* or *Herpestes pulverulentus*) was shown to be an effective wild scavenger in this environment (Finaughty, 2019). Further investigation by the author went on to show that the species can drastically accelerate the rate of carcass breakdown and cause skeletal scattering (Spies, 2017; Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018). These previous investigations form the basis upon which the current work is built.

1.3.3 The effect of scavenging and carrion biomass load

The effect of vertebrate scavengers remains a relatively understudied influence on the decomposition process (Wescott, 2018) but is a crucial component of the carrion ecosystem. Scavenging can significantly alter the rate and pattern of decomposition and, in some instances, may cause dramatic damage to soft tissue and bones or scatter skeletal elements over a great distance. This may hinder the understanding of the forensic context, the events following death, the recovery of remains, and the interpretation of skeletal trauma, directly impacting PMI estimation (Byard, James & Gilbert, 2002; Moraitis & Spiliopoulou, 2010; Ricketts, 2013; Cantu, 2014). Therefore, evaluating the taphonomic effect of scavenging is crucial, as carrion is an extensively utilised, critical food source for many vertebrate species (DeVault, Rhodes & Shivik, 2003; Ricketts, 2013). Although only a few terrestrial vertebrate species have evolved to be obligate scavengers, subsisting entirely on carrion (vultures in the Accipitridae and Cathartidae families), many species across the animal kingdom facultatively scavenge when carrion is available, including non-carnivorous species (Selva et al., 2019). The impact of scavenging on ecosystem food webs has traditionally been underestimated (Wilson & Wolkovich, 2011; Moleón et al., 2014). However, scavenging is a crucial ecological process, part of complex necrobiome food webs providing critical ecosystem services recycling the resources and energy of the numerous animals that die of natural causes; this results in scavenging being a common activity amongst numerous species across the globe (DeVault, Rhodes & Shivik, 2003; Barton et al., 2019; Beasley et al., 2019; Benbow et al., 2019; Olea, Mateo-Tomás & Sánchez-Zapata, 2019). In fact, more energy is transferred by scavenging than by predation (Wilson & Wolkovich, 2011; Moleón et al., 2014). This widespread use of available carrion is due to its incredibly rich nutrient value, for comparably less energy to procure than via predation (Moleón et al., 2014; Pereira, Owen-Smith & Moleón, 2014). Patterns of facultative scavenging are altered by carcass features (*e.g.,* cause of death, distribution), the scavenger itself (*e.g.,* body size, activity, ability to find carrion), or extrinsic variables like weather and food availability (DeVault, Rhodes & Shivik, 2003; Wilson & Wolkovich, 2011; Moleón et al., 2014, 2015). Carrion is more heavily utilised during periods of resource scarcity and high energetic demands, such as cold winters and the breeding season (Allen, Elbroch & Wittmer, 2021).

The widespread use of carrion by various species impacts forensic death investigations as numerous vertebrate scavenger species have been identified to feed on human or animal remains in forensic cases or research. These include domestic or feral cats and dogs, wolves, coyotes, foxes, badgers, bobcats, bears, wild pigs, avian species like vultures, as well as smaller vertebrates like racoons, opossums, skunks, fishers, and mongooses (Haglund, Reay & Swindler, 1989; Carson, Stefan & Powell, 2000; Morton & Lord, 2006; Sharanowski, Walker & Anderson, 2008; Kjorlien, Beattie & Peterson, 2009; Reeves, 2009; Rippley et al., 2012; Spradley, Hamilton & Giordano, 2012; Cantu, 2014; Beck et al., 2015; Hannigan, 2015; Smith, 2015; Synstelien, 2015; Young, Márquez-Grant et al., 2015; Jeong, Jantz & Smith, 2016; King et al., 2016; Pokines & Pollock, 2018; Steadman et al., 2018; Dibner, Valdez & Carter, 2019; Garcia et al., 2020; Miranker, Giordano & Spradley, 2020; Smith & Connor, 2020; Smith & Wankmiller, 2020; Allen, Elbroch & Wittmer, 2021; Byrnes & Belcher, 2021; Keyes, Myburgh & Brits, 2021b; Smith, 2021). These many species may have a prominent role in the rapid breakdown of remains (Spies, Gibbon & Finaughty, 2018; Steadman et al., 2018). Depending on the environment, scavengers can be prolific across many forensic cases, *e.g.*, 15% of cases conducted by the Federal Bureau of Investigation across the USA, 26% of cases in central

Sweden, 46% of cases in the state of New Mexico, USA, and 80% of cases in Alberta, Canada presented with postmortem animal activity (Komar, 1998, 2003; Ubelaker & DeGaglia, 2020; Alfsdotter & Petaros, 2021). Therefore, identifying local scavenger species, quantifying their effect, and understanding their activity in an ecological context is crucial for improving regional PMI estimation.

In a local context, the Cape grey mongoose is a species that historically was believed to scavenge little, but recent data provides strong evidence to the contrary (Smithers, 1983; Cavallini & Nel, 1990a,b, 1995; Spies, Gibbon & Finaughty, 2018; Finaughty, 2019). The species has a wide distribution across various habitats in southwestern South Africa and prefers thick bush over grassland (Smithers, 1983; Cavallini & Nel, 1990b, 1995). They are also poor diggers and shelter in dense vegetation, existing burrows, holes, rocky outcrops, or artificial refuges like storm drains (Smithers, 1983; Cavallini & Nel, 1990b, 1995; Finaughty, 2019). These mongooses are usually solitary animals, although they are more social during periods of greater food availability or parental association. Breeding occurs between June and December, with litters of one to three born from August to February (Smithers, 1983; Cavallini & Nel, 1990b; Labuscagne, 2018). This species of mongoose, along with the slender mongoose (*Galerella sanguinea*), water mongoose (*Atilax paludinosusis*), and yellow mongoose (*Cynictis penicillata*), also scavenges carrion in various contexts elsewhere in South Africa (Shaw et al., 2015; Keyes, Myburgh & Brits, 2021b). Scavenging by small species like mongooses is forensically important given their distribution and propensity to feed on carrion when available.

Scavenging by small vertebrates can remain undetected during highly decomposed forensic cases due to the relative lack of indicative markers on soft tissue or bone, compared to larger species like canids which often leave such marks on skeletal elements. Small mammal scavenging has also been underestimated in a broader ecological sense, as highlighted by Barton et al. (2019) and Beasley et al. (2019), with the erroneous assumption that only obligate scavengers like vultures play a significant role in carrion breakdown (Beasley et al., 2019). This underestimation has led to small mammal scavenging being historically overlooked in the forensic and ecological literature. As a result, relatively sparse data exist on scavenger guilds, scavenger-carrion dynamics, and inter- and intra-specific scavenger interactions from the many environments around the world (Barton et al., 2019; Olea, Mateo-Tomás & Sánchez-Zapata, 2019b). Most of the limited studies on small mammal scavenging have been conducted in Northern America and Europe. The small Indian mongoose (*Herpestes javanicus*) is a scavenger in Oahu, Hawaii, although they appear to have little impact on weight loss progression and mainly feed on insect larvae (Dibner, Valdez & Carter, 2019). A small vertebrate species, similar in size to the mongoose but nocturnal and native to North America, the common or northern racoon (*Procyon lotor*), begins scavenging immediately post-deposition but lasts a relatively short time (Jeong, Jantz & Smith, 2016). Racoons initiate scavenging at the snout in pigs or the limbs in humans (Steadman et al., 2018) and feed by making a small hole in the skin, removing muscle tissue with a paw and leaving behind a hollow layer of skin that rapidly mummifies (Synstelien, 2015; Jeong, Jantz & Smith, 2016; Steadman et al., 2018). Another small vertebrate nocturnal North American scavenger is the Virginia opossum (*Didelphis virginiana*), which preferentially feeds on maggots and other carrion insects, but will consume soft tissue that has begun to putrefy and soften or after the activity of an alternative scavenger species, such as the racoon (Synstelien, 2015; Steadman et al., 2018). However, the opossum may scavenge on tissue more extensively and have a more significant impact on the decomposition process directly. King et al. (2016) indicate that the opossum prolifically scavenges in semi-urban environments in central Oklahoma, USA but is underreported due to its preference to feed from existing natural orifices or those created by the decay process as its unable to create new access points (King et al., 2016). The striped skunk (*Mephitis mephitis*) also interacts with decomposing human or pig remains, mainly feeding on tissue from the limbs in a similar fashion to the racoon, burrowing under the skin and leaving loose skin around limb bones (Morton & Lord, 2006; Pokines & Pollock, 2018; Steadman et al., 2018; Smith & Connor, 2020; Smith & Wankmiller, 2020; Smith, 2021). Skunks also appear to prefer tissue that is no longer fresh, as they usually begin feeding approximately a month after deployment during moist decomposition (Morton & Lord, 2006; Smith, 2021). They left defects on the soft tissue surrounding areas of consumption, often presenting as parallel linear striae, small and large irregular superficial defects, and small puncture marks, with limited marks left on the bones (Smith, 2021). Skunks like to climb atop remains or dig beneath and around them to consume invertebrates – however, differing reports suggest feeding on maggots is a secondary activity, with most feeding occurring to tissue with the least maggot activity like the mongoose, or that skunks activity scraped away maggot masses (Smith & Wankmiller, 2020; Smith, 2021). Fishers (*Pekania pennanti*) are semi-arboreal mustelids larger than the mongoose but also opportunistically scavenge on carrion when available in Massachusetts and California, USA (Pokines & Pollock, 2018; Allen, Elbroch & Wittmer, 2021). These species of small vertebrate scavengers are forensically significant and can impact rates of decay and alter the process of decomposition.

The activity of various scavenger species may damage bone or scatter skeletal elements over various distances. The gnawing, scraping, and biting of bone by various scavengers, during soft tissue consumption or in the later stages of decay, can be misinterpreted as trauma or be taxon-specific, helping to identify scavengers and assist with PMI estimation (Haglund, Reay & Swindler, 1988; O'Brien et al., 2007; Young, Stillman, et al., 2015; Pokines et al., 2017, 2021; Keyes, Myburgh & Brits, 2020). In South Africa, researchers have explored the scavenging activity, scattering patterns, and destruction of bones due to a wide variety of opportunistic vertebrate scavengers (Keyes, Myburgh & Brits, 2020, 2021a,b). Firstly, several known scavenging species of forensic significance across South Africa were selected from the National Zoological Gardens of South Africa, including wild dog (*Lycaon pictus*), spotted hyena (*Crocuta crocuta*), lion (*Panthera leo*), leopard (*Panthera pardus*), black-backed jackal (*Canis mesomelas*), caracal (*Caracal caracal*), and Cape porcupine (*Hystrix africaeaustralis*) (Keyes, Myburgh & Brits, 2020). The researchers fed these animals sparsely fleshed bovid bones before examination for marks left on the bones. The authors found that felids left deep parallel furrows, hyenas caused massive bone trauma leaving jagged fracture edges, porcupines left distinctive fan-like parallel scores, whilst wild dogs and jackals did not leave any distinctive patterns (Keyes, Myburgh & Brits, 2020). Two follow-up studies were conducted to identify and describe the scavenging, scattering, and bone damage patterns of wild animals in the South African Highveld and Lowveld, using domestic pig carcasses (Keyes, Myburgh & Brits, 2021a,b). In the Highveld, black-backed jackals were the predominant scavenger and scattered remains a maximum of 74 m in two directions, influenced by fencing. Other scavengers included the slender mongoose (*Galerella sanguinea*), water mongoose (*Atilax paludinosusis*), yellow mongoose (*Cynictis penicillata*), honey badger (*Mellivora capensis*), and porcupine (Keyes, Myburgh & Brits, 2021b). Bone alterations by mongooses presented as jagged gnaw marks on the mandible and vertebra, comparable to the vertebral spine damage recorded by the Cape grey mongoose (Spies, Finaughty & Gibbon, 2018). Cape porcupine bone damage included gnawing marks and destruction of bones' proximal and distal ends (Keyes, Myburgh & Brits, 2021b). In the Lowveld, scavenging was predominantly by the white-backed vulture (*Gyps africanus*), hooded vulture (*Necrosyrtes monachus*), and lappet-faced vulture (*Torgos tracheliotos*). However, marabou stork (*Leptoptilos crumenifer*), common large-spotted genet (*Genetta tigrina*), African civet (*Civettictis civetta*), slender mongoose, banded mongoose (*Mungos mungo*), common warthog (*Phacochoerus africanus*), and honey badger were also observed. Remains were scattered approximately 7 m by vultures, which left scores and pits on the bones, whilst warthogs caused the splintering and fragmentation of the ribs and vertebral transverse processes if these elements were not entirely consumed (Keyes, Myburgh & Brits, 2021a). Previous work by the author in Cape Town on the scattering patterns of the Cape grey mongoose indicate that it drags skeletal elements into dense vegetation, similarly to the yellow mongoose (Spies, Finaughty & Gibbon, 2018). Identifying the common patterns of dispersal and the marks left on bone by relevant scavenger species or guilds is important for complete recovery of human remains and improved understanding of the forensic context and time since death in medico-legal cases. However, the skeletal scattering and marking activity can only occur once scavengers have located the carrion source.

Carrion has been described as an ephemeral resource patch (Finn, 2001) as, if unutilised by scavengers, it will rapidly putrefy and decompose via invertebrate and bacterial action, beyond the ability of most scavengers to tolerate (DeVault, Rhodes & Shivik, 2003; Moleón et al., 2014). Given its ephemeral nature, many vertebrate and invertebrate species have evolved strategies to sense, find, and consume carrion before the competition (Wescott, 2018). Some species have specialised in visual or olfactory skills, each having advantages and disadvantages depending on the microhabitat surrounding the carrion source (Moleón et al., 2019). Carrion is also often sourced via cues from other scavengers (Allen, Elbroch & Wittmer, 2021). The availability of carrion changes both temporally and spatially, and it usually occurs as a nutrient pulse (Yang et al., 2008; Moleón et al., 2014).

The quality and availability of carrion, as a rich but transient resource, can influence the density and diversity of scavengers in a particular area (Smallwood, 2007; Schutgens, Shaw & Ryan, 2014; Shaw et al., 2015; Costantini et al., 2017; Bernardino et al., 2020). An increase in the frequency or magnitude of nutrient pulses may alter the ecological dynamics, structure, and composition of the local facultative scavenger assemblage, often resulting in increased vertebrate scavenger attendance and species variety (Moleón et al., 2014; Baruzzi et al., 2018). In a related context, “scavenger swamping” has been described in studies on bird strike mortality rates near pylons and wind turbines (Smallwood, 2007; Shaw et al., 2015). This phenomenon occurs when scavengers are "swamped" with an abundance of carrion that they cannot entirely consume, inevitably resulting in some left to decompose and become unappetising to most scavengers (Smallwood, 2007; Shaw et al., 2015).

Applying carrion ecology theory to forensic cases, one can see that exposed human remains function as ephemeral carrion resource pulses in rural, peri-urban, and urban environments and are subjected to the same scavenging principles. Therefore, vertebrate scavengers should not be overlooked in forensic decomposition research. The practice of caging animal or human remains to prevent vertebrate scavenger access when investigating decomposition should not be encouraged unless for a specific, well-defined purpose. Previous investigations in Cape Town have shown caged and uncaged carcasses decompose at vastly differing rates, and the same is likely true in other environments where vertebrate scavengers are prevalent (Spies, 2017; Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018). Another concern arises: providing scavengers with several carcasses to increase the sample size during taphonomic research may influence the vertebrate scavenger assemblage or result in scavenger swamping. Conventional wisdom and scientific rigour dictate that samples should be large and in duplicate or triplicate to increase statistical reliability and accuracy. However, in the context of taphonomy and decomposition, could increasing the sample size (*i.e.*, the amount of available carrion) alter the ecosystem and the rate of decay, thereby reducing the forensic usability of the generated data? Except in disaster scenarios, single individuals are more common than groups of decedents. Local forensic case files show that most recovered remains in the Western Cape are found in isolation (Baliso, 2020), so large sample studies do not mirror the actual forensic environment. Deployments of multiple carcasses for taphonomic studies may also allow local vertebrate scavengers to choose from the distinct options in a sample, dividing their feeding time, thereby altering the true decomposition rate of any individual carcass or cadaver. These factors are particularly important in environments where vertebrate scavengers play a substantial role in the decomposition process, like the Cape Flats Dune Strandveld (Spies, Gibbon & Finaughty, 2018), and should be considered when designing taphonomic experiments.

1.4 Taphonomic research

Researching taphonomy can take various forms, each having advantages and limitations. A retrospective design may allow access to large samples of records from real human forensic cases or incorporate data from many individual studies to develop statistical methods and provide comprehensive descriptions of decomposition at a low cost. Some examples include Galloway et al. (1989), Mann, Bass & Meadows (1990), Megyesi, Nawrocki & Haskell (2005), Vass (2011), Cockle & Bell (2017), and Alfsdotter & Petaros (2021). Limitations of such a study design include the fact that forensic case details are often unavailable due to legal and privacy issues, individual remains are only observed once during an examination, so the progression of decay is not clear, and PMI estimations are usually based on when the deceased individual was last seen alive and may be overestimated (Cockle & Bell, 2017; Alfsdotter & Petaros, 2021). Retrospective research is also often reliant on the work of other researchers or forensic practitioners, and specific aspects of interest may be missing or not recorded in adequate detail, and acquiring additional reliable information may be challenging, such as with historical temperature data (Alfsdotter & Petaros, 2021).

Actualistic or experimental research is explicitly conducted to answer a particular set of questions where the researcher longitudinally examines the process of decomposition in a distinct habitat, using either an animal or human model. Examples of this type of taphonomic research include foundational work by Reed (1958), Payne (1965), Behrensmeyer (1978), and Rodriguez & Bass (1983) and others, which has been expanded over time to examine additional variables by Shean, Messinger & Papworth (1993), Adlam & Simmons (2007), Bachmann & Simmons (2010), Suckling, Spradley & Godde (2016), O'Brien, Appleton & Forbes (2017), Dautartas et al. (2018), Keyes, Myburgh & Brits (2020) and many more. This type of research has the advantage of allowing for the examination of the entire decomposition process and testing of specific variables and observations from casework. However, it requires sufficient space, time, and resources to conduct, and these constraints can result in smaller samples and less robust statistical analysis (Finaughty, 2019). Such limitations may be necessary compromises to ensure the prevention of scavenger swamping for example or may be managed by repeated studies. Ethical and logistical challenges may also limit the use of human remains in experimental research, requiring animal analogues to be utilised instead, which are examined in a subsequent section of this chapter.

Research in forensic taphonomy has seen a shift in the recent past towards the development of more quantitative rather than qualitative methods of estimating PMI, instigated by the Daubert standards, named after a series of precedent-setting court cases in the 1990s in the USA outlining what evidence is considered valid and admissible in court. These guidelines have since been widely accepted in the forensic sciences and other disciplines around the world (Dirkmaat et al., 2008; Christensen & Crowder, 2009). They require scientific methods to be tested with known and acceptable error rates, have standards for operation, be peer-reviewed, and generally accepted within the discipline (Steadman, Adams & Konigsberg, 2006). The guidelines favour the use of quantitative data collection techniques (Fienberg, Krislov & Straf, 1995) and longitudinal studies with objective measurement of postmortem changes (Henssge & Madea, 2007). As highlighted by Henssge & Madea (2007), methods to estimate the postmortem interval can only gain practical relevance if they meet the following criteria: quantitative measurement, mathematical description, quantitatively accounting for influencing factors, declaration of precision and independent proof of precision (Wescott, 2018). There has since been a reduction in the use of defined stages of decay as an approach to measuring where a cadaver falls on the sigmoidal decomposition pattern, as, although convenient for comparison and understanding of the decay process, it has been criticised for being subjective and not considering the continuous or the mosaic nature of decomposition (Carter, Yellowlees & Tibbett, 2007; Matuszewski et al., 2010; Michaud, Schoenly & Moreau, 2015). Despite revised methods evaluating separate body parts independently, *i.e.*, the head and neck, limbs, and torso, mosaic decomposition may still occur within these regions. A more quantitative approach would require the measurement of the underlying decomposition processes themselves, namely putrefaction (driven by bacteria and associated with bloating), active decay (driven by maggot activity and associated with weight loss), and advanced decay (associated with a reduction in the rate of weight loss, maggots leaving the remains to pupate, and the onset of tissue desiccation amongst others factors) (Carter, Yellowlees & Tibbett, 2007; Henssge & Madea, 2007; Matuszewski et al., 2010).

Following this, a widely cited method of estimating time since death, using temperature as the primary factor, was developed by Megyesi, Nawrocki & Haskell (2005). This universal model translates qualitative, visual decomposition observations into a quantitative measure, using a point-based decomposition scoring system and the average daily temperatures (above 0 ˚C) to which the remains were likely exposed. The total body score (TBS) is substituted into a regression equation developed based on 68 cases of known dates of death and provides an estimated number of accumulated degree days (ADD), the sum of thermal energy over time, accounting for approximately 80% of the variation in decomposition according to Megyesi, Nawrocki & Haskell (2005). The ADD value can then be used to calculate the number of calendar days since death, using average daily temperatures recorded from the nearest local weather station in the recent past. Similar formulae for estimating PMI have been developed for either surface or buried remains (Vass, 2011), incorporating additional variables. Although commendable for introducing much-needed quantitative methods of estimating the PMI and pushing taphonomic research in the right direction, these methods are limited. Moffatt et al. (2016) identified several statistical errors in the Megyesi formula, and both methods inaccurately estimate the PMI of pig and human decomposition in temperate Australia (Marhoff et al., 2016; Marhoff-Beard, Forbes & Green, 2018), Tennessee, USA (Dautartas et al., 2018; Giles et al., 2020), and in central Sweden (Alfsdotter & Petaros, 2021). The Megyesi method, and the improved methodology developed by Moffatt, Simmons & Lynch-Aird (2016), are also inaccurate in the Cape and elsewhere in South Africa (Myburgh et al., 2013; Forbes et al., 2019). The inaccuracy may be primarily due to the oversimplification of the decomposition process down to a select few variables and the variation in decomposition variables by geographic region. In short, a universal, global PMI estimation method is unlikely ever to be successfully created – a better solution would be various region-specific models adapted to the numerous geographic zones across the globe and the particular environmental variables seen within them (Cockle & Bell, 2015; Suckling, Spradley & Godde, 2016; Forbes et al., 2019).

1.4.1 Pigs as proxies

When studying taphonomic processes, researchers often use animal analogues serving as proxies to observe the decomposition processes undergone by a human cadaver in the same environment. Animal proxies circumvent the scarcity in availability and the cultural and ethical constraints of human cadaver use for decomposition research. Although various mammalian species have been used as animal analogues, smaller species are no longer prevalent due to increased decay rate and difficulty identifying decomposition stages, despite economic and logistical advantages (Payne, 1965; Stokes, Forbes & Tibbett, 2013). Domestic pigs, particularly those approximating human size and weight, are widely considered acceptable and appropriate proxies for establishing general trends and baseline decomposition data, despite recently reported differences between pig and human decomposition (Connor, Baigent & Hansen, 2018; Dautartas et al., 2018). When the use of human cadavers is restricted, the domestic pig is still viewed as the best analogue for taphonomic studies due to various similarities to humans; including fat distribution, internal anatomy, the size of the chest cavity, skin-to-hair ratio and sweat glands, as well as an omnivorous diet with similar enteric bacteria, a primary internal driver of decomposition (Catts, 1992; Goff, 1993; Schoenly et al., 2006; Byrd & Castner, 2009; Reeves, 2009). Ease of procurement, reasonable cost, and low public objection contribute to the continued widespread use of the domestic pig in decomposition research (Catts & Goff, 1992; Goff, 1993). The use of a porcine model also has other advantages: time and manner of death can be more easily controlled than for donated human cadavers, and simultaneous deployment of larger samples is possible without freezing individuals. Currently, in South Africa, donated human cadavers are not permitted in taphonomic research; therefore, domestic pigs are the best alternative (*National Health Act, Act No. 61 of 2003*, 2004). However, it is important to reiterate that animal-derived data only approximate human decomposition and cannot be applied directly.

Human decomposition research has increased in popularity due to the perceived increased applicability of the data compared to that derived from a non-human model. However, the use of donated human cadavers is not without its problems: donors are usually elderly and frail, with a low body mass and may have underlying medical conditions that can impact the decomposition process (Matuszewski et al., 2020; Miles, Finaughty & Gibbon, 2020). Essentially, cadaver donor populations do not correspond well with populations found in the typical forensic case. In addition, a sample of donated cadavers may be considerably less uniform than a sample of the same species of domestic pigs raised under controlled conditions for human consumption. Donations of human bodies may also occur sporadically, requiring the freezing and storage of remains for considerable lengths of time before deployment, further influencing the decay process.

1.4.2 Taphonomic research in South Africa

South African research into forensic taphonomy began in 1980 with a carrion entomology study by Prins (Williams & Villet, 2006). Prins' research resulted in a PhD and multiple publications on the identification, morphology, and developmental rates of relevant carrion insect species in the then Cape Province (Williams & Villet, 2006; Finaughty, 2019). Since then, five university-based experimental taphonomic and entomological research centres have developed in four of the country's nine provinces (Finaughty, 2019). These centres all use porcine decomposition models and are located at the University of the Free State, Rhodes University, University of Pretoria, University of the Witwatersrand, and University of Cape Town (Finaughty, 2019).

In 1992, the University of the Free State developed the first research programme in the Free State Province, following discussions in the Department of Forensic Medicine regarding the need for entomological expertise (Louw & van der Linde, 1993). This led to the establishment of the Forensic Entomology Investigation Team of the Universiteit van die Oranje Vry Staat [University of the Free State] to assist local authorities in forensic death investigations (Louw & van der Linde, 1993). The programme has since developed, and more recent research has included forensic entomology succession studies as well as topics such as the effect of clothing, burning, freezing, hanging, burial, and physical trauma on decomposition across seasons (Kolver, 2003; Kelly, 2006; Williams & Villet, 2006; Kelly, van der Linde & Anderson, 2008, 2009; Botham, 2016; van der Merwe, 2016; Moeti, 2019).

In 1993, research into invertebrate ecological succession began in the Eastern Cape at Rhodes University (Williams & Villet, 2006), with the development of the South African Forensic Entomology Research laboratory. Detailed entomological work continues on the identification, ecology, development, and distribution of forensically significant blowflies, their maggots, and other species (Williams & Villet, 2006; Finaughty, 2019).

The Forensic Anthropology Research Centre and the Forensic Anthropology Body Farm were founded in 2011 at the University of Pretoria in the Gauteng Province, focusing on forensic taphonomy research (Finaughty, 2019). Previous topics covered by researchers from Pretoria include the decomposition of both buried and surface remains, the effect of body size on decomposition, and the use of ADD and PMI estimation methods (Myburgh et al., 2013; Sutherland et al., 2013; Keough, Myburgh & Steyn, 2017; Marais-Werner et al., 2017, 2018).

The research programme at the University of the Witwatersrand, also based in Gauteng, has not focused on forensic taphonomy historically (Finaughty, 2019). However, more recently, Keyes and colleagues (2020, 2021a,b) published three papers on the scavenging activity, decomposition rates, scattering patterns, and destruction of bones due to a wide variety of opportunistic vertebrate scavengers, previously outlined in detail in Chapter 1, section 1.3.3.

Taphonomic research in the Western Cape Province conducted by the University of Cape Town began under the leadership of Morris with two PhD projects by Finaughty on terrestrial decomposition and Speed on marine decomposition in 2014 (Finaughty, 2019; Speed, submitted). The marine decomposition project was expanded under Gibbon's leadership with the development and testing of dental DNA extraction methods from porcine and human remains in marine environments in the Cape Finaughty et al. (2019), Finaughty, Reid, et al. (2020), and Heathfield et al. (2021). Although marine decomposition is not the focus of this thesis, the field has seen significant expansion in the Western Cape, alongside terrestrial decomposition.

This thesis focuses on terrestrial decomposition; as such, more depth is given to the regional development of this research. Finaughty's (2019) terrestrial decomposition study was the first to establish baseline data for the Western Cape in two forensically relevant habitats; the thicketed and open Cape Flats Dune Strandveld. His research used sixteen 60 kg domestic pig carcasses deployed in each of the two habitats in pairs over two summer and winter seasons between 2014 and 2016. The carcasses were unclothed and caged to prevent vertebrate scavenger access in line with customary practice in the discipline. Decomposition progression was tracked via daily manual weight loss measurement and the TBS method developed by Megyesi, Nawrocki & Haskell (2005). These data were correlated with the weather and invertebrate and vertebrate scavenging data. Finaughty found no significant differences in decay rate between habitats, but decomposition progressed approximately twice as fast in summer than in winter. The onset of skeletonisation occurred within 2-3 months in summer and 3-5 months in winter. Summer decomposition was also characterised by precocious natural mummification, with carcasses mummifying in under 30 days due to the high temperatures, strong winds, and low humidity (Finaughty & Morris, 2019). Finaughty identified several key species of invertebrates relevant to local decomposition and entomological succession, as well as the Cape grey mongoose as a highly active vertebrate scavenger in the thicketed habitat (Finaughty, 2019).

The entomological research conducted by Finaughty (2019) led to the founding of the Cape Forensic Taphonomy and Entomology laboratory in 2016 in conjunction with Heyns from the Pathology Department at UCT (Finaughty, 2019). The laboratory is now predominantly a research unit based in the Division of Forensic Medicine and is currently under the leadership of Mole. Students continue to conduct valuable entomological research, such as the recent submission of an MSc thesis on identifying forensically relevant blowfly species via DNA barcoding (Kulenkampff, 2019) and ongoing entomological work by Uys and Adetimehin.

Building upon other areas of interest identified by Finaughty (2019), terrestrial decomposition research has continued in the region under the leadership of Gibbon. For a one-year BMedSci (Hons) degree in 2017, the author of this work compared the decomposition of caged and uncaged porcine remains in the same thicketed habitat (Spies, 2017). Three small 20 kg unclothed domestic pigs were utilised, with decomposition tracked via a modified TBS scoring method, scavenging activity recorded via motion-activated cameras, and skeletal scattering manually recorded. As a follow-up to Finaughty's (2019) study, the author confirmed the Cape grey mongoose to be the only prolific scavenger in the thicketed environment able to drastically accelerate decomposition with a six-fold increase in mean decay rate compared to the caged control (Spies, Gibbon & Finaughty, 2018). The study also highlighted some common patterns of scavenger-induced skeletal scattering over a maximum distance of approximately 13 m into dense undergrowth, which was similar to scatter by the yellow mongoose observed in a forensic case (Spies, Finaughty & Gibbon, 2018).

Using the TBS and ADD data gathered by Finaughty (2019), Forbes et al. (2019) evaluated and compared the accuracy of the PMI estimation methods developed by Megyesi, Nawrocki & Haskell (2005) and Moffatt, Simmons & Lynch-Aird (2016). Both methods inaccurately estimated the ADD and PMI in winter and were only partially accurate in summer (Forbes et al., 2019). The authors found that Megyesi's model was more reliable in the later stages of decomposition, whilst the Moffat model was more accurate in the early decay stages. They attributed the inaccuracy of these models to the difference in environmental variables between the Cape and the regions where the models were developed (Forbes et al., 2019). In addition, they highlighted the models' issues of subjectivity, large possible interobserver error, and an over-simplification of the decay process to one variable, temperature. They also emphasised the need for local data to develop regionally specific PMI estimation methods (Forbes et al., 2019).

Since the onset of the current investigation, as part of a BMedSci (Hons) degree, Du Toit (2019) compared the weight loss and scavenging activating of a single clothed winter carcass to that of the clothed winter carcasses examined by the author in 2018. This pilot study was conducted in 2019 as a follow-up to initial data from this PhD and took place in the same habitat, using identical clothing as those used in the study being examined. Du Toit's (2019) study served as a proof of concept to field test an automated weighing apparatus and the use of a single clothed carcass like those used later in the current investigation (Finaughty et al., submitted) (more detail provided in Chapter 2: Materials and Methods). Crucially, this study provided the first evidence of total carrion biomass load altering decay rates – the single clothed carcass lost weight more rapidly and experienced more mongoose scavenging activity than the mean of the two clothed carcasses examined during this PhD (Finaughty et al., submitted). Additional analysis and comparison between the two studies, along with further information, are presented in the results and discussion chapters.

During the current investigation, French (2020) completed an additional in-depth follow-up study under Finaughty's leadership into the common feeding characteristics of the Cape grey mongoose using one of this study's carcasses and additional video and photographic data explicitly collected by the author for this purpose. French (2020) examined the frequencies of defined feeding behaviours and where on the remains they occurred. Mongooses most often exhibited biting and pulling behaviour, with most activity occurring to the head, abdomen, and eye socket (French, 2020; French et al., 2021). Video footage also confirmed mongooses feeding on maggot masses, although this occurred substantially less frequently than feeding on flesh, with most mongoose visits occurring when maggot masses were small. In addition, the orbital fossa was identified as the most likely place for mongoose-specific skeletal marks to occur, given it was one of the only skeletal areas with a high frequency of activity. This may be useful to determine if small mammal scavenging activity has occurred in forensic cases.

In 2020, the Cape Forensic Taphonomy research unit was established by Gibbon and Finaughty and is based in the Department of Human Biology. Additional taphonomic research continues under their leadership, such as a long-term clothing degradation investigation by the author and a sister study to this PhD being conducted by Adams, who is similarly investigating clothed decomposition but in different habitats. Future projects, like sensors to measure desiccation, are in development, and discussions for future collaboration with the entomology team in the Pathology Department are underway.

The previous taphonomic studies highlighted here, especially those conducted by Finaughty (2019), Forbes et al. (2019), and the author (Spies, 2017; Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018), provide a foundation for the current investigation, which began as an MSc in 2018 but was upgraded to a PhD in 2020. These studies help guide the development of the design and rationale for the current investigation to expand local taphonomic research and provide data on critical variables missing from the literature.

1.5 Study design and rationale

The number of unidentified and unclaimed bodies remain a significant problem in Cape Town; the city has the highest murder rate for any metropolitan region in South Africa, markedly more than the second-highest city, Nelson Mandela Bay (Gqeberha) (64/100,000 vs 51/100,000), ranking 10th overall worldwide (Mexican Council for Public Security and Criminal Justice, 2021). Although not directly influencing the number of murders, accurate PMI estimates are essential for forensic death investigations and help identify the decedent. Generating more accurate PMI estimates in the Western Cape Province based on forensically realistic data incorporating missing variables and local environmental conditions will significantly and positively impact case resolution. This will facilitate both social and criminal justice for the benefit and safety of all South Africans and provide closure for the family of crime victims, giving dignity in death to the decedent. Previous work in the region has established baseline data on unclothed decomposition, identified the Cape grey mongoose as a critical scavenger, indicated that ADD-TBS methods are inaccurate in the Cape, and highlighted carrion biomass load as a variable affecting decay rates (Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018; Du Toit, 2019; Finaughty, 2019; Forbes et al., 2019). However, no data exists on how clothing influences decomposition and scavenging in the Western Cape, despite most local forensic cases involving clothed individuals (Baliso, Finaughty & Gibbon, 2019; Baliso, 2020). In addition, no known taphonomic research besides Du Toit's (2019) pilot study has quantitatively examined whether carrion biomass load influences scavenging activity and decay rates, despite most common forensic scenarios involving single individuals (Baliso, 2020). These two variables are gaps in the literature and may also be influenced by seasonal variations in weather variables. As such, this investigation will use a quantitative method and forensically realistic materials in a relevant habitat to generate baseline data on the effect of clothing, season, and carrion biomass load on decomposition and scavenging. Some of these data have been published in *Forensic Science International* (Figure B.1 in Appendix B) and accepted for presentation at the 89th Annual Meeting of the *American Association of Biological Anthropologists* in 2020, with the abstract published in the *American Journal of Physical Anthropology* (Figure B.2 in Appendix B).

1.5.1 Aims and objectives

The purpose of this study is to examine the effect of clothing and carrion biomass load on the process of surface decomposition and vertebrate scavenging in Rooikrans thickets in the Cape Flats Dune Strandveld habitat of Delft, Cape Town, South Africa. This will be accomplished by completing the following objectives:

1. Determine the most common clothing types found in local forensic cases using a retrospective analysis of all Forensic Anthropology Cape Town (FACT) case files.
    - Are there commonalities in clothing types for warm and cool weather?

2. Using a quantitative experimental decomposition study design with clothed and unclothed domestic pig carcasses, monitor and assess the effect of clothing on the rate of decomposition and scavenger activity.
    - Is the rate of decay of unclothed carcasses validated with previous research?
    - Is there a difference in the rate and process of decomposition between clothed and unclothed individuals?
    - Does clothing inhibit scavenger access/activity?

3. Comparing data from four separate decomposition experiments done in winter and summer, assess how seasonality influences the decomposition process of clothed carcasses.

    - Is the influence of clothing on decomposition altered by seasonality (environmental conditions plus weather-appropriate clothing type)?

4. Comparing data from single and multiple carcass deployments, assess how carrion biomass load influences scavenger behaviour and the decomposition process.
    - Is vertebrate scavenger behaviour altered when multiple carrion options are available?

These objectives will address the hypotheses that clothing will inhibit vertebrate and invertebrate access and reduce the rate of decomposition; that the effect of seasonally appropriate clothing will be greater in the winter than in the summer; and lastly, that single carcass deployments will show increased scavenging and decay more rapidly than multi-carcass deployments.

Chapter 2: Materials and Methods

2.1 Experimental design and research materials

To rule out anomalous results in the decomposition of an individual and ensure replicability and reliability whilst still maintaining a manageable overall budget, this research was designed with four deployments of a total of ten domestic pig carcasses. The first two deployments had four carcasses each (two clothed experimental treatments and two unclothed controls), and the second two deployments had only a single clothed carcass each, as indicated by the flow diagram in Figure 2.1. The first two trials were conducted to assess the effect of seasonality and generate data on the average decomposition process within different seasons, in the presence and absence of clothing. Two additional single carcass trials were subsequently conducted to provide seasonal comparisons and assess the possible impact of varying carrion biomass on the rate of decomposition. The first trial was carried out in 2018 during the colder and wetter winter months (June – September), continuing into spring, whereas the second trial began in the hotter and drier summer months (November – February) of 2019, continuing into autumn. The third and fourth trials were deployed on the same or similar dates in the following winter 2019 and summer 2020 periods, respectively. For ease of comparison and discussion, the winter deployments were defined as those that began in the winter period, and the summer deployments as those that began during the summer period, despite some overlap with spring and autumn, respectively. All carcasses were deployed in the same thicketed environment with the clothed carcasses dressed according to season; "winter clothing" defined as typical clothing observed in forensic casework, to be worn during cooler weather, and "summer clothing" defined as typical clothing worn during warmer weather.

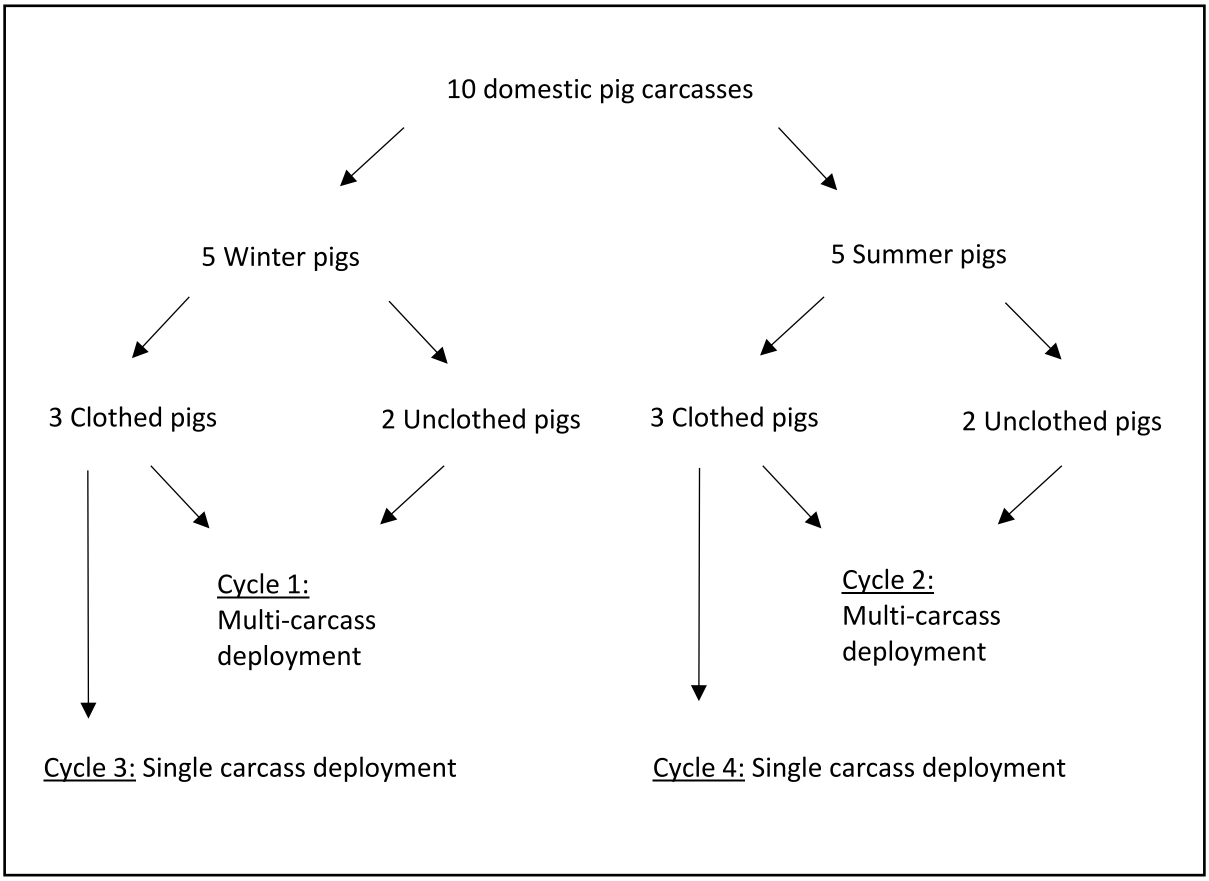

Figure 2.1: Flow chart of study design: ten domestic pig carcasses were separated equally by season and then separated again into three clothed and two unclothed carcasses each. Two clothed and two unclothed carcasses were simultaneously deployed in each season, in cycles 1 and 2. The remaining two clothed carcasses were deployed as single carcasses, one in winter for cycle 3 and one in summer for cycle 4.

2.1.1 Domestic pig carcasses

As outlined in Chapter 1, section 1.4.1, domestic pigs are considered acceptable and appropriate proxies for establishing general trends and baseline decomposition data when human cadavers are unavailable. Ten male domestic pig (*Sus scrofa domesticus*) carcasses of approximately 60 kg in weight were used as proxies for adult human decomposition in a total of four deployments: two deployments of four carcasses each and two deployments of one carcass each. The carcasses were purchased from the Mariendahl Experimental Farm (Stellenbosch University), and termination of life was achieved by a 0.22 calibre long rifle gunshot to the base of the brain (Faculty of Health Sciences Animal Ethics Committee, University of Cape Town: AEC 018_023; see figures C.1, C.2, D.1, and D.2 in Appendices C and D). This is a quick and humane form of termination that meets the needs of this project; the small calibre bullet causes minor physical damage to the carcass, unlike conventional exsanguination methods, and no potential contaminants of unknown effect are introduced, such as with methods involving lethal injection. Additionally, the small entry wound is quickly clogged with clotted blood and does not form a site of attraction to accelerate blowfly oviposition (Spies, Gibbon & Finaughty, 2018). A detailed termination of life protocol, approved by the UCT FHS AEC, is available in Appendix E.

2.1.2 Clothing

The seasonal sets of clothes used in this study were chosen based on anecdotal evidence from senior members of our local service provider Forensic Anthropology Cape Town (FACT), as well as a thorough retrospective analysis of 222 FACT case files (1990-2018), both supporting the choice of inexpensive, seasonally appropriate primarily-cotton type clothing. Further details may be found in section 3.3.1 of the Results chapter.

Each clothed treatment group was clothed appropriately for the season, with “winter clothing” defined as underwear, denim jeans with a leather belt, a cotton T-shirt, jersey, socks, and shoes. The “summer clothing” comprised: underwear, denim jeans with a leather belt, and a cotton T-shirt (Figure 2.2). The clothes were identical and newly purchased at the same time from Pep Stores, an inexpensive clothing retailer widespread and popular across South Africa due to its affordability. The percentages of fibre types for the chosen clothes, as indicated on the labels, are as follows: underwear (65% polyester, 35% cotton), T-shirt (100% cotton), jersey (100% acrylic), denim jeans (60% cotton, 30% polyester, 10% viscose), socks (97% polyester, 3% elastane), shoes (sole: synthetic, lining: textile), and belt (bonded leather).

The newly purchased clothes required alterations to ensure a reliable and realistic fit, accounting for the anatomical differences between pigs and humans. Measurements taken from a live 60 kg pig were used as a guide: chest circumference = 87 cm; pelvis circumference = 81 cm; armpit height = 31 cm; shoulder height = 54 cm; groin height = 33 cm; thigh circumference = 45 cm; snout-to-tail length = 136 cm. The sizes of the clothes reflected these measurements: the jerseys and T-shirts were size medium (to fit a human chest size 92-97 cm), the jeans were size 40 (to fit a human waist of circumference 102 cm), and the underwear was size large. The socks and shoes were both sized to fit a small child, as pig hooves are relatively small and short compared to human feet.

After discussion and testing with a seamstress, an alteration plan was developed. The clothes were first washed, and then alterations were made before deployment. These included shortening and tapering of the trouser legs, in addition to the jersey arms. The denim jeans required the most significant changes to shorten and taper the legs, as they were deliberately purchased in a large size to accommodate the deep in-seam required for the relatively elongated pelvis of the pig. Additionally, the rear seam of each pair of denim trousers was opened to facilitate dressing the pigs on-site and to ensure an appropriately tight fit, as the seams were securely sewn closed by hand once the pigs were dressed. The jerseys used in the winter deployments were similarly altered to shorten and taper the arms, whereas the T-shirts, underwear, socks, and shoes were left unaltered. The limbs of the initial set of altered clothes were all slightly too long, requiring the legs and arms of the trousers and jerseys to be rolled up, respectively. Some minor adjustments to this plan were made as the study commenced and new sets of clothing were altered.

Figure 2.2: The altered clothing used for the six clothed carcasses. A) The altered denim trousers and unaltered underwear, socks, and shoes. B) Jersey/pullover with shortened and tapered arms. C) Unaltered cotton T-shirt.

2.1.3 Comparative data

To assess the effect of clothing on decomposition, a validation of unclothed carcass decomposition is required. A comparative dataset from Finaughty (2019) was utilised to validate the collected data, consisting of eight unclothed pig carcasses deployed in the same environment for two summer and two winter seasons during 2014-2016. An additional comparative dataset derived from a single clothed winter carcass from Du Toit (2019) was also utilised to compare to the carcass deployed under the same conditions examined in this study. Both datasets consisted of recordings of daily weight loss, multiple weather variables, and recordings of scavenging activity.

2.2 Research location and deployment

The South African Police Service ranks police precincts across the country by the incidence of specific crimes. Concerning the number of recorded cases of murder, seven of the top-ten precincts fall within the City of Cape Town Metropole (South African Police Service, 2021). All of these are located in the geographical region known as the Cape Flats: an extensive, low-lying, flat area situated to the southeast of the central business district, bordered by the Cape Peninsula mountain chain to the west, the Hottentots-Holland and Boland mountains to the east, and coastline to the north and south. The Cape Flats area is the central region of habitable land in the Cape Metropole and is subsequently densely populated, having numerous suburbs with over 3000 inhabitants per square kilometre (Htonl, 2015) (Figure 2.3). Excluding the seven police precincts mentioned above, many others in the Cape Flats region fall within the top 20% of precincts nationwide for recorded cases of murder (Figure 2.3). These figures indicate that the Cape Flats region has a critical problem with serious contact crimes. This research took place in Delft, a suburb within the Cape Flats, falling within the Mfuleni police precinct that recorded 172 cases of murder and 141 cases of attempted murder during the 2020/2021 fiscal year (South African Police Service, 2021).

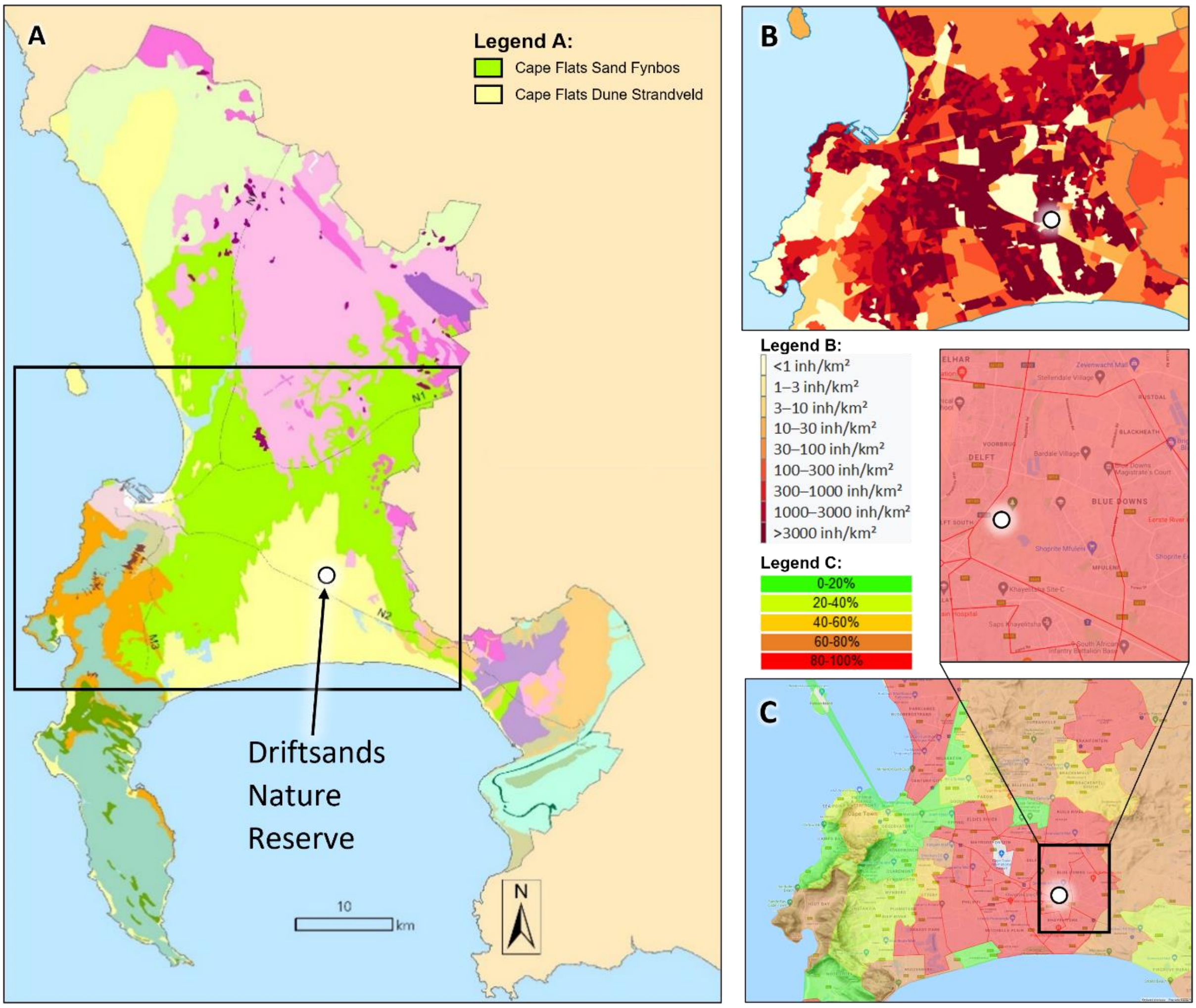

Figure 2.3: Maps of vegetation subtype, population density, and crime rate for the City of Cape Town Metropole. A) Vegetation subtypes of the City of Cape Town Metropole, with Cape Flats Dune Strandveld and Cape Flats Sand Fynbos, indicated in the legend. The location of Driftsands Nature Reserve is also indicated. The area of interest for B and C is highlighted (adapted from Shawka, 2010). B) Population density of the City of Cape Town Metropole, measured by inhabitants/square kilometre (inh/km^2) (adapted from Htonl, 2015). C) Heat map of the City of Cape Town Metropole indicating quintiles of contact crimes (murders) per police precinct (adapted from ("Crime Stats SA", 2021). Precincts within the fifth quintile (top 20%) in terms of the number of murders are indicated in red. Legend is indicated above. The precinct the research site is located in (Mfuleni) is enlarged in the inset, with 172 murders in this precinct during 2020/2021 (SAPS, 2021). This figure is adapted from Spies, Gibbon & Finaughty (2018).

As indicated in Chapter 1, section 1.3.2, this densely populated region containing crime-ridden pockets coincides with two predominant habitats; Cape Flats Dune Strandveld and Cape Flats Sand Fynbos, which are often covered with dense thickets of invasive Port Jackson and Rooikrans tree species (Figure 2.2). A considerable proportion of the forensic cases conducted by FACT are found within this general region and within these vegetation subtypes (Baliso, 2018), as they provide optimal locations for the disposal and concealment of human remains. The chosen research site is located within the region of interest and owned by the South African Medical Research Council (S 33°59’24.27” E 18°39’12658”). Adjacent to the secure facility is the Driftsands Nature Reserve: approximately 490 ha of protected Cape Flats Dune Strandveld vegetation. A horse paddock, approximately two acres in size with characteristic dense thickets of invasive Port Jackson and Rooikrans, was used for this study (Figure 2.3). Previous research in this thicketed microhabitat has revealed extensive scavenging activity by Cape grey mongoose (Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018; Finaughty, 2019).

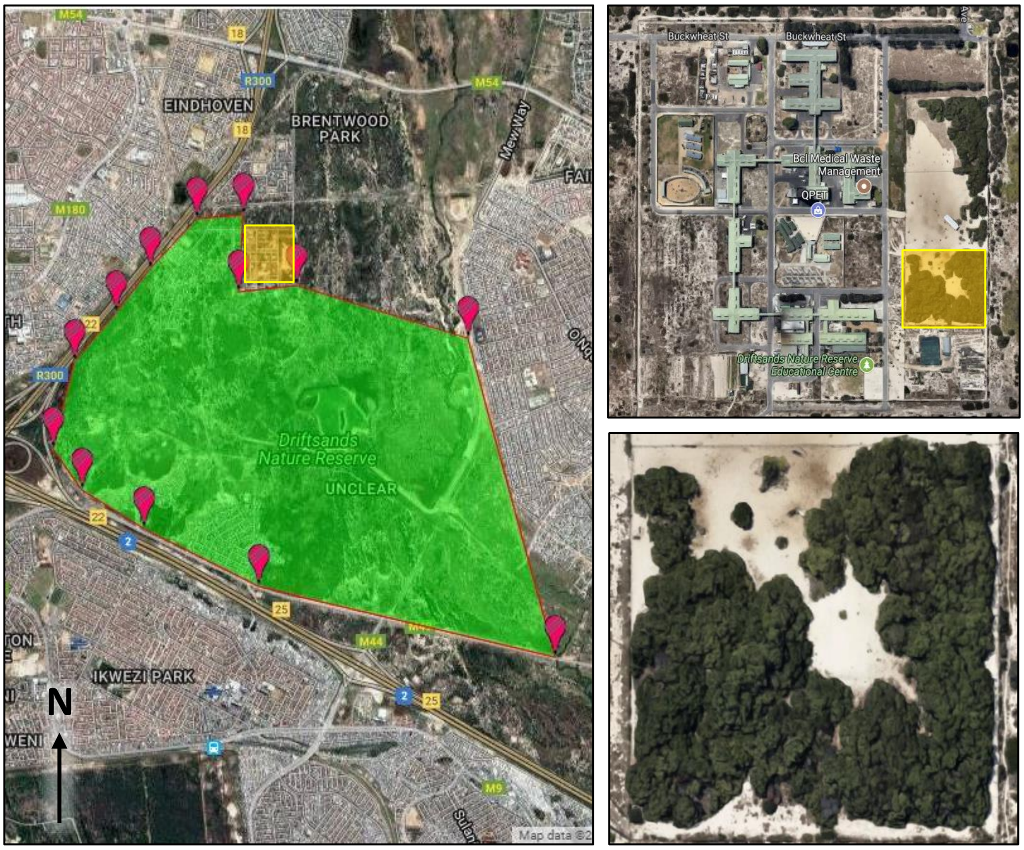

Figure 2.4: Map of study location. A) Approximate area of Driftsands Nature Reserve (489.60 ha), with Medical Research Council facility in yellow (https://www.daftlogic.com/projects-google-maps-area-calculator-tool.htm). B) Medical Research Council facility in Delft, with study site indicated in yellow. C) Close-up of thicketed horse paddock used for this study, approximately 100 x 100 m (Google Maps, 2019).

The carcasses were terminated early in the morning to ensure minimal blowfly activity. Immediately afterwards, the carcasses were washed with water using a hose, sealed in individual body bags, and transported to the research facility in the back of a utility truck without refrigeration or freezing. They were deployed within two to three hours of termination of life, as soon as the treatment groups were clothed upon reaching the research site. The first two multi-carcass deployments were designed in duplicate to mitigate the effect of possible outliers, with two unclothed controls and two clothed experimental treatments per seasonal deployment. The additional, single carcass deployments were designed to evaluate the effect that deploying multiple carcasses simultaneously (representing a larger carrion biomass load than a single carcass) could have on the decay rate. The carcasses are labelled in the following manner; all clothed carcasses are denoted by C and unclothed by UC, followed by the carcass number. The season of deployment is denoted by S for summer and W for winter. Finally, the year of deployment is denoted by the numbers at the end of the label. The first clothed carcass from the winter deployment of 2018 serves as an example of the labelling format; C1-W18. All carcasses were deployed in a standard position lying on the right side with limbs outstretched. To minimise overlap of ground-dwelling insect populations, new deployment locations, unused in previous decomposition cycles, were chosen within the thicketed horse paddock, at least 20-30 m away from the nearest neighbouring carcass (Figure 2.5). With approximately one acre (~4000 m^2) of equally thicketed land allocated to this study, greater distances between carcasses were not feasible. Each carcass was deployed on a steel weighing grid (10 cm x 10 cm squares), modified with wire mesh designed to hinder mongooses burrowing and scavenging from beneath; a previously documented behaviour in this habitat (Finaughty, 2019). Such behaviour is undesirable, as it unnaturally limits carcass contact with the ground and promotes mummification. The mesh also served to prevent any small bony elements from falling through the grid when weighing, which would disturb the carcass further, and confound the measurement of the rate of weight loss towards the end of the cycle.

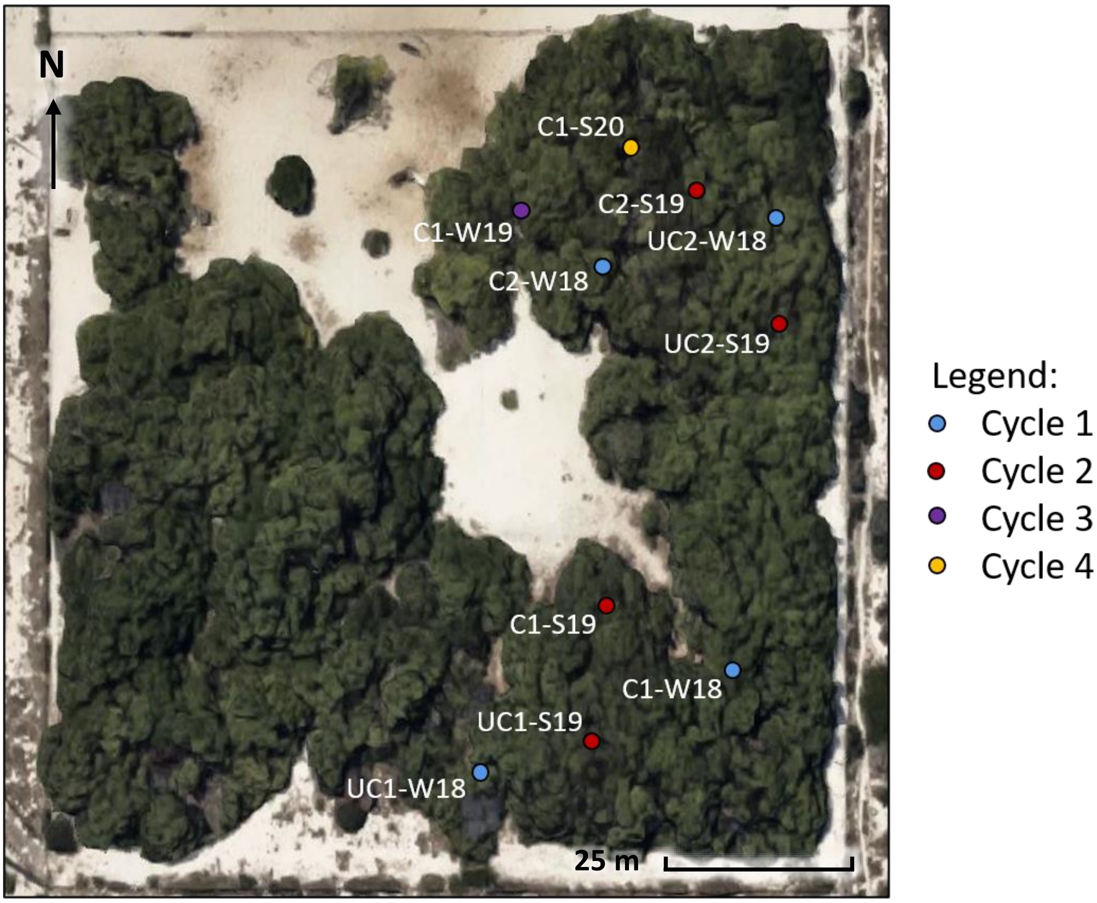

Figure 2.5: Close-up of tree-covered horse paddock used for this study indicating approximate deployment location of each carcass, colour coded by cycle (Google Maps, 2019). C = clothed, UC = unclothed, W = winter, S = summer, 18/19/20 = year of deployment.

2.3 Data collection

2.3.1 Weather

A Davis Vantage Pro 2 weather station was used on-site, in the vicinity of the carcasses, to track the following weather variables within the habitat at an hourly resolution: ambient temperature (°C), relative humidity (%), rainfall (mm), pressure (bar), wind velocity (km.h^{-1}), and solar radiation (W.m^{-2}). On-site, within-habitat measurement was selected, as using weather data generated from nearby national weather service stations is potentially unreliable (Dabbs, 2010). Accumulated degree days (ADD) were calculated using 0°C as the minimum developmental threshold (Megyesi, Nawrocki & Haskell, 2005).

2.3.2 Decomposition

The methods of scoring decomposition in the literature, such as the method developed by Megyesi, Nawrocki & Haskell (2005) or the version adapted for use on pigs by Keough, Myburgh & Steyn, (2017), rely on the observation and scoring of visual changes to the whole carcass as decomposition progresses. This is difficult when the subject is covered with clothing, doubly so when mammalian scavengers rapidly eat certain parts of the carcass; both factors are not accounted for in any decomposition scoring methodology known at the time of writing. Short of regularly removing the clothing to visually assess the progression of decomposition, which would invariably affect the results, there are no viable means to score decomposition based on the visual appearance of the carcass. Although previous studies have altered clothing to include slits with Velcro hook-and-loop-fasteners to facilitate opening and closing of the clothing for decomposition scoring purposes (Phalen, 2013), the unknown effect of this frequent interference is difficult to quantify. Therefore, such a method was not undertaken for the current investigation. Visual decomposition scoring was only used in a supporting role to specifically estimate the onset and end of bloating in the head and neck of each carcass from photographs, using the method developed by (Keough, Myburgh & Steyn, 2017) as a guide. Evidence of bloat onset was confirmed via an increase in the width of the neck by at least 1 cm compared to day one, measuring from approximately the middle of the throat perpendicularly to the back of the neck. This was done using freely available software, ImageJ, with the 10 x 10 cm metal grid used to calibrate the pixels per centimetre factor for each photo. The head and neck was the only region assessed in this manner, as it was the only region not obscured by clothing in the sample as a whole. In addition, the abdomen was consistently a primary target of scavenging activity in most cases, preventing the reliable measuring of abdominal bloat, even for the unclothed group.

To track decomposition via a non-visual quantitative method, less prone to researcher bias, weight loss measurements were taken every day, approximately 24 hours apart (± 30 min). During the initial multi-carcass deployments, weighing of each carcass during daily site visits was facilitated by a block and tackle and analogue scale mounted to a steel tripod (Figure 2.6A). Although labour intensive and time-consuming, the frequency of daily site visits ensures an even and reliable spread of data with equal intervals separating data points to facilitate statistical analysis. The date and time of each weighing event were recorded, together with comments on the visual state and insect presence. Later, the two single carcass deployments were weighed by a prototype automated weighing apparatus, consisting of a winch powered by a 12 V battery, a pulley system attached to the steel tripod, and a sub-frame mounted above the weighing grid (Figure 2.7). The automated system was designed and developed by Dr Devin Finaughty and Associate Professor Victoria Gibbon with the assistance of the author and an electrical engineer, Justin Pead, who developed a custom-built and -coded microcomputer to manage the timing and duration of lifts and to log the resultant data. The second and third versions of the system were implemented in the last two cycles to assess its use in actualistic studies. The automated system was designed to increase the accuracy and reliability of the weight measurements, and critically, to reduce the need for frequent site visits, limit disturbance to the environment, and reduce the time and costs associated with travel to and from the research site. The system was coded to weigh at midnight to reduce carcass disturbance further, as local scavenging activity was observed to be strictly diurnal.

Figure 2.6: Equipment used for weight loss and scavenger monitoring in cycles 1 and 2. A) The steel tripod with a block and tackle system used to lift the carcasses and grid (1 x 2 m) to take daily weight readings from an analogue scale in cycles 1 and 2. B) The wooden four-legged structure used to mount the motion-activated cameras directly above each carcass in cycles 1 and 2.

Decomposition was deemed in a condition of stasis, and data collection was terminated when all carcasses in a given decomposition cycle met at least one of the following criteria:

- Skeletonisation was reached (Adlam & Simmons, 2007);
    - Obvious loss of internal abdominal structure, only spine and ribs remaining underneath dried skin;
    - Substantial unweathered/greasy bone exposed (>50% of carcass) and no wet decomposition when observed underneath the carcass (facilitated by the grid with block and tackle);
    - Significant areas (>30% of carcass) of bleached or weathered bone exposed.
- The weekly accumulated weight loss declined to below 5% of the original weight value for three consecutive weeks;
- Minimal insect appearance/activity.

Figure 2.7: Equipment used for weight loss and scavenger monitoring in cycles 3 and 4. A) Prototype automated weighing apparatus (09/2019) consisting of a 12V battery-powered winch, a pulley system attached to the steel tripod, and a sub-frame mounted above the weighing grid, used in cycle 3. B) Version 2 (01/2020) of the automated weighing system with a shorter sub-frame, wide-angle camera, and improvements to the code used in cycle 4 (Finaughty et al., 2020, 2021).

2.3.3 Scavenging activity

Each subject in the multi-carcass deployments was monitored by a motion-activated, infrared-capable time-lapse wildlife camera (Primos Proofcam model 3), set to capture three photos per motion trigger, along with a time-lapse sequence comprising one photo in hourly intervals. The hardware limited the time-lapse mode to daylight hours only, but the motion-activated burst mode was still triggered at night. Each camera was fitted with an 8-gigabyte standard secure digital (SD) memory card and mounted directly above its carcass onto a specially built four-legged wooden structure (Figure 2.6B). Every day, these structures were moved for weighing to occur. To ensure they were returned to the same position (to ensure the camera view of the carcass remained consistent), plastic funnels were sunk into the ground, acting as placeholders for the locations of the four legs. During the later single carcass deployments, a Bushnell camera (Trophy Cam 119436) and a Foxelli camera (Oak's Eye 2) were used instead due to their increased field of view, necessitated by the automated system restricting the available height above the carcasses. These cameras were similarly programmed and affixed to the static sub-frame of the weighing rig, ensuring a consistent and complete view of the carcass.

Photographs captured by the cameras were downloaded daily from the SD cards during multi-carcass deployments and weekly during single carcass deployments, with scavenger activity processed using freely available software, Timelapse2 (Greenberg, 2017). The photographs captured the presence of scavenger species, along with the time and area of scavenging. The laborious process of analysing the photographs involved cycling through each image captured since the previous data download, digitally marking and noting the presence of each scavenger, deleting any corrupt or dark images, and noting any distinctive features of worth, such as when disarticulation occurred. The software was used to generate spreadsheets populated with scavenger-related data for each image, such as the species of scavenger and how many individuals were captured per photo. These spreadsheets were then processed in Microsoft Excel, where entries with no scavenger data were deleted, and modified spreadsheets were created. These were then used to calculate the number of visits per day by a given species, length of visit and accumulated duration of visits. Individual visits were defined by an absence of a scavenger from the carcass and immediate surroundings visible in the field of view for at least 10 minutes between visits, *i.e.,* cleaning behaviour in the frame on and around the carcass was included in the duration of a visit. The duration of simultaneous visits by multiple scavengers was defined as the absolute amount of time two or more scavengers spent in the frame within a given visit.

2.4 Data analysis

The weather data were processed using Microsoft Excel v2102 into average maximum, mean, and minimum values for 24-hours, day, and night for each cycle and each of the following variables: temperature, rainfall, pressure, humidity, wind speed, and solar radiation. Day and night were defined by civil dawn and civil dusk. These data were exported as tables using Microsoft Excel or graphed using RStudio v1.4.1106. The normality of weather variables was graphically assessed. Seasonal averages were then compared employing Welch's two-sample *t*-test, which performs well with large samples regardless of whether the variables are assumed to be normally distributed or not. This was conducted using RStudio, with a *p*-value ≤ 0.05 chosen as the cut-off for significance for all statistical tests. Occasional failure of the system created gaps in the weather record. Missing hourly temperature, humidity, rainfall, and wind speed data were estimated using linear regression from records at the South African Weather Service's weather station at Cape Town International Airport, located 5.5 km away to the northwest. Missing solar radiation values were estimated via the normal distribution of recorded values for each hour within each cycle.

The sample was first assessed for significant differences in biographic characteristics between summer and winter, clothed and unclothed, and across both season and clothing. The median values for carcass height, length, and weight were tested using a Kruskal-Wallis test for non-parametric data in RStudio to identify possible confounders in the sample prior to further analysis.

The onset and end of bloating in the head and neck, measured in number of days, were used to calculate the duration of bloat, and then simply averaged, tabulated, and numerically compared between different groups. Weight loss data were tabulated in Microsoft Excel and graphed in RStudio for visual comparison. Missing data points were estimated using linear regression in RStudio. Each carcass's time (in 24-hour days) to reach mass loss milestones was calculated to compare decay rates numerically. Total thermal energy (in accumulated degree days [ADD]) required to reach each mass loss milestone was similarly calculated. The resultant time and thermal energy values were tested for significant differences across seasons using a Kruskal-Wallis test in RStudio, but the small sample size precluded additional testing between clothed and unclothed groups and single and multi-carcass groups. Instead, the mean number of days and ADD to reach mass loss milestones were graphically compared for each cohort using bar charts created in RStudio.

Scavenger data were similarly tabulated and graphed in Excel and RStudio, respectively. The number and duration of scavenger visits, as well as the duration and proportion of simultaneous visits by multiple scavengers, were calculated for each mass loss milestone. These were numerically and graphically compared across the different experimental scenarios examined in this study. Significant differences between seasons were statistically tested using a Kruskal-Wallis test, but further testing between other groups was not possible due to the small sample size. Scavenging activity was graphically correlated with weight loss and weather variables in RStudio.

The comparative data sets from Finaughty (2019) and Du Toit (2019) were similarly processed and interpolated using linear regression were necessary. Comparisons of the weather data were conducted as outlined above, except a limited weather dataset was available from Finaughty (2019) with a differing definition of day/night, where daylight was defined by a solar radiation value >30 W.m^{-2}. Therefore, weather data comparisons with Finaughty's dataset followed the same definitions and used only the same available weather variables.

Weight loss data from the unclothed carcasses studied by Finaughty and the single clothed winter carcass studied by Du Toit were similarly calculated and summarised into the same weight loss milestones previously described. These data were tabulated and graphed to compare with the unclothed carcasses and the single clothed winter carcass examined in the present study, respectively.

Chapter 3: Results

The results chapter is divided into four sections, starting with some general observations and then covering the major research questions of this thesis: the effect of clothing, the effect of seasonality, and the effect of carrion biomass load. Each section of the results chapter follows a similar pattern, delving into more detail and presenting data on each topic. For ease of the reader's understanding, all values in the text are rounded to the nearest whole number, with more detail, significance values, and statistical outputs provided in the referred tables. Some additional scavenging data are presented in Appendices F and G, and the raw data is available digitally on request.

3.1 General observations

This section of the results gives a broad overview of the research and the types of data collected over the four trials conducted between 2018 and 2020. Both cycles 1 and 2 utilised four pig carcasses each, two clothed and two unclothed per deployment. The subsequent cycles examined only a single clothed carcass each. To begin with, some general observations are provided on the study sample, the typical rate of weight loss, and the recorded activity by attendant vertebrate scavengers.

3.1.1 Sample characteristics

An analysis of the sample's biographic details required measurements of the starting weight, snout-to-tail length, and shoulder height for each of the ten carcasses, and these are summarised in Table 3.1. These measures were tested for significant differences across seasons, clothing, and concerning both season and clothing (Table 3.2). All carcasses were similar in starting weight, height and length compared across seasons, but a significant difference in median length was observed comparing the clothed and unclothed subsets of the sample. Clothed carcasses were slightly but significantly longer than unclothed carcasses, with a median length of 117 cm compared to 115 cm. However, when compared by both season and clothing, this difference was no longer significant, indicating that, as a sample, no biographic measures are likely to confound further analysis.

Table 3.1: Summary of sample biographic measurements of snout-to-tail length, shoulder height and starting weight.

Season	Clothing	Carcass ID	Length (cm)	Height (cm)	Weight (kg)
Winter	Clothed	C1-18W	114.36	59.37	61.00
		C2-18W	116.66	59.62	60.50
		C1-19W	120.41	59.95	60.50
	Unclothed	UC1-18W	115.11	59.51	60.50
		UC2-18W	114.31	60.39	60.00
Summer	Clothed	C1-19S	117.57	60.50	60.50
		C2-19S	116.92	58.92	61.00
		C1-20S	127.00	59.06	60.00
	Unclothed	UC1-19S	113.67	56.09	61.50
		UC2-19S	115.07	59.45	59.50
	Overall Mean		117.11	59.29	60.50

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; cm = centimetre; kg = kilogram.

Table 3.2: Kruskal-Wallis statistical tests for differences in sample biographic measurements by season (A), by clothing (B), and both season and clothing (C).

A. Sample measurements by season

Measure	Summer (n=5)	Winter (n=5)	Total (n=10)	*H*-statistic (1)	*p*-value
Height (cm)	59.06	59.62	59.48	1.844	0.175
Length (cm)	116.92	115.11	115.89	0.273	0.602
Weight (kg)	60.50	60.50	60.50	0.000	1.000

B. Sample measurements by clothing

Measure	Clothed (n=6)	Unclothed (n=4)	Total (n=10)	*H*-statistic (1)	*p*-value
Height (cm)	59.50	59.48	59.48	0.045	0.831
Length (cm)	117.25	114.69	115.89	4.545	**0.033**
Weight (kg)	60.50	60.25	60.50	0.441	0.507

C. Sample measurements by season and clothing

Season	Measure	Clothed (n=3)	Unclothed (n=2)	*H*-statistic (1)	*p*-value
Winter	Height (cm)	59.62	59.95	0.333	0.564
	Length (cm)	116.66	114.71	1.333	0.248
	Weight (kg)	60.50	60.25	1.667	0.197
Summer	Height (cm)	59.06	57.77	0.333	0.564
	Length (cm)	117.57	114.37	3.000	0.083
	Weight (kg)	60.50	60.50	0.000	1.000

cm = centimetre; kg = kilogram; n = number; *H* = statistic from Kruskal-Wallis test for nonparametric data, with degrees of freedom denoted in parenthesis; significant differences ($p < 0.05$) are denoted by bold type.

3.1.2 Decomposition

Mass loss was used as a measure of decomposition progression. Figure 3.1. provides the mass loss plots for each carcass in each of the four decomposition cycles. A wide range in the rate of mass loss is seen both within the first two multi-carcass deployments and across all four cycles. A brief examination of Figure 3.1 indicates that the time and season of deployment clearly played a role in the variation of decomposition progression as measured by weight loss, but as indicated in the preamble, the effects of different variables on the decomposition process are highlighted in due course.

Although invertebrate activity is a critical component of the decomposition process, and maggot masses were observed feeding on carcasses and contributed substantially to the removal of biomass and reduction in weight, a thorough analysis of insects was beyond the scope of this investigation. The following weight readings are therefore due to the combined effect of all types of biomass breakdown, including both invertebrate and vertebrate activity.

No weight readings were obtained during the final 30 days for each of the first two cycles, as access to the research site was restricted, and decomposition had begun to plateau, with only very gradual change occurring at that time. One final weight reading per carcass was taken after these 30 days, and the missing data values were estimated using linear regression interpolation in RStudio (Version 1.3.1056). Missing readings due to occasional failure or error of the automated system in the final deployment were similarly interpolated. The linear regression coefficients (R^2 values) are provided in Table 3.3, showing a high accuracy for the estimated values.

Table 3.3: Percentage interpolated values and linear regression coefficients for interpolations of missing or unrecorded weight data.

Carcasses			Percentage interpolated values (%)	Linear regression coefficient (R^2)
Winter 2018	Clothed	1	19.29	0.999
		2	19.29	0.999
	Unclothed	1	19.29	0.999
		2	19.29	0.999
Summer 2019	Clothed	1	34.78	0.999
		2	34.78	0.999
	Unclothed	1	34.78	0.999
		2	34.78	1
Winter 2019	Clothed	1	0.00	-
Summer 2020	Clothed	1	7.14	0.997

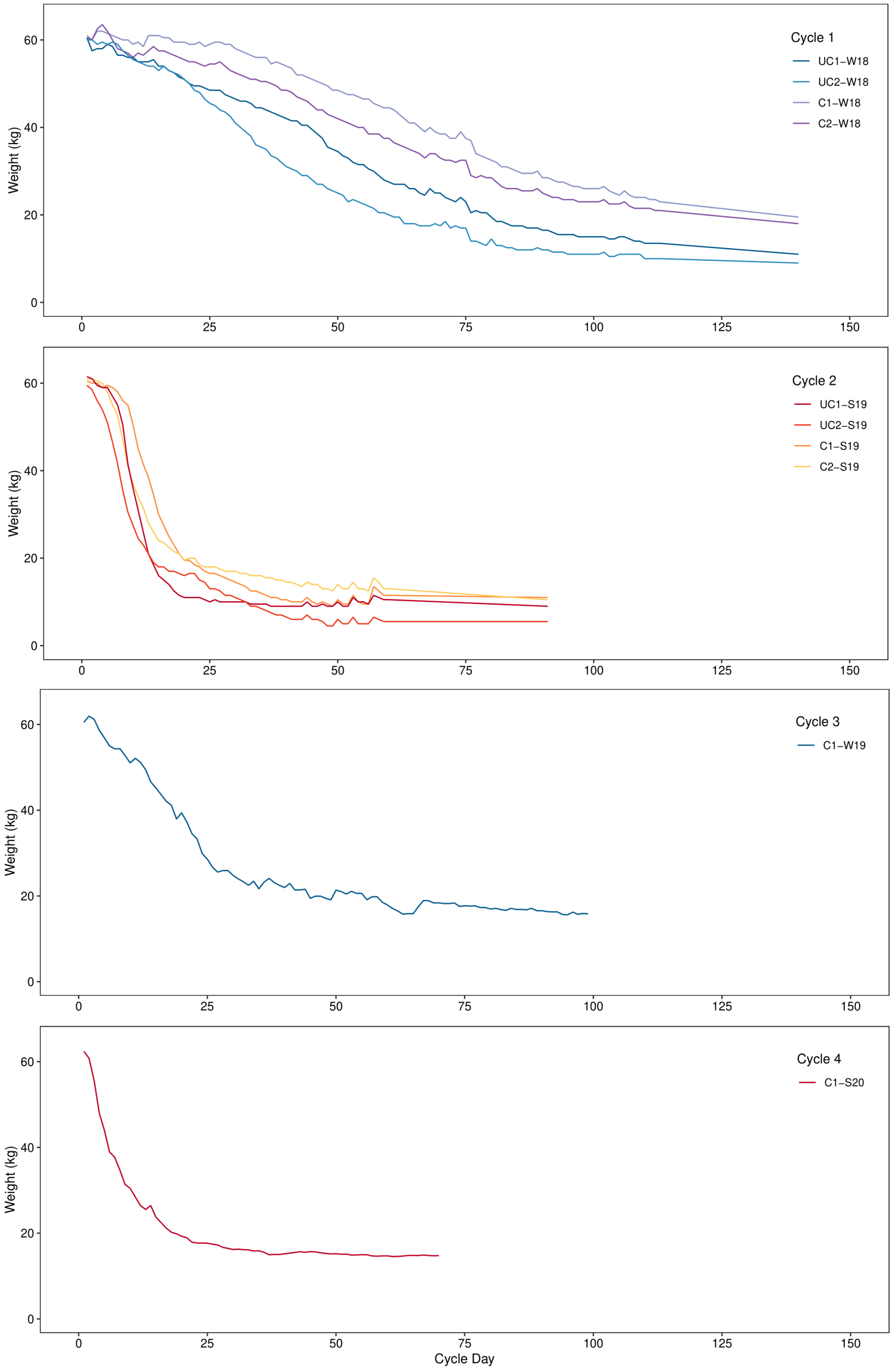

Figure 3.1: Weight loss plots for each carcass in each of the four decomposition cycles.
C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram.

The onset and duration of bloat in the head and neck also exhibited a wide range of values recorded across the ten-carcass sample, influenced by additional variables such as the presence of clothing and seasonality. One particular carcass, UC1-W18, did not exhibit reliable indicators of bloat as it was rapidly scavenged, with substantial tissue removal from the throat continuing down to the abdomen. Therefore, UC1-W18 was excluded from further analysis of bloat. As seen in Table 3.4, the mean number of days required for the onset of bloat across all carcasses was eight days, ranging from two to 19 days. The mean duration of bloat was 13 days, ranging from two to 38 days.

Table 3.4: The start, end, and duration of bloat in the head and neck, measured in days, for each carcass.

Season	Clothing	Carcass ID	Cycle start	Bloat Start (Cycle day)	Bloat End (Cycle day)	Duration (days)
Winter	Clothed	C1-W18	24-08-2018	07-09-2018 (15)	15-10-2018 (53)	38
		C2-W18	24-08-2018	10-09-2018 (18)	12-10-2018 (50)	32
		C1-W19	02-09-2019	06-09-2019 (5)	16-09-2019 (15)	10
	Unclothed	UC1-W18	24-08-2018	-	-	-
		UC2-W18	24-08-2018	11-09-2018 (19)	28-09-2018 (36)	17
Summer	Clothed	C1-S19	14-01-2019	16-01-2019 (3)	23-01-2019 (10)	7
		C2-S19	14-01-2019	17-01-2019 (4)	20-01-2019 (7)	3
		C1-S20	13-01-2020	14-01-2020 (2)	17-01-2020 (4)	2
	Unclothed	UC1-S19	14-01-2019	16-01-2019 (3)	21-01-2019 (8)	5
		UC2-S19	14-01-2019	16-01-2019 (3)	20-01-2019 (7)	4
Overall Mean				8	21	13

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment.

To benchmark the rate of decomposition across different individuals within the sample of 10 carcasses, mass loss milestones were defined: 17%, 34%, 51%, and 68%. These were decided upon as experimental study conditions inhibited decomposition to such an extent that all three clothed, cool-weather winter carcasses did not attain 75% mass loss. Therefore, a more conventional method of sectioning in quartiles was deemed inappropriate, and the highest possible mass loss percentage (68%) met by all individuals within the sample was chosen.

The overall mean time required to reach 68% mass loss across all carcasses was 55 days, shown in Table 3.5, with a broad range from 14 to 140 days. However, individual decomposition cycles lasted considerably longer, on average 109 days, but ranging from 70 days to a total of 140 days in length. At the end of a decomposition cycle, the mean final mass loss was 80%, with a minimum of 68% and a maximum mass loss of 91%. This large degree of variance in cycle duration and final mass loss percentage is similarly seen across both measures of time and accumulated degree days (ADD) to reach each of the stipulated mass loss percentiles. The mean time to reach 17% mass loss for all carcasses was 17 days, ranging from 3 to 46 days. The mean number of days to 34% mass loss was 26, with a range of 6 to 66 days. The mean time to reach 51% mass loss was 34 days, with a range from 9 to 85 days.

Accumulated degree days (ADD) showed similarly high variability across all ten carcasses, also presented in Table 3.5. The mean ADD required to reach 17% mass loss was 252 ADD, ranging from 74 to 639 ADD; the mean to 34% loss was 408 ADD, with a range of 143 to 1035 ADD; the mean to 51% loss was 561 ADD, with a range from 185 to 1376 ADD; and the mean ADD required to reach 68% mass loss across all carcasses was 983 ADD, with a range from 295.38 to 2512 ADD. However, individual decomposition cycles lasted on average 2083 ADD, ranging from 1495 ADD to a total of 2512 ADD.

Table 3.5: Time in days and thermal energy in accumulated degree days (ADD) in parentheses to reach mass loss milestones for each carcass.

Season	Clothing	Carcass ID	17% mass loss	34% mass loss	51% mass loss	68% mass loss	Total	Final Weight %
Winter	Clothed	C1-W18	46 (638.8)	66 (1034.51)	85 (1375.76)	140 (2512.45)	140 (2512.45)	68.03
		C2-W18	37 (476.4)	54 (776.98)	76 (1194.00)	140 (2512.45)	140 (2512.45)	70.25
		C1-W19	13 (203.56)	20 (318.91)	24 (380.12)	45 (740.92)	99 (1738.58)	73.81
	Unclothed	UC1-W18	21 (255.9)	45 (618.29)	58 (851.60)	80 (1278.02)	140 (2512.45)	81.82
		UC2-W18	21 (255.9)	32 (401.68)	43 (576.24)	61 (921.26)	140 (2512.45)	85
Summer	Clothed	C1-S19	10 (204.35)	13 (269.41)	15 (321.06)	20 (440.65)	91 (1886.19)	81.82
		C2-S19	7 (143.47)	9 (185.43)	13 (269.41)	20 (440.65)	91 (1886.19)	82.79
		C1-S20	3 (73.56)	6 (143.59)	10 (226.93)	18 (393.49)	70 (1495.08)	76.61
	Unclothed	UC1-S19	8 (164.46)	9 (185.43)	11 (224.76)	14 (295.38)	91 (1886.19)	85.37
		UC2-S19	5 (106.11)	7 (143.47)	9 (185.43)	14 (295.38)	91 (1886.19)	90.76
Overall Mean			17.1 (252.76)	26.1 (407.77)	34.4 (560.53)	55.2 (983.06)	109.3 (2082.82)	79.62

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; % = percentage.

The data in Table 3.5 is visually presented in the form of bar charts in Figure 3.2, highlighting the variety in the decay rate recorded across the ten carcasses as measured by the number of days and ADD to reach each defined mass loss percentile. Particularly evident in Figure 3.2 is the difference in the total number of days between carcasses deployed in the winter months (W18 or W19) and those deployed in summer months (S19 or S20).

The variability in the measures of bloat and mass loss is a consequence of environmental and experimental conditions accelerating or decelerating the decomposition process; the principal factor is the difference in weather variables associated with seasonality, but additional variables, such as the influence of clothing and carrion biomass availability, are explored further in subsequent chapters.

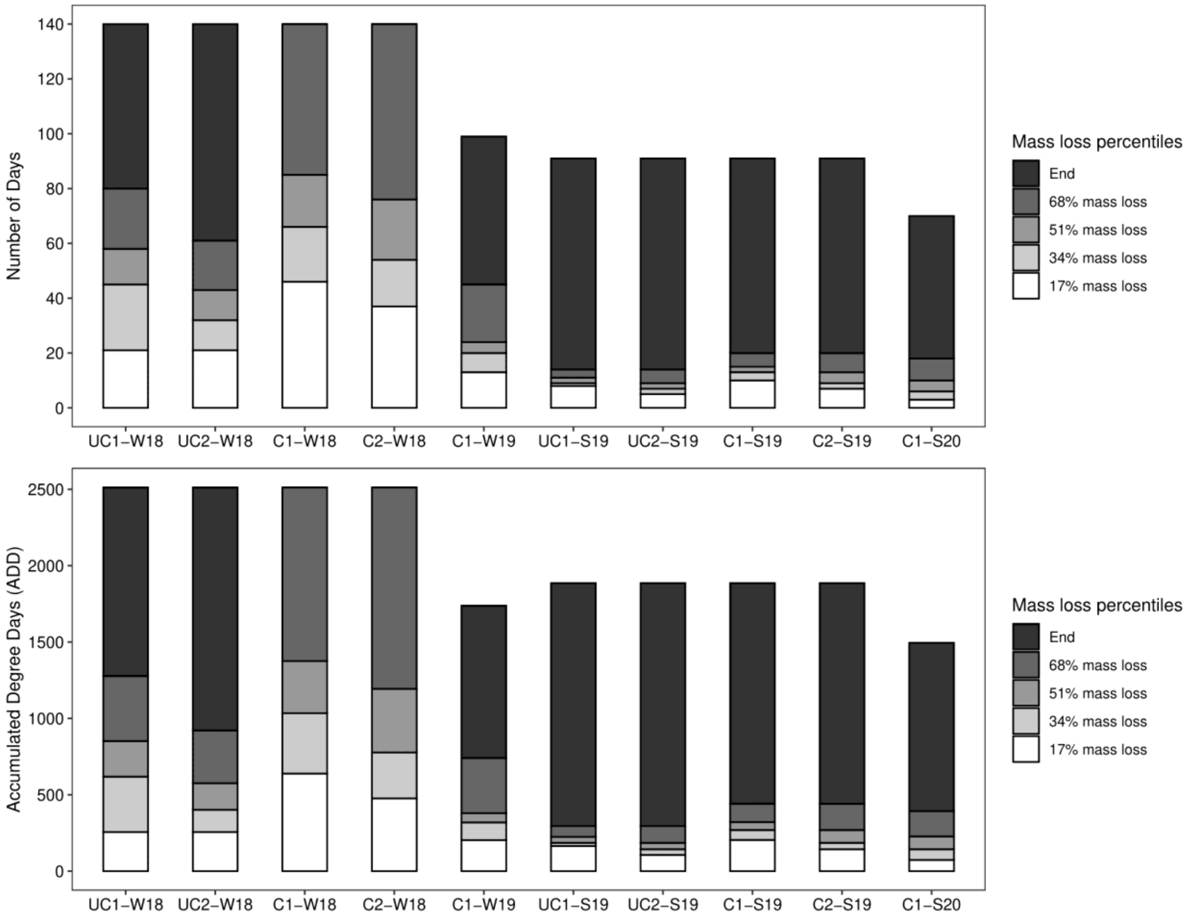

Figure 3.2: Number of days (top panel) and amount of thermal energy in accumulated degree days (bottom panel) to reach mass loss milestones per carcass. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; % = percentage.

3.1.3 Scavenging

Scavenging was observed in all deployments and on all carcasses: the Cape or small grey mongoose (*Galerella pulverulenta*) was the only vertebrate scavenger species observed. Some avian species, such as the Cape robin-chat (*Cossypha caffra*), common starling (*Sturnus vulgaris*), hadeda ibis (*Bostrychia hagedash*), Cape francolin (*Pternistis capensis*), red-eyed dove (*Streptopelia semitorquata*), and southern double-collared sunbird (*Cinnyris chalybeus*) along with an unconfirmed species of field mouse and a domestic cat (*Felis catus*) were observed to visit the carcasses briefly and infrequently. No discernible scavenging activity was attributable to any of these animals, which were presumably simply inquisitive or attracted to the concentrated insect populations. The Cape robin-chat was the most frequent avian species to visit the carcasses and was photographed swooping above the remains to catch flies. Clear video and photographic evidence depict mongooses as the only animal to feed on carcasses.

The average pattern of scavenging by the Cape grey mongoose was initially similar across all carcasses, with activity beginning near the head, on the mouth, nose, eyes, or ears, usually occurring within a few hours on the first day of deployment. Next, scavenging occurred anew, typically near the anal region in the unclothed carcasses or the abdomen for the clothed carcasses, with the clothing retracted up towards the head. Examples of a sequence of scavenging behaviour for clothed and unclothed carcasses in summer and winter are provided in Figures 3.3 – 3.6. The one exception to the unclothed pattern above was Unclothed 1 Winter 2018 (UC1-W18), which was initially also scavenged at the mouth, but then feeding continued down the throat before reaching the abdomen via the sternal area, as opposed to the anal area (photographs of this pattern, along with the other carcasses not shown here, are available in Appendix F).

Most scavenging activity was primarily focused on the unclothed carcasses during the first two multi-carcass deployments. Across all carcasses, typical mongoose feeding behaviour involved stripping out subcutaneous fat and muscle and fresh viscera from beneath the skin, often resulting in tissue being pulled out of the abdominal cavity. Although feeding on the skin itself did occur, it was often left comparatively intact and was either burrowed under or pulled with paws and mouth to widen an opening, often resulting in sections of skin dehydrating and adhering to underlying skeletal tissue. Little scattering of skeletal elements was observed later in the cycles, beyond the immediate vicinity of the carcasses: C1-W19 was the only carcass that was scattered. Specifically, the hoof of the left hindlimb was removed and dragged approximately 7 m to the southeast into denser vegetation. The shoe had been previously removed by mongoose activity, but the hoof remained within the sock.

Figure 3.3: Mongoose scavenging sequence of Unclothed 2 Winter 2018 (UC2-W18) used as an example for unclothed winter carcasses. A) Scavenging activity begins early on day two on the lips, mouth, and nose. B) Feeding begins near the anus on day four. C) Feeding continues on the thighs before the abdominal cavity is opened. D) The abdominal opening is expanded, with mongooses reaching the ribs before feeding on internal organs. E) Feeding continues up the chest, exposing more ribs. F) The inner upper forelimbs are exposed. G) As desiccation sets in, mongooses return to available viscera and fresh abdominal skin and fat contacting the ground. H) Desiccation prevents most mongoose feeding from continuing.

Figure 3.4: Mongoose scavenging sequence of Clothed 1 Winter 2018 (C1-W18) used as an example for clothed winter carcasses. A) Scavenging activity begins on day one around the mouth and nose before the eye is removed. B) Feeding continues at the mouth with some scratching of the abdomen. C) A small opening is made in the abdomen on day four, with the T-shirt and jersey pushed up. D) The abdominal opening is expanded, puncturing the digestive tract. E) Bloating of head and neck begins. F) Limited further feeding on the abdomen. G) Desiccation sets in. H) Desiccation prevents most mongoose feeding from continuing.

Figure 3.5: Mongoose scavenging sequence of Unclothed 2 Summer 2019 (UC2-S19) used as an example for unclothed summer carcasses. A) Scavenging activity begins on day two on the mouth and tongue. B) Feeding begins at the anal region on day three. C) Feeding continues near the pelvis, with bloat beginning on day 5. D) The pelvic opening is expanded, and extensive maggot activity begins near the head. E) Maggot masses extend down forelimbs and chest. F) Scavenging to the abdomen. G) Desiccation sets in. H) Dry, disarticulated bones with some tissue present at the end of the cycle.

Figure 3.6: Mongoose scavenging sequence of Clothed 1 Summer 2019 (C1-S19) used as an example for clothed summer carcasses. A) Mongoose arrives within minutes of deployment, scratching and investigating before moving the T-shirt. B) Bloat evident by day four. C) Abdomen ruptures on day six and feeding begins on the abdomen. D) Maggot masses present at the head, with abdominal opening expanded. E) Maggot masses extend to the abdomen, limiting mongoose scavenging. F) Desiccation of the head begins. G) Desiccation spreads to most of the carcass. H) Dry, disarticulated bones with some tissue present.

Mongoose visits occurred strictly diurnally, with one exception; a short visit was observed in the early morning hours to clothed carcass 1 in the Winter 2019 deployment (C1-W19). This is depicted in Figure 3.7: an intensity map of all mongoose visits across all carcasses with overlapping visits occurring at the same time of day represented in red. The red colour indicates a slight preference to feed in the afternoon/evening rather than the morning and a slight aversion for midday. This figure also shows a clear average pattern of frequent, extended visits clustering near the beginning of a decomposition cycle, from day 1-25, with mongooses maintaining a relatively high visit frequency and length until around day 40 before decreasing substantially in duration. Beyond this point, mongoose visits are incredibly short, often lasting less than the 60 s camera re-arming interval and may decrease in frequency but do not cease entirely. These short mongoose visits continue to occur even up until the termination of a particular cycle, with little to no feeding taking place at this stage. Plots of individual mongoose scavenger data for each carcass are available in Appendix G.

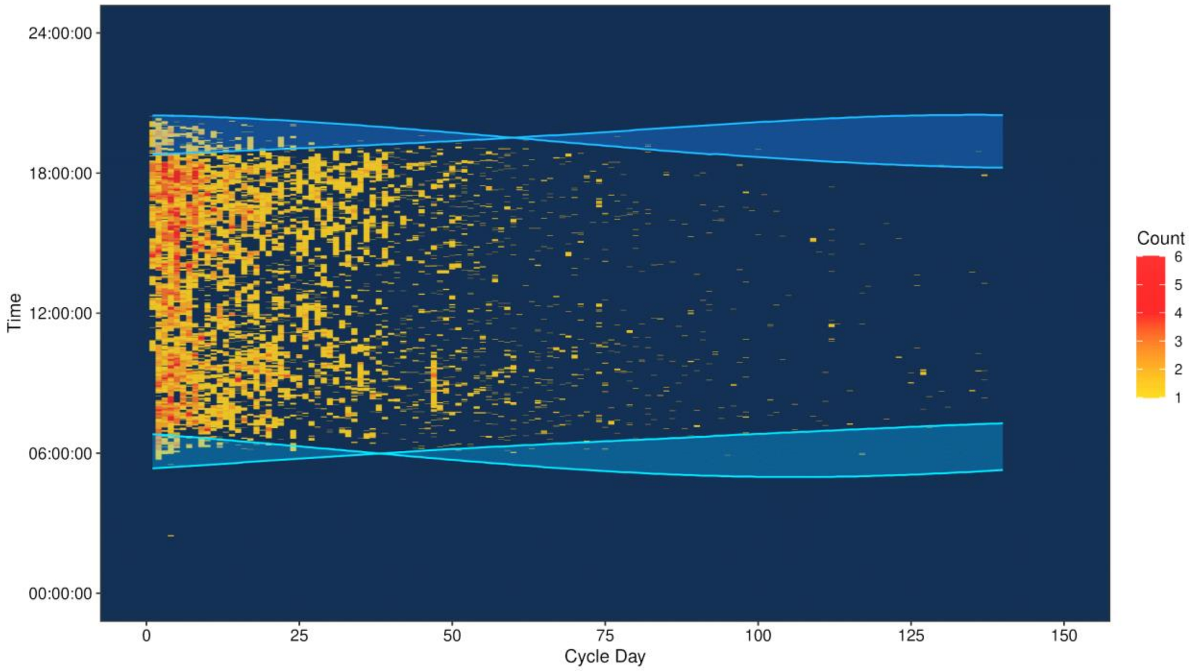

Figure 3.7: Intensity map of all individual scavenger visits to all carcasses, with light blue range polygons representing civil dawn and civil dusk overlayed for both summer and winter. The length of yellow vertical bars indicates the duration of the visit. Red indicates an overlap of multiple visits to individual carcasses occurring at the same time of day. Note: in this graph, the minimum time of a visit has been defined as 1 minute for illustrative purposes.

The average number of mongoose visits across all carcasses was 388, with a wide range from 114 to 797, as shown in Table 3.6. The mean total duration of visits was 36 hours, with a similarly broad range from 4 to 97 hours. Based on the number and duration of total mongoose visits, a pattern of preferred scavenging on unclothed carcasses appears, which is investigated in more detail in section 3.3.4 of this chapter. Another observable pattern is for mongooses to preferentially feed on unclothed carcasses located in the northeast of the research site within each season, specifically UC2-W18 and UC2-S19.

The high variability in mongoose visit number and duration is also present in the data recorded for each mass loss percentile, reported in Table 3.7, with most activity associated with the first 17% mass loss. The mean number of visits before 17% mass loss was 141, with a range from 46 to 271; mean visits to reach 34% mass loss were 67, ranging from 2 to 165; mean visits to 51% mass loss were 44, ranging from 3 to 142; and mean visit number to reach 68% mass loss was 49 with a range from 2 to 138. Mongoose visit duration was similarly varied: the mean duration of time spent on and around carcasses before 17% mass loss was 20 hours, ranging from 3 hours up to 43 hours. The mean visit duration to reach 34% mass loss was 6 hours ranging from 1 min to 33 hours; to reach 51% mass loss was 3 hours, ranging from 10 min to 22 hours; and the mean duration to reach 68% mass loss was 2 hours, with a range from 1 min to 14 hours.

Table 3.6: Total scavenging visit number and duration for each carcass.

Season	Clothing	Carcass ID	Total visit number	Total visit duration (h:m:s)	Multi-mongoose duration (h:m:s)	% Multi-mongoose
Winter	Clothed	C1-W18	299	15:17:10	00:13:38	1
		C2-W18	403	29:31:58	00:01:07	<1
		C1-W19	391	60:15:13	01:31:56	3
	Unclothed	UC1-W18	446	41:43:37	00:42:16	2
		UC2-W18	797	97:41:41	02:53:48	3
Summer	Clothed	C1-S19	274	17:55:21	00:37:54	4
		C2-S19	302	16:03:43	02:32:24	16
		C1-S20	377	46:36:04	10:20:01	22
	Unclothed	UC1-S19	114	03:53:38	00:14:47	6
		UC2-S19	474	33:23:36	08:01:15	24
Overall Mean			388	36:14:12	02:42:55	8

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; h:m:s = hours: minutes: seconds; ID = identity; % = percentage.

Table 3.7: Visit number and duration (h:m:s) in parentheses for each carcass, by mass loss percentile.

Season	Clothing	Carcass ID	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End
Winter	Clothed	C1-W18	181 (13:54:43)	60 (0:49:21)	30 (0:17:02)	28 (0:16:04)	0 (0:00:00)
		C2-W18	190 (25:11:18)	107 (3:19:16)	66 (0:51:49)	40 (0:09:35)	0 (0:00:00)
		C1-W19	159 (43:35:44)	98 (12:32:11)	24 (1:01:21)	46 (1:57:12)	64 (1:08:45)
	Unclothed	UC1-W18	202 (36:44:28)	128 (2:56:45)	58 (1:26:38)	40 (0:17:51)	18 (0:17:55)
		UC2-W18	271 (37:03:23)	165 (32:51:56)	142 (21:57:37)	109 (4:26:47)	110 (1:21:58)
Summer	Clothed	C1-S19	103 (10:15:28)	15 (1:20:35)	13 (1:19:36)	20 (0:44:53)	123 (4:14:49)
		C2-S19	94 (9:20:26)	32 (2:38:48)	24 (1:26:58)	17 (0:24:06)	135 (2:13:25)
		C1-S20	46 (11:37:27)	29 (9:02:52)	53 (5:36:01)	138 (13:52:29)	111 (6:27:15)
	Unclothed	UC1-S19	71 (3:25:56)	2 (0:01:39)	3 (0:10:40)	2 (0:01:24)	36 (0:13:59)
		UC2-S19	88 (14:02:27)	32 (2:39:13)	30 (2:09:15)	48 (3:28:38)	276 (11:04:03)
	Overall Mean		141 (20:31:08)	67 (6:49:16)	44 (3:37:42)	49 (2:33:54)	87 (2:42:13)

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; h:m:s = hours: minutes: seconds; ID = identity; % = percentage.

Most scavenger visits were of a single mongoose, but photographs were captured of up to four mongooses feeding simultaneously on and around one carcass. Simultaneous visits by multiple mongooses occurred on average 8% of all scavenger hours ranging from <1% to 24%, with a mean total duration of 3 hours and a range from 1 minute to 10 hours, as shown in Table 3.6. Further data on multi-mongoose visits for each mass loss milestone are available in Table 3.8. The mean duration of simultaneous visits for the first 17% mass loss period was 1 hour (10%), ranging from 1 min (<1%) to 5 hours (34%); mean duration to 34% loss was 26 min (7%), ranging from 0 (0%) to 2 hours (18%); mean duration to 51% loss was 18 min (10%), ranging from 0 (0%) to 2 hours (30%); and mean duration to 68% mass loss was 21 min (6%) with a range from 0 (0%) to 3 hours (19%).

Table 3.8: Multi-visit duration (h:m:s) and percentage in parentheses, by mass loss percentile.

Season	Clothing	Carcass ID	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End
Winter	Clothed	C1-W18	0:01:02 (<1%)	0:00:00 (0%)	0:05:47 (34%)	0:00:00 (0%)	0:00:00 (0%)
		C2-W18	0:01:07 (<1%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)
		C1-W19	1:21:25 (3%)	0:07:42 (1%)	0:00:00 (0%)	0:00:00 (0%)	0:02:49 (4%)
	Unclothed	UC1-W18	0:42:14 (2%)	0:00:01 (<1%)	0:00:00 (0%)	0:00:01 (<1%)	0:00:00 (0%)
		UC2-W18	0:56:58 (3%)	1:15:19 (4%)	0:41:30 (3%)	0:00:00 (0%)	0:00:01 (<1%)
Summer	Clothed	C1-S19	0:33:43 (5%)	0:00:00 (0%)	0:02:56 (4%)	0:01:15 (3%)	0:00:00 (0%)
		C2-S19	1:28:01 (16%)	0:34:09 (22%)	0:05:02 (6%)	0:03:56 (16%)	0:21:16 (16%)
		C1-S20	3:11:01 (27%)	1:38:37 (18%)	1:39:20 (30%)	2:41:27 (19%)	1:09:36 (18%)
	Unclothed	UC1-S19	0:14:47 (7%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)
		UC2-S19	4:44:05 (34%)	0:46:58 (30%)	0:30:33 (24%)	0:49:06 (24%)	1:10:33 (11%)
	Overall Mean		1:19:26 (10%)	0:26:17 (7%)	0:18:31 (10%)	0:21:35 (6%)	0:16:25 (5%)

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; h:m:s = hours: minutes: seconds; ID = identity; % = percentage.

Graphical bar chart representations of mongoose visit number and duration associated with each carcass are provided in Figure 3.8. Most mongoose visits and those of the longest duration were clustered in the first 17% mass loss period, but some variation was observed. The second unclothed carcass from the second cycle, in winter 2018 (UC2-W18), experienced the greatest number and duration of visits. The fewest mongoose visits and the shortest duration were recorded by Unclothed 2 Summer 2019 from cycle 3 (UC1-S19). To control for the longer duration of specific deployments, allowing more time for recordings of mongoose activity to accumulate, Figure 3.9 depicts the proportion of overall visit number and duration per mass loss milestone instead of the absolute value. This figure confirms that most mongoose visits occur in the initial stages of decomposition, along with the vast majority of scavenging time, regardless of cycle length. Certain individual carcasses, such as UC2-W18, UC2-S19, and C1-S20, experienced more equally distributed mongoose visits and visit duration across the mass loss percentiles.

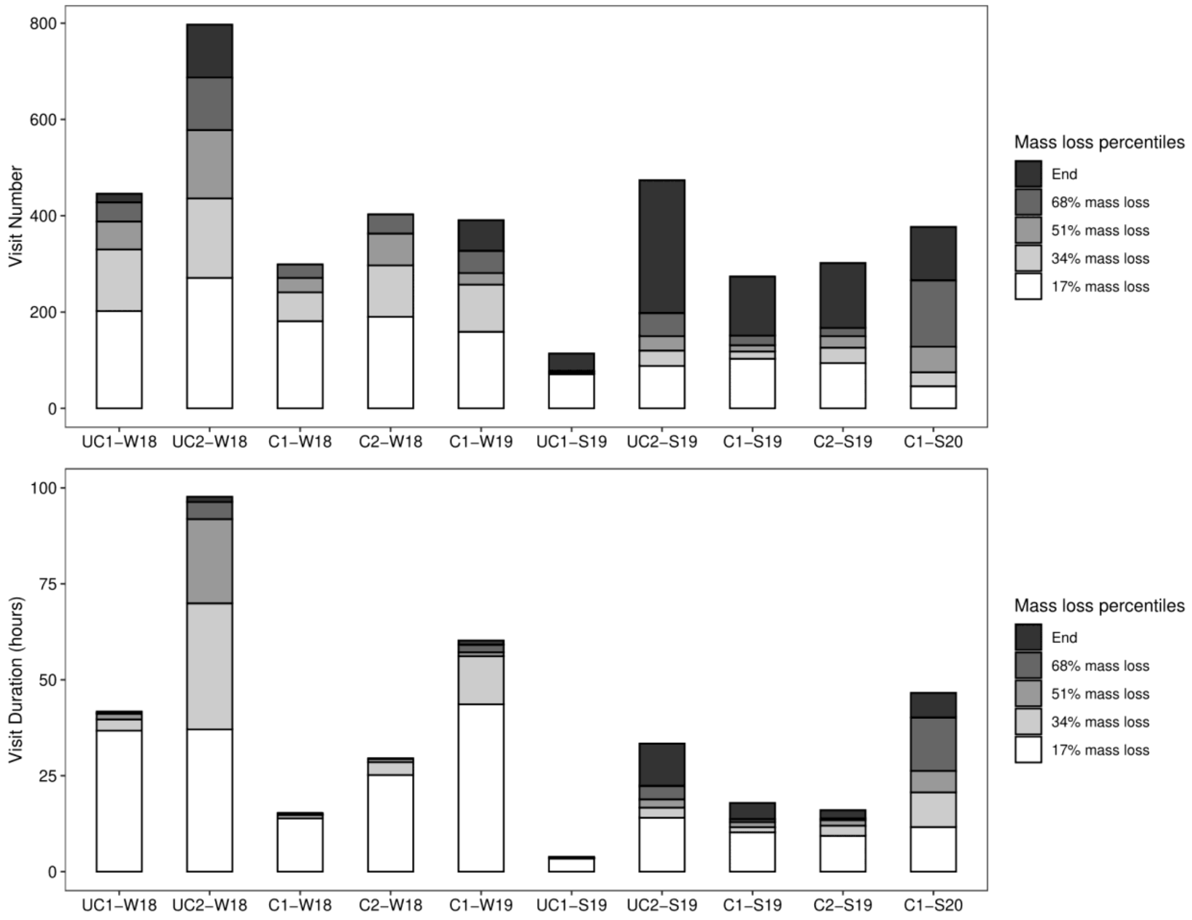

Figure 3.8: Bar chart of mongoose visit number (top panel) and visit duration (bottom panel) per mass loss percentile for each carcass. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; % = percentage..

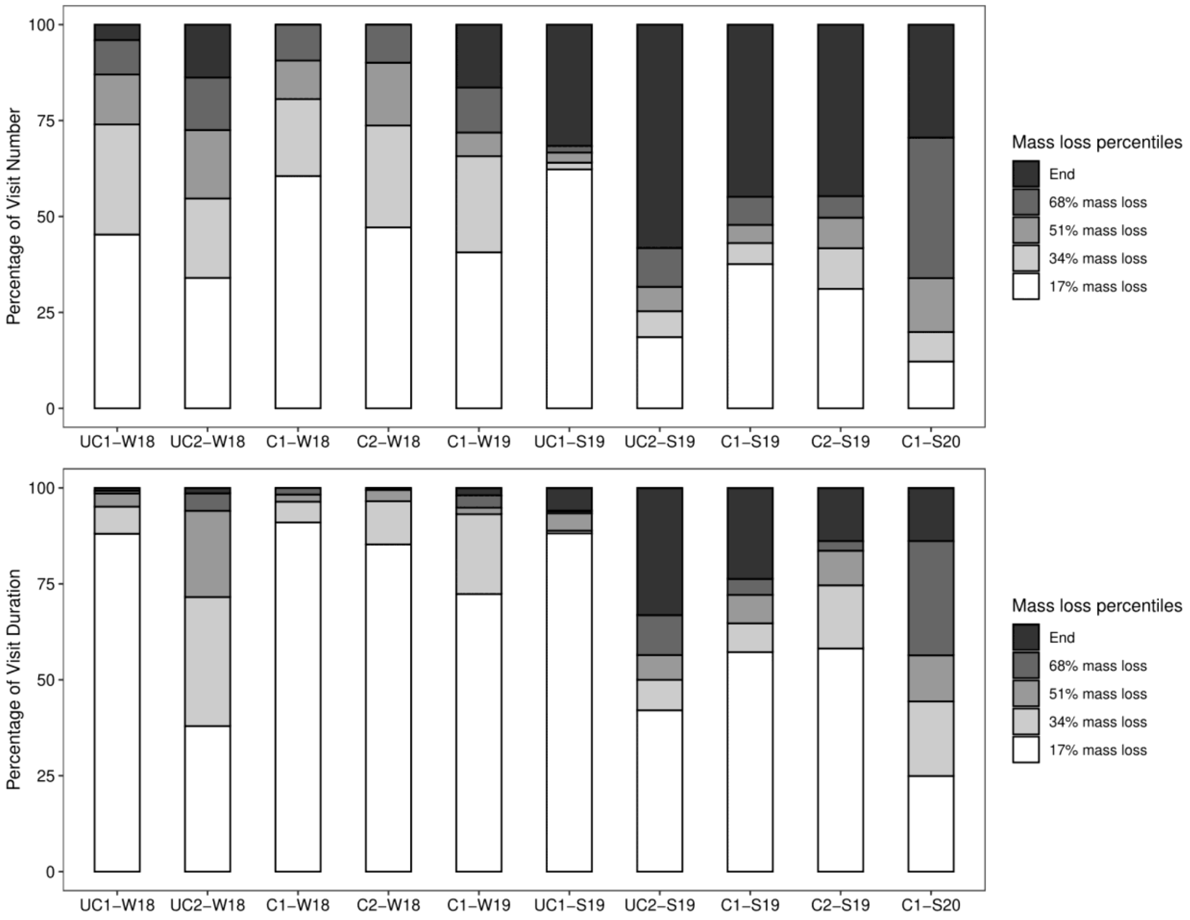

Figure 3.9: Bar chart of the percentage of mongoose visit number (top panel) and visit duration (bottom panel) per mass loss percentile for each carcass. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; % = percentage.

3.1.4 Summary

Ten near-uniformly sized carcasses were examined in this study to assess decomposition rate and scavenging activity in both summer and winter settings for clothed and unclothed cohorts. The decomposition rate was highly variable across the different experimental conditions, as measured by the onset and duration of bloat, weight loss over time, number of days, and the amount of thermal energy in accumulated degree days to reach defined mass loss milestones. Scavenging activity by the only observed scavenger, the Cape grey mongoose, followed some common patterns in terms of a sequence of feeding behaviour, starting with the mouth, nose, ears, and eyes, before beginning to feed near the anus if unclothed, or the abdomen if clothed, after displacing the T-shirt, and jersey during winter. The number and duration of mongoose visits were also highly variable across the study sample. This variability in decay rate and mongoose activity is investigated in the subsequent sections of this results chapter, starting with the influence of clothing.

3.2 The effect of clothing

Before the results on clothed and unclothed decomposition are compared, data gathered from a retrospective analysis of local forensic case files are presented to identify the common clothing types used to define the clothing utilised in this study. This is followed by a comparison of the unclothed carcasses used in this study and those examined by Finaughty (2019) to validate the unclothed decay rate. The effect of clothing on mass loss and mongoose scavenging activity is then presented before the key findings are summarised. A portion of these data, focusing on clothing's impact during winter, has been published in *Forensic Science International* (Spies et al., 2020a) and was accepted for presentation at the *American Association of Biological Anthropologists* conference in 2020 (Spies et al., 2020b) (see appendix B).

3.2.1 Clothing in casework: creating an appropriate clothing model

Casework and field research have shown that clothing may influence the rate and process of decomposition in several ways, depending on environmental factors. Retrospective studies have also indicated that most forensic cases in an international context involve clothing of some type. To investigate the local effect of clothing, a thorough analysis was performed on how frequently clothing is associated with remains in local forensic cases, along with an assessment of the types of clothing most often observed.

Initial anecdotal discussions with senior forensic anthropologists from the local service provider, Forensic Anthropology Cape Town (FACT), suggested that clothing was common in forensic anthropology cases, and cotton T-shirts, hooded sweatshirts, and denim jeans were observed most frequently. A retrospective analysis of 222 files from cases conducted by FACT between 1990 and 2018 revealed 89 cases (40% of all cases) that recorded the presence of clothing; 94 (42%) recorded no information regarding clothing, and 39 (18%) recorded no clothing, 10 (5%) of which were classified as archaeological remains (Figure 3.10). Other cases without information on the presence of clothing consisted of only animal bones or fragments of human bones. FACT members only analysed other cases after initial examinations were already conducted by the FPS, and therefore, artefacts such as clothing may not have been observed or recorded in such cases. When the case files without information regarding the presence of clothing were excluded from analysis, the percentage of cases with clothed remains increased to 70%.

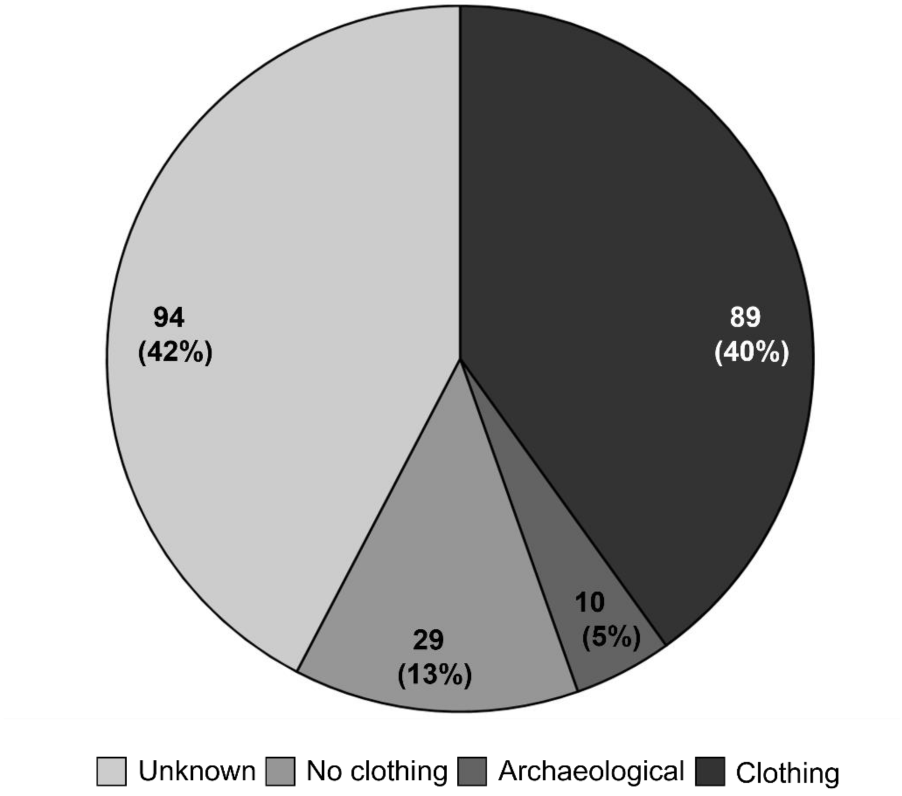

Figure 3.10: Presence of clothing reported in 222 forensic cases conducted by Forensic Anthropology Cape Town from 1990 to 2018. % = percentage.

Photographs of clothing from cases were limited, and although fibre types were infrequently recorded in case files, these were reasonably estimated from descriptions of the clothes worn. There were 35 recorded instances of the terms “T-shirt” or “shirt”, sometimes accompanied by “cotton”, and 21 recorded instances of “jeans” or “denim”, along with other instances of “chino” or “tweed”. These clothing types can be assumed to be predominantly made of cotton, although synthetic mixtures are possible. Additional documented items of clothing may be made of either natural, synthetic or a blend of fibre types, such as with the generic terms “jersey”, “top”, or “fleecy hooded jacket”. Certain case files lacked detail concerning the types of clothes observed, and 22 cases had no information other than documenting that clothing was present.

The generated clothing sets were designed to be consistent with typical clothing worn in either warmer or cooler weather conditions to account for the different seasons under investigation. As described in section 2.3.2 of the Materials and Methods, “winter clothing” was defined as underwear (men’s briefs), denim jeans with a leather belt, a cotton T-shirt, jersey, socks, and shoes. The “summer clothing” set was similarly composed of underwear, denim jeans with a leather belt, and a cotton T-shirt.

The sets of clothing used for the study were assembled based on the gathered information and from cost-effective and available items at a nationwide affordable clothing retailer, Pep Stores, chosen based on its widespread accessibility, popularity, and affordability. These clothing sets were designed to represent a realistic mixture of both fibre and clothing types that one may encounter in typical clothing found in local forensic anthropology cases. Some alterations were required to ensure the clothing fit the pigs appropriately, with a plan developed in consultation with a seamstress. Details have been provided under section 2.3.2 in the Materials and Methods chapter.

3.2.2 The effect of clothing on decomposition

To assess the effect of clothing on decomposition rate, a validation of how unclothed carcasses decompose was required. To do this, data from the four unclothed carcasses used in this study are compared with data collected by Finaughty (2019) during two summer and two winter deployments of two unclothed carcasses each between 2014-2016, conducted in the same environment. However, an important caveat to the following comparisons of decomposition rate, is that Finaughty’s unclothed carcasses and those used in the current study experienced some significant differences in several average weather variables, which are known to influence the decomposition process and may account for some of the variation observed between the two studies. These differences in weather variables are examined in more detail in section 3.3.

The differences in the mean rate of weight loss over time between the two sets of unclothed carcasses (Spies and Finaughty) are represented graphically as line charts in Figure 3.11. This figure illustrates the similarities among the unclothed carcasses examined in this study and those used by Finaughty and their combined distinction from the clothed carcasses. However, the unclothed carcasses show greater visual similarity in winter than in summer. In winter, the figure shows a noticeable separation between the weight loss curves for both unclothed groups, which follow a similar trajectory, and that of the clothed group. In summer, Finaughty's carcasses experienced weight loss at a rate somewhere in between that of the clothed and unclothed carcasses investigated in this study: starting rapidly like the other unclothed carcasses, slowing down slightly, before accelerating again and losing more total weight, plateauing at a level similar to the unclothed carcasses from the current study.

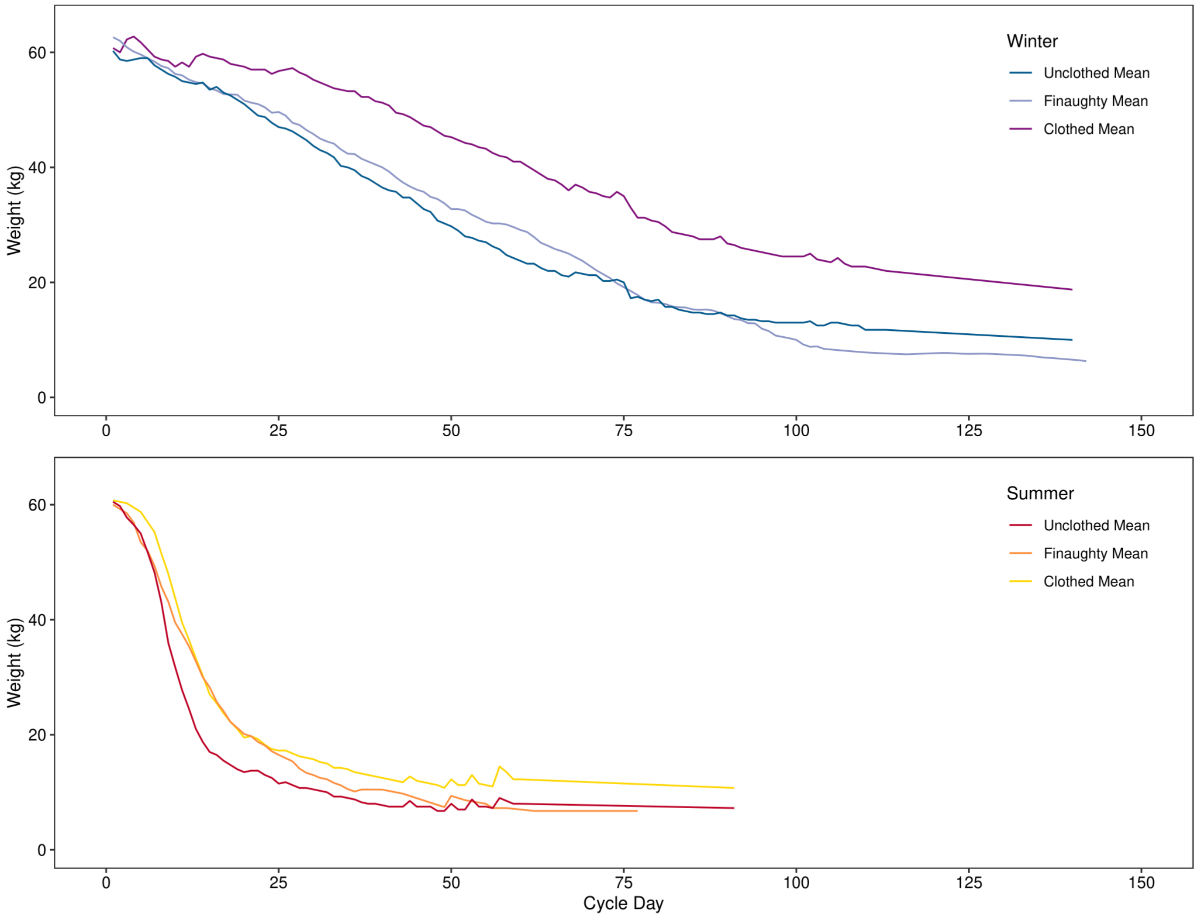

Figure 3.11: Weight loss plotted over time for clothed and unclothed carcasses, as well as unclothed carcasses examined by Finaughty (2019), in winter (top panel) and summer (bottom panel). kg = kilogram.

The overall mean number of days for all unclothed carcasses to reach 17% mass loss was 14 for both sets of unclothed carcasses; 23 days versus 25 for Finaughty to reach 34% loss; 30 days versus 36 to reach 51% loss; and 42 days compared to 50 days for Finaughty to reach 68% mass loss, as shown in Table 3.9. The same table also depicts similar patterns for the total unclothed mean ADD values to reach each mass loss percentile. Mean ADD to lose 17% mass was 195.60 compared to 201 ADD for Finaughty; ADD to reach 34% mass loss was 337 versus 357; 460 ADD versus 522 to reach 51% loss; and ADD of 698 on average compared to 774 for Finaughty required to reach 68% mass loss.

When analysed by season, the unclothed winter carcasses took on average 21 days to reach 17% mass loss compared to Finaughty's 20; 39 days versus 38 to reach 34% mass loss; 51 days versus 57 to reach 51% mass loss; and 71 days compared to Finaughty's mean of 75 days to reach 68% mass loss. The differences were similarly slight for the ADD values in winter: the mean ADD to 17% mass loss was 256 compared to 225 ADD for Finaughty; 510 versus 453 ADD to reach 34% loss; 714 versus 719 ADD to reach 51% loss; and a mean of 1100 ADD compared to Finaughty's 988 ADD to reach 68% mass loss.

In summer, the unclothed carcasses examined for this study took slightly, but consistently less time to reach all weight loss milestones compared to Finaughty's unclothed carcasses: 7 days on average compared to 8 to lose 17% of their mass; 8 days versus 11 to reach 34% mass loss; 10 days versus 14 to reach 51% loss; and 14 days compared to a mean of 25 days for Finaughty to reach 68% mass loss. The mean ADD values to reach mass loss milestones for summer unclothed carcasses were also consistently lower than experienced by Finaughty's unclothed carcasses. To reach 17% mass loss, the summer carcasses required on average 135 ADD compared to Finaughty's 177; 164 versus 261 ADD to reach 34% mass loss; 205 versus 324 ADD to reach 51% mass loss; and 295 ADD compared to a mean of 560 for Finaughty's carcasses to reach 68% mass loss.

Despite some differences, particularly prominent in summer, on aggregate, there were relatively low levels of variation between the current unclothed carcasses and those studied by Finaughty in 2014-2016. Based on the available graphical and numerical data, and in the absence of any viable statistical method to test these differences due to the small sample size, the presented differences may be reasonably attributed to normal variation in the decomposition rate due to the differences in recorded weather variables, presented in section 3.3. This indicates the unclothed carcasses in the current investigation decomposed with sufficient consistency to previous studies in the area for them to be a fair base of comparison to the clothed carcasses used in this study.

Table 3.9: The minimum, maximum, and mean number of days and accumulated degree days (ADD) in parentheses to reach mass loss percentiles for clothed and unclothed carcasses by season, along with unclothed means of data collected by Finaughty (2019) for comparison. Differences between Finaughty's unclothed carcasses and those from this dataset are heat-mapped by row to indicate intensities, with darker colours representing an increase.

Carcass	Season	Measure	17% mass loss	34% mass loss	51% mass loss	68% mass loss	Total	% Weight loss
Clothed	Winter	Max	46 (638.80)	66 (1034.51)	85 (1375.76)	140 (2512.45)	140 (2512.45)	73.81
		Mean	32 (439.59)	47 (710.13)	62 (983.29)	108 (1921.94)	126 (2254.49)	70.70
		Min	13 (203.56)	20 (318.91)	24 (380.12)	45 (740.92)	99 (1738.58)	68.03
	Summer	Max	10 (204.35)	13 (269.41)	15 (321.06)	20 (440.65)	91 (1886.19)	82.79
		Mean	7 (140.46)	9 (199.48)	13 (272.47)	19 (424.93)	84 (1755.82)	80.40
		Min	3 (73.56)	6 (143.59)	10 (226.93)	18 (393.49)	70 (1495.08)	76.61
	Overall	Max	46 (638.80)	66 (1034.51)	85 (1375.76)	140 (2512.45)	140 (2512.45)	82.79
		Mean	19 (290.02)	28 (454.81)	37 (627.88)	64 (1173.43)	105 (2005.16)	75.55
		Min	3 (73.56)	6 (143.59)	10 (226.93)	18 (393.49)	70 (1495.08)	68.03
Unclothed	Winter	Max	21 (255.90)	45 (618.29)	58 (851.60)	80 (1278.02)	140 (2512.45)	85.00
		Mean	21 (255.90)	39 (509.99)	51 (713.92)	71 (1099.64)	140 (2512.16)	83.41
		Finaughty Mean	20 (224.87)	38 (453.41)	57 (719.09)	75 (988.49)	142 (2140.10)	90.02
		Min	21 (255.90)	32 (401.68)	43 (576.24)	61 (921.26)	140 (2512.45)	81.82
	Summer	Max	8 (164.46)	9 (185.43)	11 (224.76)	14 (295.38)	91 (1886.19)	90.76
		Mean	7 (135.29)	8 (164.45)	10 (205.10)	14 (295.38)	91 (1886.19)	88.06
		Finaughty Mean	8 (177.09)	11 (261.17)	14 (324.38)	25 (559.61)	54 (1176.30)	83.80
		Min	5 (106.11)	7 (143.47)	9 (185.43)	14 (295.38)	91 (1886.190	85.37
	Overall	Max	21 (255.90)	45 (618.29)	58 (851.60)	80 (1278.02)	140 (2512.45)	90.76
		Mean	14 (195.60)	23 (337.22)	30 (459.51)	42 (697.51)	116 (2199.32)	85.74
		Finaughty Mean	14 (200.98)	25 (357.29)	36 (521.74)	50 (774.05)	98 (1658.20)	86.91
		Min	5 (106.11)	7 (143.47)	9 (185.43)	14 (295.38)	91 (1886.19)	81.82
Overall		Max	46 (638.80)	66 (1034.51)	85 (1375.76)	140 (2512.45)	140 (2512.45)	90.76
		Mean	17 (252.25)	26 (407.77)	34 (560.53)	55 (983.06)	109 (2082.82)	79.62
		Min	3 (73.56)	6 (143.47)	9 (185.43)	14 (295.38)	70 (1495.08)	68.03

% = percentage.

Since the unclothed carcasses decayed at a rate fairly comparable to those studied by Finaughty (2019), further comparisons and analyses mentioning unclothed carcasses will refer exclusively to those deployed for this study and not Finaughty's carcasses, unless otherwise indicated. In general, the clothed carcasses experienced more variation than the unclothed carcasses in both the number of days and amount of thermal energy required to reach mass loss milestones, as indicated by the minimum and maximum values shown in Table 3.9.

Clothed carcasses had a slower rate of weight loss and lost notably less weight in total when compared to unclothed carcasses. A mean final weight loss value of 76% for the clothed carcasses with a range from 68% to 83%, compared to a mean of 86% for the unclothed group, ranging from 82% to 91%, as listed in Table 3.9. The same table also provides additional information on the length in days of each cycle and the associated ADD values. Along with losing less weight overall, the clothed cohort took longer on average than the unclothed carcasses to reach each mass loss milestone, as depicted in Table 3.9. The mean number of days to lose 17% mass of the clothed carcasses was 19 compared to 14 days for the unclothed group; 28 days versus 25 days to reach 34% mass loss; 37 days versus 36 days to reach 51% mass loss; and 64 days compared to a 42 day mean for the unclothed carcasses to reach 68% mass loss. Similarly, the clothed carcasses required more thermal energy to reach the same milestones than unclothed carcasses. The mean ADD to 17% mass loss for the clothed cohort was 290 compared to 196 for the unclothed; 455 ADD versus 337 to reach 34% mass loss; 628 versus 460 ADD to reach 51% mass loss; and 1173 ADD to lose 68% mass compared to a mean of 698 ADD for the unclothed group.

Clothing also affected the onset and duration of bloat in the head and neck; data are provided in Table 3.10. Although both clothed and unclothed carcasses began to bloat on day eight on average (with similar ranges from day two or three to day 19), clothed carcasses experienced a slightly longer bloat period, lasting 15 days on average compared to a mean of nine days for the unclothed group. However, there was considerable overlap for the range of each group; the clothed cohort had a bloat duration range of two to 38 days, whilst the range for the unclothed group was four to 17 days.

Table 3.10: The minimum, maximum, and mean start, end, and duration of bloat in the head and neck, measured in days, for clothed and unclothed carcasses.

Clothing	Season	Measure	Start Day	End Day	Duration
Clothed	Winter	Max	18	53	38
		Mean	13	39	27
		Min	5	15	10
	Summer	Max	4	10	7
		Mean	3	7	4
		Min	2	4	2
	Overall	Max	19	53	38
		Mean	8	23	15
		Min	2	4	2
Unclothed	Winter	Max	19	36	17
		Mean	19	36	17
		Min	19	36	17
	Summer	Max	3	8	5
		Mean	3	8	5
		Min	3	7	4
	Overall	Max	19	36	17
		Mean	8	17	9
		Min	3	7	4

When assessing the influence of clothing within each season, in winter, clothed carcasses took consistently longer to decompose than unclothed carcasses, as shown in Table 3.9. Clothed winter carcasses required on average 32 days to reach 17% mass loss compared to 21 days for the unclothed winter carcasses; 47 versus 39 days to reach 34% mass loss; 62 versus 51 days to reach 51% mass loss; and 108 days compared to a mean of 71 to reach 68% mass loss for the unclothed winter group. The mean ADD required to reach mass loss milestones was similarly greater for clothed than unclothed carcasses in winter. Clothed winter carcasses required on average 440 ADD to reach 17% mass loss, compared to 256 ADD for unclothed winter carcasses; 710 versus 510 ADD to reach 34% mass loss; 983 versus 714 ADD to reach 54% mass loss; and 1922 ADD compared to a mean of 1100 to reach 68% mass loss for unclothed winter carcasses. Clothed winter carcasses began to bloat on day 13 on average, ranging from five to 18 days, compared to day 19 for the remaining unclothed winter carcass that showed evidence of bloat, as presented in Table 3.10. However, the clothed cohort experienced a longer bloat duration of 27 days on average, ranging from 10 to 38 days, compared to 17 days for the unclothed winter carcass.

In summer, Table 3.9 shows that although clothed carcasses took longer to reach mass loss milestones on average, the difference was slight, especially when rounding to the nearest whole day. On average, the clothed summer group required 7 days to reach 17% mass loss, with the unclothed summer needing the same; 9 days versus 8 days to reach 34% mass loss; 13 versus 10 days to reach 51% mass loss; and 19 days compared to a mean of 14 days for the unclothed summer cohort to lose 68% of their mass. Clothed carcasses also required greater ADD on average to reach milestones in summer, but as with the difference in days, this difference was also slight. Mean ADD required to reach 17% mass loss was 140 for clothed summer carcasses, compared to 135 ADD for unclothed summer carcasses; 199 versus 164 ADD to reach 34% mass loss; 272 versus 205 ADD to reach 51% mass loss; and 425 ADD compared to 295 ADD on average for unclothed carcasses to lose 68% of their mass. Table 3.10 indicates that both clothed and unclothed groups in summer experienced similar bloating periods. The clothed summer carcasses first showed evidence of bloat on day three on average, ranging from day two to four, whereas unclothed summer carcasses all began bloating on day three. Similarly, summer clothed bloat lasted four days on average, ranging from two to seven days, whilst the unclothed group lasted five days on average, ranging from four to five days.

Although the sample of a total of four unclothed carcasses is too small to test for significant differences in decay rate, the bar charts in Figure 3.12 provide a good visual aid and clearly depict how clothed carcasses require more time and thermal energy on average in the decomposition process. This is especially evident when analysing total time and ADD to reach 68% mass loss, and most prominent when comparing clothed and unclothed carcasses in winter. The bar charts for clothed carcasses show mass loss milestones that are more distributed through time on average, although this is less prominent in the summer cohort. Mongoose scavenging activity plays a substantial role in the decomposition process in this environment; how it is influenced by clothing is assessed next.

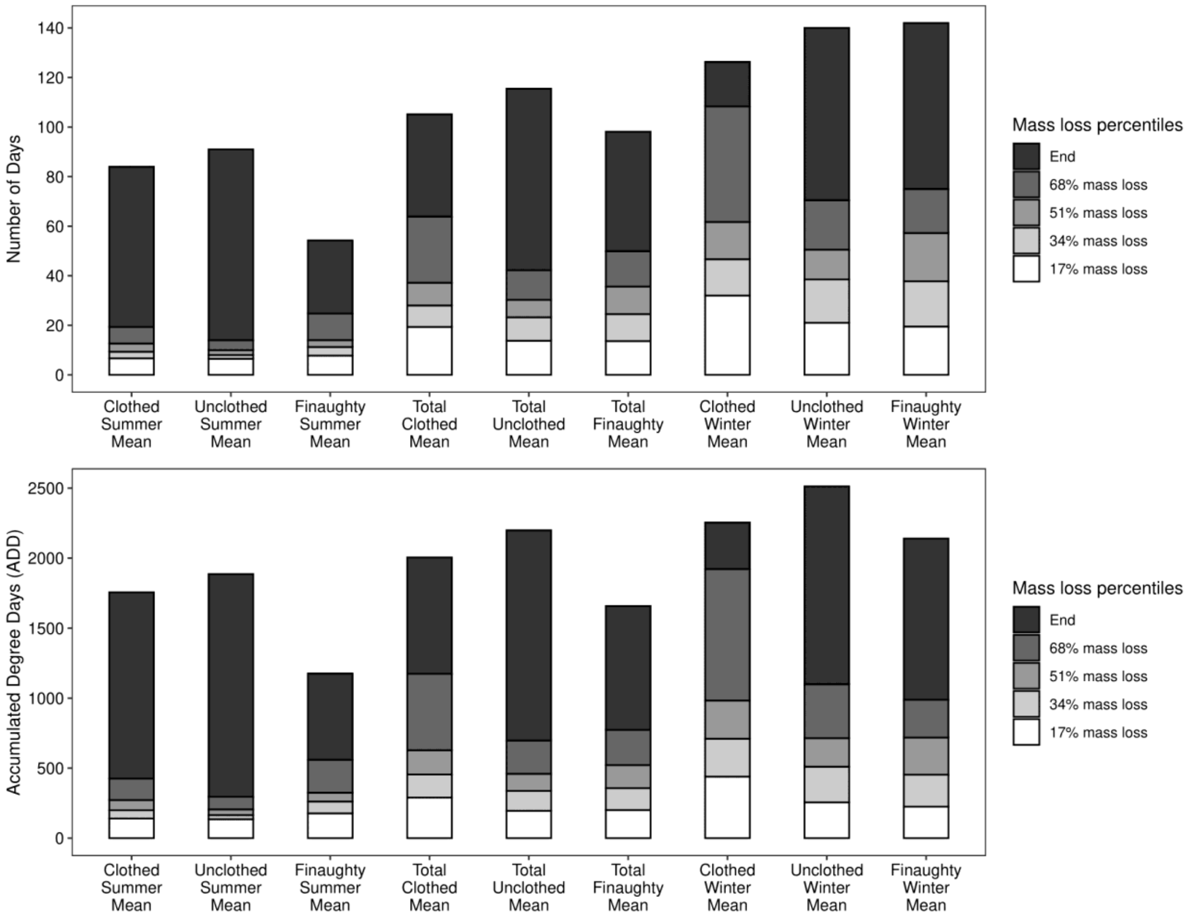

Figure 3.12: The mean number of days (top panel) and accumulated degree days (bottom panel) to reach mass loss percentiles for clothed and unclothed carcasses by season and corresponding unclothed data collected by Finaughty (2019) for comparison. % = percentage.

3.2.3 The effect of clothing on scavenging

The total maximum, minimum, and mean number of mongoose visits, total visit duration, as well as the duration of visits made by multiple mongooses simultaneously, and the percentage of those multi-mongoose visits are available in Table 3.11. Clothed carcasses experienced fewer visits on average than unclothed carcasses, at 341 versus 458 total visits. However, the unclothed carcasses experienced a greater spread of mongoose activity, with a lower minimum visit number of 114 versus 274 for the clothed group and a greater maximum of 797 compared to 403. Finaughty's unclothed carcasses were visited more than those from this study, with a mean total visit number of 536 and a duration of 91 hours compared to 458 mean visits and 44 hours mean duration for this study's unclothed carcasses. The clothed carcasses were visited for a shorter total duration of 31 compared to 44 hours for this study's unclothed carcasses, with a similarly increased spread of data for the unclothed group, indicated by the maximum and minimum duration. The unclothed maximum mongoose visit duration was 98 vs 60 hours for the clothed group, and the minimum duration was 4 vs 15 hours. The clothed carcasses experienced a slightly lower multi-mongoose visit duration and percentage of 2.5 hours and 8% compared to 3 hours and 9% for the unclothed group. The spread of multi-mongoose visit data was similar for both the clothed and unclothed cohorts.

Table 3.11: Maximum, mean, and minimum total mongoose visit number, duration, multi-mongoose duration, and percentage for clothed and unclothed carcasses, along with unclothed data collected by Finaughty (2019) for comparison.

Clothing	Season	Measure	Total visit number	Total visit duration (h:m:s)	Multi-mongoose duration (h:m:s)	% Multi-mongoose
Clothed	Winter	Max	403	60:15:13	1:31:56	3
		Mean	364	35:01:27	0:35:34	1
		Min	299	15:17:10	0:01:07	<1
	Summer	Max	377	46:36:04	10:20:01	22
		Mean	318	26:51:43	4:30:06	14
		Min	274	16:03:43	0:37:54	4
	Overall	Max	403	60:15:13	10:20:01	22
		Mean	341	30:56:35	2:32:50	8
		Min	274	15:17:10	0:01:07	<1
Unclothed	Winter	Max	797	97:41:41	2:53:48	3
		Mean	622	69:42:39	1:48:02	2
		Finaughty Mean	673	111:30:05	-	-
		Min	446	41:43:37	0:42:16	2
	Summer	Max	474	33:23:36	8:01:15	24
		Mean	294	18:38:37	4:08:01	15
		Finaughty Mean	399	71:20:46	-	-
		Min	114	3:53:38	0:14:47	6
	Overall	Max	797	97:41:41	8:01:15	24
		Mean	458	44:10:38	2:58:02	9
		Finaughty Mean	536	91:25:26	-	-
		Min	114	3:53:38	0:14:47	2
Overall		Max	797	97:41:41	10:20:01	24
		Mean	388	36:14:12	2:42:55	8
		Min	114	3:53:38	0:01:07	<1

h:m:s = hours: minutes: seconds; % = percentage.

Comparing within each season, the clothed winter carcasses were visited on average 364 times for a duration of 35 hours, whereas unclothed winter carcasses had a mean of 622 total visits and duration of 69 hours. Clothed winter carcasses received less activity by multiple mongooses, with a duration of 35 min (1%) contrasted with 2 hours (2%) for the unclothed winter mean.

Clothed summer carcasses had a total mean visit number of 318 and duration of 27 hours compared to 294 and 18 hours for the unclothed summer means, respectively. The multi-mongoose activity was similar in summer; clothed carcasses had a mean duration of 4.5 hours (14%) compared to 4 hours (15%) for the unclothed summer group.

Finaughty's carcasses experienced more scavenging activity than this study's unclothed carcasses in both winter and summer: a mean of 673 vs 622 visits and mean duration of 111 vs 70 hours in winter; and a mean visit number of 399 vs 294 and duration of 71 vs 18.5 hours in summer.

The mean differences in total mongoose visit number and duration, as well as those occurring within each mass loss milestone, are depicted as bar charts in Figure 3.13. Here, one sees that most mongoose visits and scavenging time is spent in the first period, up until 17% mass loss, for all groups. Winter carcasses, particularly those unclothed, show a greater number of total visits and total duration, which are more equally dispersed across the mass loss percentiles. By contrast, the unclothed summer cohort shows the fewest mongoose visits and the shortest duration across the mass loss milestones, with a high degree of milestone clustering. The proportion of visit number and duration per mass loss milestone are shown in Figure 3.14, which clearly shows that in summer, the number of mongoose visits to clothed carcasses is more distributed than unclothed summer carcasses. The figure also shows that in winter, mongoose visit duration is even more concentrated in the first 17% of mass loss than for the unclothed winter group.

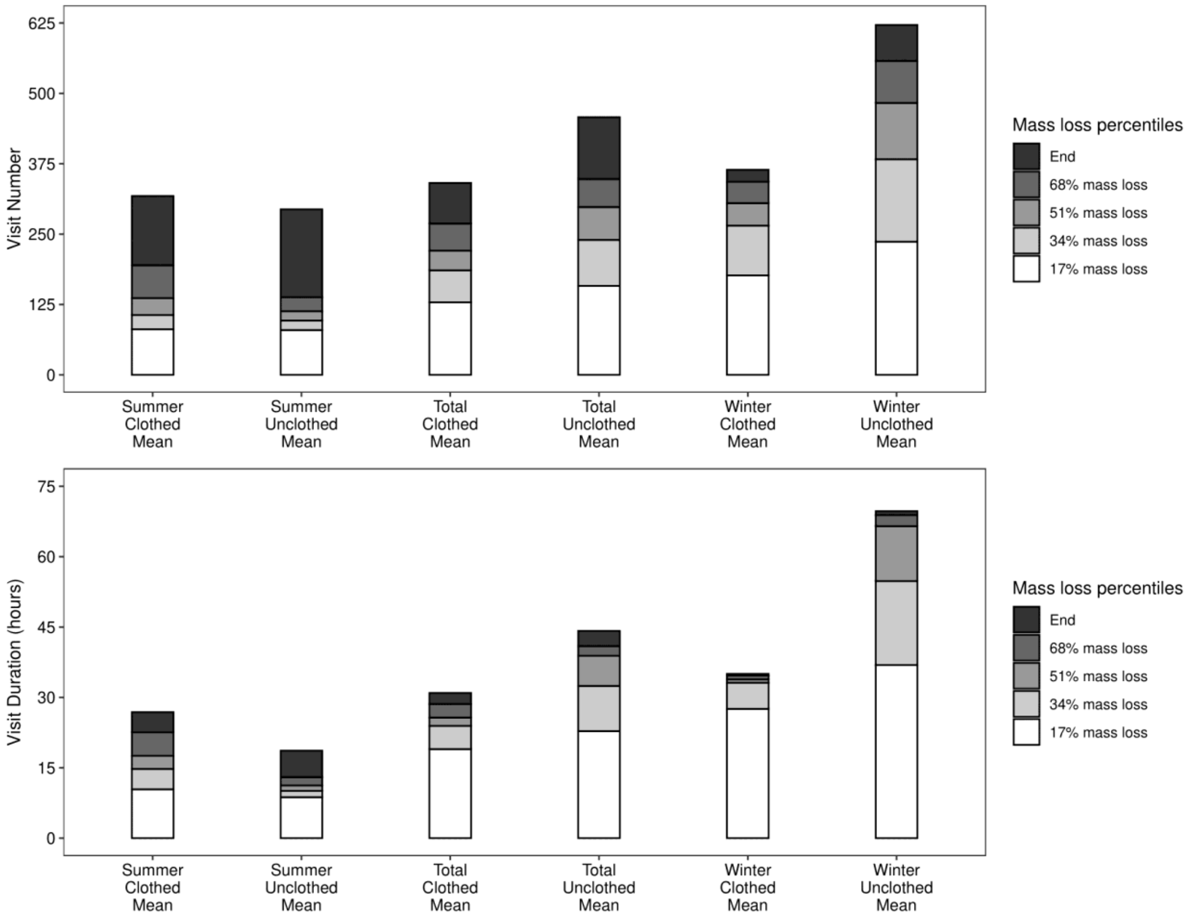

Figure 3.13: Mean scavenger visit number (top panel) and duration (bottom panel) to reach mass loss percentiles for clothed and unclothed carcasses by season. % = percentage.

Table 3.12 provides the data used in Figure 3.13, the mean mongoose visit number and duration for clothed and unclothed carcasses across seasons by percentile. Across all mass loss milestones, there are fewer visits to the clothed group than the unclothed group: 129 versus 158 to reach 17% loss; 57 versus 82 to reach 34% loss; 35 versus 58 to reach 51% loss; and 48 versus 50 visits to reach 68% mass loss. Similarly, the total mean mongoose visit duration was less for the clothed than the unclothed group for each percentile, except to reach 68% mass loss: 19 hours for the clothed versus 23 hours for the unclothed group to reach 17% loss; 5 versus 10 hours to reach 34% loss; 2 versus 6 hours to reach 51% loss; and 3 versus 2 hours to reach 68% mass loss.

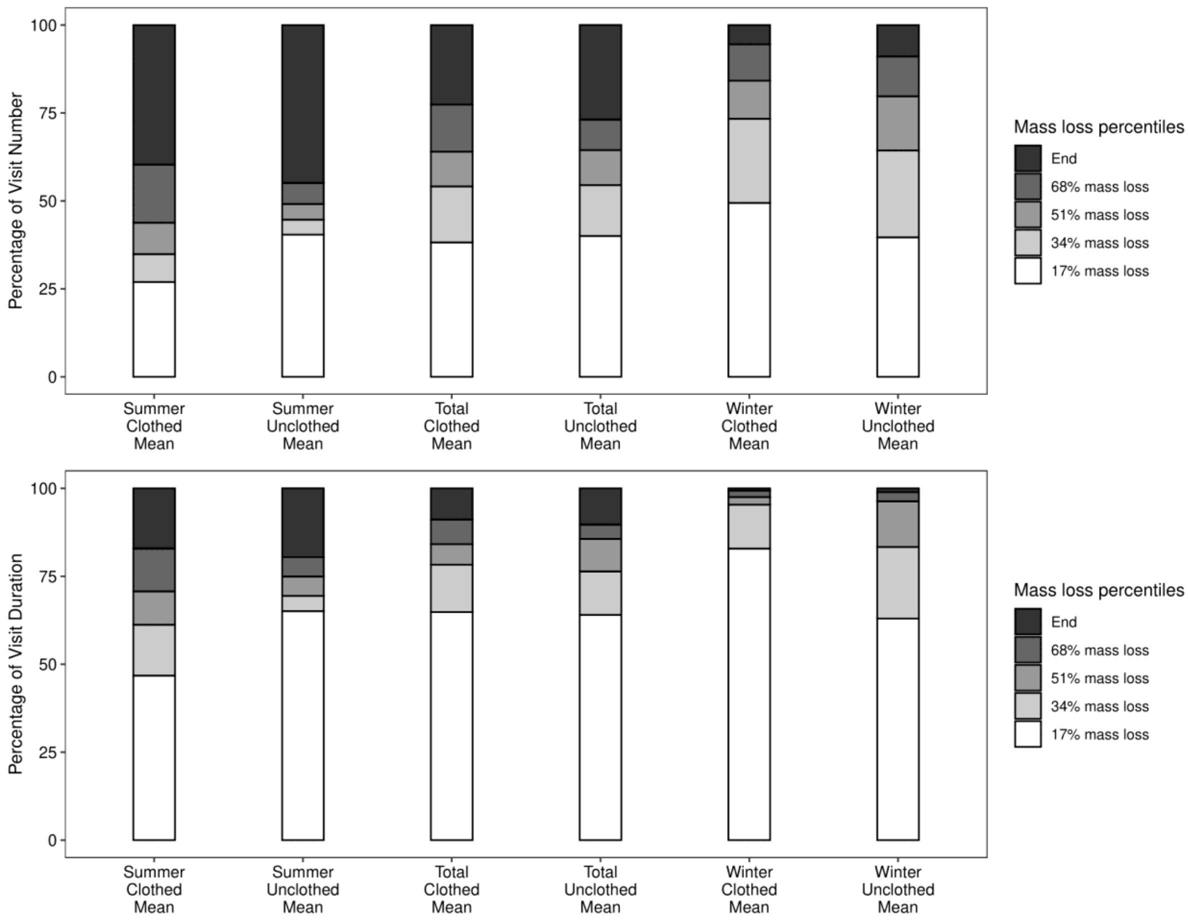

Figure 3.14: The mean percentage scavenger visit number (top panel) and visit duration (bottom panel) to reach mass loss percentiles for clothed and unclothed carcasses by season. % = percentage.

Similar patterns are observed in winter when assessing clothing within each season. Clothed winter carcasses were visited by mongooses on average 177 times before 17% mass loss, compared to 237 times for the unclothed carcasses; 88 visits versus 147 to reach 34% loss; 40 versus 100 to reach 51% loss; and 38 versus 75 to reach 68% mass loss. Differences in winter mongoose visit duration between clothed and unclothed carcasses were similar to winter visit number, with greater parity initially to reach 17% mass loss, 27.5 versus 37 hours, followed by increasing disparity between the two groups: 5.5 hours for the clothed group versus 18 hours to reach 34% loss; 43 min versus 12 hours to reach 51% loss; and 47 min versus 2 hours to reach 68% mass loss.

Table 3.12: The mean number of mongoose visits and visit duration (h:m:s) in parentheses to reach mass loss percentiles for clothed, unclothed, and Finaughty (2019) carcasses by season.

Clothing	Season	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End
Clothed	Winter	177 (27:33:55)	88 (5:33:36)	40 (0:43:24)	38 (0:47:37)	21 (0:22:55)
	Summer	81 (10:24:27)	25 (4:20:45)	30 (2:47:32)	58 (5:00:29)	123 (4:18:30)
	Overall	129 (18:59:11)	57 (4:57:10)	35 (1:45:28)	48 (2:54:03)	72 (2:20:42)
Unclothed	Winter	237 (36:53:56)	147 (17:54:21)	100 (11:42:08)	75 (2:22:19)	64 (0:49:56)
	Finaughty Winter	169 (44:30:20)	144 (23:39:25)	149 (21:28:52)	137 (15:01:51)	75 (6:49:37)
	Summer	80 (8:44:11)	17 (1:20:26)	17 (1:09:57)	25 (1:45:01)	156 (5:39:01)
	Finaughty Summer	77 (27:51:13)	44 (4:47:35)	24 (3:33:12)	90 (18:14:13)	165 (16:54:32)
	Overall	158 (22:49:03)	82 (9:37:23)	58 (6:26:03)	50 (2:03:40)	110 (3:14:29)
	Finaughty Overall	123 (36:10:47)	94 (14:13:30)	86 (12:31:02)	113 (16:38:02)	120 (11:52:04)

h:m:s = hours: minutes: seconds; % = percentage.

In summer, mongoose scavenging data showed the opposite trend within each percentile, with clothed carcasses experiencing greater visit numbers on average. There was a mean of 81 mongoose visits to clothed summer carcasses to reach 17% mass loss compared to 80 for the unclothed group; 25 versus 17 to reach 34% loss; 30 versus 17 to reach 51% loss; and 58 versus 25 to reach 68% mass loss. This trend was also true for the visit duration: a mean duration to reach 17% mass loss of 10 hours for the clothed group compared to 9 hours for the unclothed group; 4 versus 1 hour to reach 34% loss; 3 versus 1 hour to reach 51% loss; and 5 versus 2 hours to reach 68% mass loss.

When examined by mass loss percentile, simultaneous visits by more than one mongoose did not follow the same patterns as previously described. Unclothed carcasses initially showed greater mean multi-mongoose visit duration and percentage, but this was reversed later in the cycle, as shown in Table 3.13. Clothed carcasses had a mean visit duration by multiple mongooses of 1 hour (9%) to reach 17% mass loss compared to 2 hours (11%) for the unclothed mean; 23 min (7%) versus 30 min (8%) to reach 34% loss; 18 min (12%) versus 18 min (7%) to reach 51% loss; and 27 min (6%) versus 12 min (6%) to reach 68% mass loss.

Table 3.13: The mean duration (h:m:s) of simultaneous visits by multiple mongooses and percentage in parentheses to reach mass loss percentiles for clothed and unclothed carcasses by season.

Clothing	Season	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End
Clothed	Winter	0:27:51 (1%)	0:02:34 (<1%)	0:01:56 (11%)	0:00:00 (0%)	0:00:56 (1%)
	Summer	01:44:15 (16%)	0:44:15 (13%)	0:35:46 (13%)	0:55:33 (13%)	0:30:17 (11%)
	Overall	01:06:03 (9%)	0:23:25 (7%)	0:18:51 (12%)	0:27:46 (6%)	0:15:37 (6%)
Unclothed	Winter	0:49:36 (2%)	0:37:40 (2%)	0:20:45 (2%)	0:00:01 (<1%)	0:00:01 (<1%)
	Summer	02:29:26 (21%)	0:23:29 (15%)	0:15:17 (12%)	0:24:33 (12%)	0:35:16 (5%)
	Overall	01:39:31 (11%)	0:30:34 (8%)	0:18:01 (7%)	0:12:17 (6%)	0:17:38 (3%)

h:m:s = hours: minutes: seconds; % = percentage.

Winter clothed carcasses had a mean duration of 28 min (1%) for scavenging by multiple mongooses before 17% mass loss, compared to 49 min (2%) for the unclothed group; 2 min (<1%) versus 37 min (2%) to reach 34% loss; 2 min (11%) versus 20 min (2%) to reach 51% loss; and practically zero time before 68% mass loss for both clothed and unclothed carcasses.

In summer, clothed carcasses experienced 2 hours (16%) of scavenging by multiple mongooses to reach 17% mass loss, compared to 2.5 hours (20%) for unclothed; 44 min (13%) versus 23 min (15%) to reach 34% loss; 36 min (13%) versus 15 min (12%) to reach 51%; and 1 hour (13%) versus 24 min (12%) to reach 68% mass loss.

3.2.4 Summary

The clothing used in this study, drawn from casework, inhibited decay as measured by the number of days and accumulated degree days to reach various mass loss percentiles, compared to unclothed carcasses, which decomposed at a rate similar to Finaughty's (2019) unclothed carcasses previously studied in this habitat. Clothing also prolonged the bloating of the head and neck but did not appear to influence its onset. Clothing's inhibiting effect was prominent in winter but only slightly evident in summer. In winter, clothed carcasses received fewer mongoose visits of shorter duration than unclothed carcasses, but the opposite was true for summer. Finaughty's unclothed carcasses experienced consistently longer visits than the unclothed carcasses from the current study, regardless of the season. Simultaneous visits by multiple mongooses to clothed carcasses were shorter than unclothed carcasses across the mass loss benchmarks in winter. Initially, the same was true in summer, but this was reversed later in the decomposition cycle, with clothed carcasses receiving longer multi-mongoose visits. The effect of clothing on decomposition and scavenging activity showed considerable variation depending on the season; therefore, the effect of seasonal weather is presented next.

3.3 The effect of season

As indicated in the introduction chapter, weather and season can drastically affect the decomposition process, and therefore any assessment of decomposition needs to account for seasonal variation. To assess the effect of seasonality on decomposition, four trials were conducted alternating between winter and summer cycles. The first winter deployment, cycle 1, began on the 24th of August 2018 and was terminated on the 10th of January 2019, lasting 140 days. Cycle 2, the first summer deployment, began on the 14th of January 2019, lasting for 91 days before termination on the 14th of April 2019. The subsequent cycles followed a similar pattern as close in date as logistically feasible; the third deployment began on the 2nd of September 2019 and ended on the 9th of December 2019, after 100 days. The fourth and final cycle began on the 13th of January 2020 and was terminated after 71 days on the 23rd of April 2020. The average weather variables collected during the four cycles over 24-hours, daytime, and night-time are available in Table 3.14, along with significant seasonal differences.

3.3.1 Weather data and seasonal differences

On average, the winter deployments experienced a 24-hour mean temperature of 18 °C, which was 3 °C cooler than the significantly warmer 21 °C of the summer deployments (see Table 3.12 for significance values). This pattern was followed for both the 24-hour average maximum, with a significant difference of 4 °C, and the 24-hour average minimum, with a significant difference of 3 °C. Cycle 2 recorded the highest maximum temperature of an absolute, unrounded value of 38.60 °C, and the lowest temperature was recorded during the first cycle, with an absolute, unrounded value of 3.40 °C, with no freezing temperatures recorded (≤ 0°C). The seasonal difference in precipitation was also statistically significant; the average sum of winter rainfall over 24 hours was 0.5 mm more than in summer. Similarly, the maximum and mean rainfall averaged over 24-hours were also significantly greater in winter. The first cycle, winter 2019 (W-19), received a cumulative total of 109 mm of rain over the 140 days, and the second winter deployment, cycle 3, received 34 mm of rain over 100 days. By contrast, in cycle 2, the first summer deployment, only 17 mm of rainfall was collected over the 91 days, and even less in the final summer deployment, cycle 4, with a cumulative total of 4 mm over 71 days. This equates to a winter mean of 71 mm of cumulative rainfall and a summer mean of 11 mm, which is only 15% of winter rainfall. Besides cycle 1, which saw 77 mm of night-time rainfall, most rainfall occurred during daylight hours. Differences in 24-hour average atmospheric pressure were significant between summer and winter, with 3 bar greater maximum pressure in winter on average, 2.5 bar more mean pressure, and 2 bar more minimum pressure.

Although other differences in 24-hour average weather variables were observed between seasons, such as humidity and wind speed, none were significant. The 24-hour average winter humidity reached a mean of 82% compared to a mean of 82% in summer, a maximum of 90% for both seasons, and a winter minimum of 52% compared to 51% in summer. Overall, the maximum recorded humidity reading was 100% in cycle 2 (S-19), with a minimum reading of 15% in cycle 1 (W-18). Wind speed was also not significantly different between summer and winter cycles. The 24-hour mean wind speed was 1 km.h^{-1} for both summer and winter, and the average maximum was 3 km.h^{-1} for both summer and winter. The windiest deployment was cycle 4, summer 2020 (S-20), with a 24-hour average maximum of 4 km.h^{-1} and a mean of 2 km.h^{-1}. However, cycle 3, winter 2019 (W-19), had the greatest recorded wind speed overall at 11 km.h^{-1}.

Similar patterns of seasonal differences are present when filtering the weather data by daytime and night-time, respectively. In winter, the mean daily temperature was 20 °C compared to 23 °C in summer, a significant difference of 3 °C (see Table 3.14). The daily minimum recorded average temperature was 13 °C in winter and 16 °C in summer, which is a significant difference of 3 °C. The daily maximum is the same as the previously mentioned 24-hour maximum. Seasonal differences in daytime rainfall were not significant, but atmospheric pressure differences were significant and consistent with those over 24-hours; winter mean pressure was 3 bar greater for the maximum, 2.5 bar greater for the mean and 2 greater for the minimum. Daytime humidity showed no significant seasonal differences, with an average daily mean of 68%, with maximum humidity recorded at 89%, and a minimum of 52% for both seasons, respectively. The seasonal difference in solar radiation was also not significant, with a daily mean solar radiation reading of 89 W.m^{-2} in winter and a similar mean of 88 W.m^{-2} recorded in summer. The daily maximum and daily sum of solar radiation were similarly not significantly different when comparing across seasons. Wind speeds were consistently greater during the day than at night but were similarly not significant across seasons.

At night, winter rainfall was significantly greater than in summer, with a maximum difference of 0.15 mm, a mean difference of 0.03 mm, and a difference in nightly summated rainfall of 0.32 mm. Winter atmospheric pressure was also significantly greater than summer, with 3 bar greater for the maximum, 3 bar greater for the mean, and 2 bar greater for the minimum.

Occasionally, the system malfunctioned, and data were not recorded or wirelessly transmitted to the data logger, resulting in the loss of segments of data. These missing values comprised 3% of the total dataset and were found exclusively in the second and third cycles. To resolve this, missing hourly temperature, humidity, rainfall, and wind speed data were estimated using linear regression from records at the South African Weather Service's weather station at Cape Town International Airport, located 5.5 km away to the northwest. Missing solar radiation values were estimated via the normal distribution of recorded values for each hour within each cycle.

In summary, the winter deployments were, on average, colder by approximately 3 °C and experienced greater rainfall and atmospheric pressure compared to the summer deployments. However, the four cycles experienced similar solar radiation, humidity, and wind speed levels. The following subsection of this chapter will investigate how these seasonal differences affected the decomposition process.

Now that the seasonal differences between the recorded weather variables in summer and winter have been established, it is necessary to assess differences through time in weather within the same season for the comparison of decomposition between the unclothed carcasses in this study and those from Finaughty's (2019) study collected in 2014-2016.

In summer, both this study and the Finaughty (2019) study were similar in 24-hour mean and maximum temperature, but Finaughty's minimum temperature was significantly colder on average at 15 °C vs 16 °C, as indicated in Table 3.15. Finaughty's summer deployments were also significantly less humid (71% vs 74%), significantly more windy (7.5

km/h vs 1 km/h), but experienced similar levels of average 24-hour rainfall. During the day, Finaughty's minimum temperature was similarly significantly colder in summer (17 °C vs 20 °C), windier (10 km/h vs 2 km/h), and experienced 398 W/m^2 more solar radiation (530 W/m^2 vs 131 W/m^2). Night-time temperatures were all significantly colder for Finaughty's summer deployments: a maximum of 22 °C vs 23 °C, a mean of 18 °C vs 19 °C, and a minimum of 15 °C vs 16 °C. Summer windspeed at night was also similarly greater in Finaughty's deployments: 5 km/h vs 1 km/h.

In winter, all the weather variables compared across 24-hours and both day and night were significantly different. Finaughty's winter cycles were significantly colder over the 24-hour average: a maximum of 21 °C vs 24 °C, a mean of 15 °C vs 18 °C, and a minimum of 11 °C vs 17 °C. There was also significantly more rain (2 mm vs 1 mm), humidity (78% vs 74%), and greater windspeed (6 km/h vs 1 km/h) on average. During the day, Finaughty's deployments were also significantly colder on average: a maximum of 21 °C vs 24 °C, a mean of 18 °C vs 21 °C, and a minimum of 11 °C vs 17 °C. There was also significantly more solar radiation (392 W/m^2 vs 133 W/m^2), more total rain (0.44 mm vs 0.06 mm), more humidity (68% vs 62%), and greater windspeed (7 km/h vs 2 km/h) on average. Night-time temperatures were also significantly colder in Finaughty's cycles: a maximum of 16 °C vs 20 °C, a mean of 12 °C vs 16 °C, and a minimum of 9 °C vs 13 °C. There was also significantly more night-time total rain (1 mm vs 0.5 mm), more humidity (86% vs 82%), and greater windspeed (4 km/h vs 1 km/h) on average.

Table 3.14: Average weather variables recorded during all four cycles for 24 hours, daytime, and night-time, along with seasonal differences. Individual variables are heat-mapped by row to indicate intensities, with darker colours representing an increase.

Period	Weather Variable	Measure	Cycle 1: Winter 2018	Cycle 2: Summer 2019	Cycle 3: Winter 2019	Cycle 4: Summer 2020	Summer Mean	Winter Mean	Difference	*t*-statistic	*p*-value
24 hours	Temperature (°C)	Max	24.69	27.81	23.17	27.61	27.72	24.06	3.66	7.89	**0.000**
		Mean	17.95	20.75	17.58	21.32	21.00	17.80	3.20	11.21	**0.000**
		Min	12.85	15.38	12.99	16.62	15.92	12.91	3.01	10.02	**0.000**
	Rainfall (mm)	Max	0.39	0.13	0.13	0.04	0.09	0.28	-0.19	-2.75	**0.006**
		Mean	0.03	0.01	0.01	0.00	0.01	0.03	-0.02	-3.26	**0.001**
		Sum	0.78	0.19	0.34	0.05	0.13	0.59	-0.46	-3.26	**0.001**
	Pressure (bar)	Max	1019.73	1017.14	1020.31	1016.66	1016.93	1019.97	-3.04	-7.69	**0.000**
		Mean	1017.02	1014.83	1017.63	1014.61	1014.73	1017.27	-2.54	-6.73	**0.000**
		Min	1014.62	1012.86	1015.48	1012.65	1012.77	1014.98	-2.21	-5.76	**0.000**
	Humidity (%)	Max	90.61	90.20	90.19	89.45	89.87	90.43	-0.56	-0.94	0.347
		Mean	73.96	73.27	74.33	74.11	73.64	74.11	-0.48	-0.53	0.594
		Min	51.11	49.51	52.99	53.15	51.11	51.89	-0.79	-0.58	0.563
	Windspeed (km.h^{-1})	Max	2.05	1.27	3.73	4.40	2.64	2.72	-0.09	-0.36	0.717
		Mean	0.73	0.43	1.54	1.74	1.00	1.06	-0.05	-0.42	0.677
		Min	0.01	0.00	0.19	0.25	0.11	0.08	0.03	0.46	0.643
Day	Temperature (°C)	Max	24.69	27.81	23.16	27.60	27.72	24.05	3.66	7.89	**0.000**
		Mean	19.74	22.74	19.15	23.03	22.87	19.50	3.37	10.46	**0.000**
		Min	13.23	15.87	13.38	16.90	16.32	13.29	3.03	10.13	**0.000**
	Rainfall (mm)	Max	0.14	0.10	0.10	0.04	0.08	0.13	-0.05	-1.12	0.261
		Mean	0.02	0.01	0.02	0.00	0.01	0.02	-0.01	-1.49	0.137
		Sum	0.22	0.15	0.27	0.05	0.10	0.24	-0.14	-1.49	0.138
	Pressure (bar)	Max	1018.56	1016.08	1018.97	1015.92	1016.01	1018.73	-2.73	-6.86	**0.000**
		Mean	1016.92	1014.76	1017.46	1014.60	1014.69	1017.15	-2.45	-6.31	**0.000**
		Min	1015.20	1013.28	1015.88	1013.11	1013.20	1015.48	-2.28	-5.88	**0.000**
	Humidity (%)	Max	89.56	88.99	88.19	88.37	88.71	88.99	-0.27	-0.38	0.707
		Mean	68.17	66.72	68.94	68.80	67.63	68.49	-0.86	-0.79	0.428
		Min	51.12	49.84	53.26	53.15	51.29	52.01	-0.72	-0.52	0.606
	Solar Radiation (W.m^{-2})	Max	473.61	435.39	202.17	231.66	346.10	360.51	-14.41	-0.62	0.535
		Mean	109.44	102.91	60.99	68.72	87.93	89.25	-1.33	-0.34	0.737
		Sum	1582.38	1435.22	858.77	968.93	1230.86	1280.87	-50.02	-0.82	0.414
	Windspeed (km.h^{-1})	Max	1.95	1.23	3.54	4.24	2.55	2.60	-0.04	-0.19	0.846
		Mean	0.96	0.60	1.91	2.17	1.29	1.35	-0.06	-0.39	0.695
		Min	0.08	0.05	0.37	0.43	0.22	0.20	0.02	0.25	0.805
Night	Temperature (°C)	Max	17.80	20.68	17.83	21.14	20.88	17.81	3.07	11.90	**0.000**
		Mean	15.32	18.05	15.39	18.91	18.43	15.35	3.08	12.76	**0.000**
		Min	13.21	15.82	13.37	17.00	16.34	13.28	3.06	10.33	**0.000**
	Rainfall (mm)	Max	0.28	0.05	0.04	0.01	0.03	0.18	-0.15	-2.88	**0.004**
		Mean	0.05	0.00	0.01	0.00	0.00	0.03	-0.03	-3.37	**0.001**
		Sum	0.55	0.05	0.07	0.01	0.03	0.35	-0.32	-3.22	**0.001**
	Humidity (%)	Max	88.24	88.01	88.37	87.45	87.77	88.30	-0.53	-0.86	0.388
		Mean	82.48	82.07	81.90	81.63	81.88	82.24	-0.36	-0.52	0.605
		Min	74.89	74.34	73.44	74.06	74.21	74.28	-0.07	-0.08	0.940
	Pressure (bar)	Max	1019.63	1016.98	1020.16	1016.44	1016.74	1019.85	-3.11	-7.89	**0.000**
		Mean	1017.17	1014.92	1017.86	1014.62	1014.79	1017.46	-2.67	-7.28	**0.000**
		Min	1015.06	1013.22	1015.95	1013.06	1013.15	1015.43	-2.28	-6.05	**0.000**
	Windspeed (km.h^{-1})	Max	1.09	0.58	2.29	2.61	1.47	1.57	-0.10	-0.52	0.603
		Mean	0.37	0.19	1.02	1.12	0.60	0.64	-0.04	-0.32	0.747
		Min	0.02	0.02	0.27	0.34	0.16	0.12	0.04	0.51	0.613

°C = degrees Celsius; mm = millimetres; % = percentage; W.m^{-2} = Watts per square meter; km.h^{-1} = kilometres per hour; *t* statistic from Welch two-sample *t*-test; significant differences ($p < 0.05$) are denoted by bold type.

Table 3.15: Differences in average weather variables between Finaughty and Spies deployments in summer and winter. For comparative purposes, daytime is defined by solar radiation > 30 W/m^2.

Season	Period	Weather Variable	Measure	Finaughty	Spies	Difference	*t*-statistic	*p*-value
Summer	24 hours	Temperature (°C)	Max	27.99	27.72	0.28	0.64	0.526
			Mean	21.17	21.00	0.18	0.67	0.501
			Min	14.63	15.92	-1.30	-4.04	**0.000**
		Rainfall (mm)	Sum	0.43	0.13	0.30	1.84	0.067
		Humidity (%)	Mean	71.11	73.64	-2.53	-2.84	**0.005**
		Windspeed (km/h)	Mean	7.47	1.00	6.46	21.31	**0.000**
	Day	Temperature (°C)	Max	27.99	27.68	0.31	0.71	0.480
			Mean	24.48	25.01	-0.52	-1.46	0.146
			Min	16.74	20.39	-3.66	-11.96	**0.000**
		Solar Radiation (W/m^2)	Mean	529.67	131.25	398.42	45.79	**0.000**
		Rainfall (mm)	Sum	0.08	0.05	0.04	1.29	0.197
		Humidity (%)	Mean	60.23	60.56	-0.33	-0.27	0.787
		Windspeed (km/h)	Mean	9.92	1.61	8.31	23.75	**0.000**
	Night	Temperature (°C)	Max	21.95	23.11	-1.16	-3.74	**0.000**
			Mean	18.00	18.62	-0.62	-2.78	**0.006**
			Min	14.63	15.94	-1.31	-4.09	**0.000**
		Rainfall (mm)	Sum	0.34	0.08	0.26	1.66	0.099
		Humidity (%)	Mean	81.53	81.39	0.14	0.18	0.854
		Windspeed (km/h)	Mean	5.09	0.66	4.43	15.38	**0.000**
Winter	24 hours	Temperature (°C)	Max	21.25	24.06	-2.81	-6.28	**0.000**
			Mean	14.83	17.80	-2.97	-10.04	**0.000**
			Min	9.03	12.91	-3.88	-12.23	**0.000**
		Rainfall (mm)	Sum	1.61	0.59	1.01	3.24	**0.001**
		Humidity (%)	Mean	77.73	74.11	3.62	4.48	**0.000**
		Windspeed (km/h)	Mean	5.70	1.06	4.64	21.81	**0.000**
	Day	Temperature (°C)	Max	21.25	24.08	-2.83	-6.32	**0.000**
			Mean	18.06	21.43	-3.37	-9.21	**0.000**
			Min	11.43	16.68	-5.25	-17.38	**0.000**
		Solar Radiation (W.m-2)	Mean	392.13	133.38	258.75	24.79	**0.000**
		Rainfall (mm)	Sum	0.44	0.06	0.37	3.49	**0.001**
		Humidity (%)	Mean	67.81	61.81	6.00	5.31	**0.000**
		Windspeed (km/h)	Mean	7.44	1.62	5.83	23.34	**0.000**
	Night	Temperature (°C)	Max	16.47	20.15	-3.68	-12.18	**0.000**
			Mean	12.30	15.60	-3.31	-12.78	**0.000**
			Min	9.03	12.91	-3.88	-12.22	**0.000**
		Rainfall (mm)	Sum	1.17	0.53	0.64	2.38	**0.018**
		Humidity (%)	Mean	85.70	81.53	4.16	6.57	**0.000**
		Windspeed (km/h)	Mean	4.30	0.72	3.58	17.67	**0.000**

°C = degrees Celsius; mm = millimetres; % = percentage; $W.m^{-2}$ = Watts per square meter; $km.h^{-1}$ = kilometres per hour; *t* statistic from Welch two sample *t*-test; significant differences ($p < 0.05$) are denoted by bold type.

3.3.2 The effect of season on decomposition

Plotting the recorded weight data over time reveals some evident trends with respect to season (Figure 3.15), regardless of the presence of clothing, due to the difference in average weather variables described in section 3.3.1. Taken as a whole, the summer cohort of carcasses rapidly decreased in weight over time, whilst the winter carcasses experienced a more prolonged weight reduction. Also depicted in Figure 3.15 is the wider variation in the weight loss curves of the individual winter carcasses, with larger separation compared to the close clustering seen in the individual plots of the summer carcasses. The contrast between summer and winter weight loss curves may be more readily visualised when viewing the seasonal average plots, shown in Figure 3.16. This figure depicts average weight loss curves for the summer and winter cohorts and highlights the slow and steady average decline in weight during winter, compared to the much more rapid average decline in summer. The difference in seasonal decomposition occurred regardless of the presence of clothing, the effect of which has been previously presented in section 3.2. As indicated, summer carcasses experienced a rapid weight decline on average, effectively plateauing by day 40, whereas winter carcasses lost weight gradually and only began to plateau much later in the cycle, approximately by day 110 on average. The winter cohort also appeared to plateau at a higher weight value than summer carcasses, *i.e.,* less total weight was lost during winter, although further decreases in weight may have occurred with sufficient time. At the end of each cycle, the final percentage of weight loss was greater in summer than in winter, although this difference was not significant: summer median of 83% compared to 74% median weight loss in winter.

Seasonal variation in weather also influenced head and neck bloat, both in terms of the timing of onset and the total duration; this is presented in Table 3.16. Winter carcasses took longer to begin bloating than summer carcasses, with a mean onset of day 14, ranging from day five to 19, compared to a mean of day three in summer, ranging from day two to four. Winter carcasses also experience a more prolonged bloat than in summer, lasting on average 24 days, ranging from 10 to 38 days, compared to a mean of 4 days in summer, ranging from two to seven days.

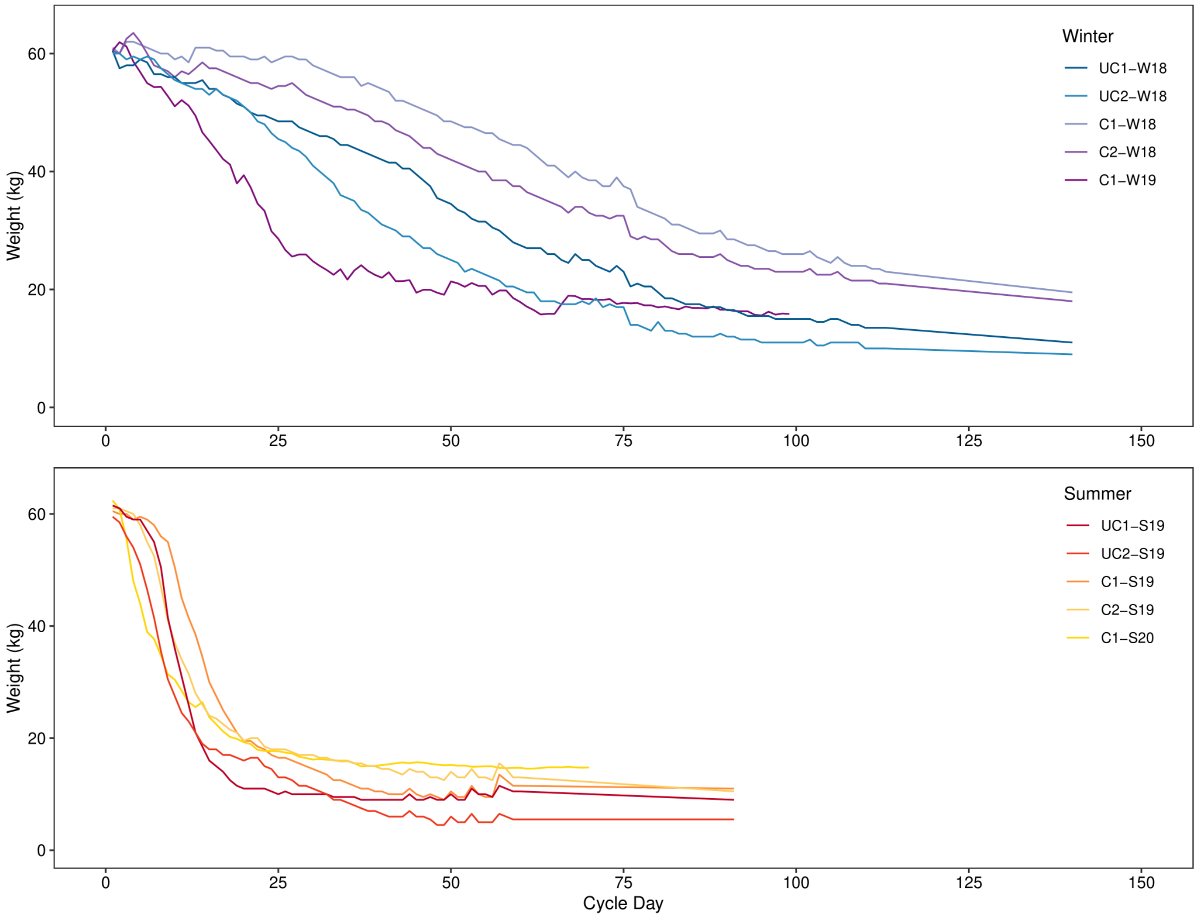

Figure 3.15: Weight loss plotted over time for winter carcasses (top panel) and summer carcasses (bottom panel) to illustrate the effect of seasonality. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram.

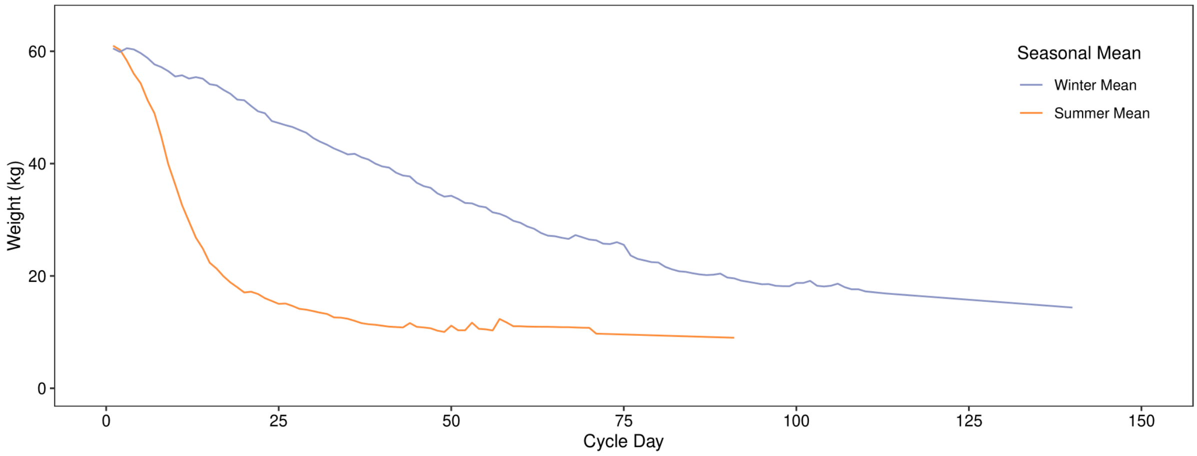

Figure 3.16: Seasonal average weight loss plotted over time. kg = kilogram.

Table 3.16: The minimum, maximum, and mean start, end, and duration of bloat in the head and neck, measured in days, for winter and summer.

Clothing	Measure	Start day	End day	Duration
Winter	Max	19	53	38
	Mean	14	39	24
	Min	5	15	10
Summer	Max	4	10	7
	Mean	3	7	4
	Min	2	4	2

When comparing mass loss benchmarks, the time in days to reach each milestone was quicker in summer than winter, as shown in Table 3.17. Summer carcasses took on average 7 days to reach 17% mass loss, compared to a winter mean of 28 days; 9 days versus 43 days to reach 34% loss; 12 days versus 57 days to reach 52% loss, and 17 days compared to 93 days to reach 68% mass loss in winter. Similarly, summer decomposition required less thermal energy measured in accumulated degree days (ADD) to reach each weight loss milestone. On average, summer carcasses required 138 ADD to reach 17% mass loss compared to 366 ADD in winter; 185 versus 630 ADD to reach 34% loss; 246 versus 876 ADD to reach 51% loss, and 373 versus 1593 ADD in winter to reach 68% mass loss.

Table 3.17: Minimum, maximum, and mean measures of time in days and thermal energy in accumulated degree days (ADD) to reach mass loss milestones for summer and winter and across all deployments. Individual variables are heat-mapped by row to indicate intensities, with darker colours representing an increase.

Season	Measure		17% mass loss	34% mass loss	51% mass loss	68% mass loss	Total
Summer	Days	Max	10	13	15	20	91
		Mean	7	9	12	17	87
		Min	3	6	9	14	70
	ADD	Max	204.35	269.41	321.06	440.65	1886.19
		Mean	138.39	185.47	245.52	373.11	1807.97
		Min	73.56	143.47	185.43	295.38	1495.08
Winter	Days	Max	46	66	85	140	140
		Mean	28	43	57	93	132
		Min	13	20	24	45	99
	ADD	Max	638.80	1034.51	1375.76	2512.45	2512.45
		Mean	366.11	630.07	875.54	1593.02	2357.68
		Min	203.56	318.91	380.12	740.92	1738.58

% = percentage.

Despite a broad range in the maximum and minimum values per mass loss milestone, depicted in Table 3.17, the median differences between seasons were significant, with decomposition requiring fewer days in summer than in winter across all percentiles. Time to 17% mass loss: median time of 7 days for summer, 21 days for winter; time to 34% mass loss: median time of 9 days for summer, 45 days for winter; time to 51% mass loss: median time of 11 days for summer, 58 days for winter; and time to 68% mass loss: median time of 18 days for summer, 80 days for winter. Significance values are provided in Table 3.18. Similarly, the amount of thermal energy in ADD required to reach the same milestones was also significantly less in summer than in winter. ADD to 17% mass loss: median of 143 ADD for summer, 256 for winter; ADD to 34% mass loss: median of 185 ADD for summer, 618 for winter; ADD to 51% mass loss: median of 227 ADD for summer, 852 for winter; ADD to 68% mass loss: median of 393 ADD for summer, 1278 for winter.

Table 3.18: Kruskal-Wallis tests for seasonal differences in the median time in days and thermal energy in accumulated degree days (ADD) to reach weight loss milestones.

Measure		***H*-statistic (1)**	***p*-value**
Days	17% mass loss	6.86	**0.009**
	34% mass loss	6.86	**0.009**
	51% mass loss	6.82	**0.009**
	68% mass loss	6.94	**0.008**
ADD	17% mass loss	5.81	**0.016**
	34% mass loss	6.82	**0.009**
	51% mass loss	4.81	**0.028**
	68% mass loss	6.82	**0.009**

H = statistic from Kruskal-Wallis test for nonparametric data, with degrees of freedom denoted in parenthesis; significant differences ($p < 0.05$) are denoted by bold type; % = percentage.

The seasonal differences in mean values are represented graphically in Figure 3.17, visually depicting the numerical descriptions above: the rapid progression through the mass loss percentiles during summer decomposition, compared to winter. This figure displays the apparent clustering of mass loss milestones within the first 20 days of the summer cycles, compared to those same milestones dispersed across the first 90 days in winter, exhibiting the more prolonged nature of winter decomposition. A pattern mirrored across both the summer, winter, and total mean measures was the comparatively little time and thermal energy required to attain the middle milestones, 34% and 51% mass loss, relative to the other percentiles. These required the least amount of time and thermal energy to achieve which is indicative of the semi-sigmoidal pattern typical of the decomposition process visible in Figure 3.15 (Carter, Yellowlees & Tibbett, 2007).

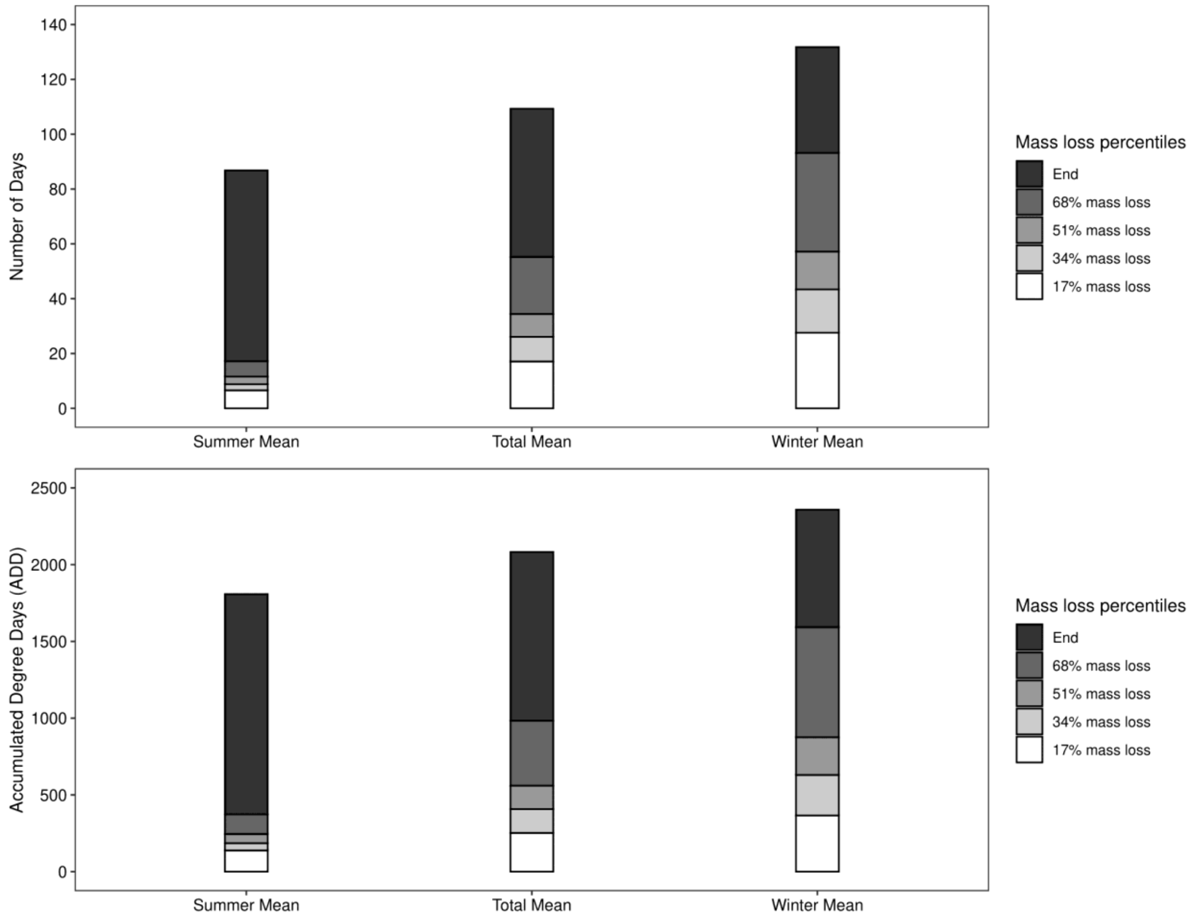

Figure 3.17: The seasonal mean time in days (top panel) and thermal energy in accumulated degree days (bottom panel) to reach each mass loss percentile. % = percentage.

3.3.3 The effect of season on scavenging

Figures 3.18 and 3.19 provide a visual representation of the number and duration of mongoose scavenging visits and the timing of their occurrence for the carcasses in winter and summer cycles, respectively. Taken as a whole, the winter cohort received more visits than in summer, with visits of substantial length occurring until approximately day 40, whereas in summer, visit duration was noticeably reduced by day 25. Despite this, some renewed activity occurred near the 50th day in summer. Summer visits were also more concentrated in the morning and afternoon, with a gap of reduced activity near midday compared to those recorded in winter.

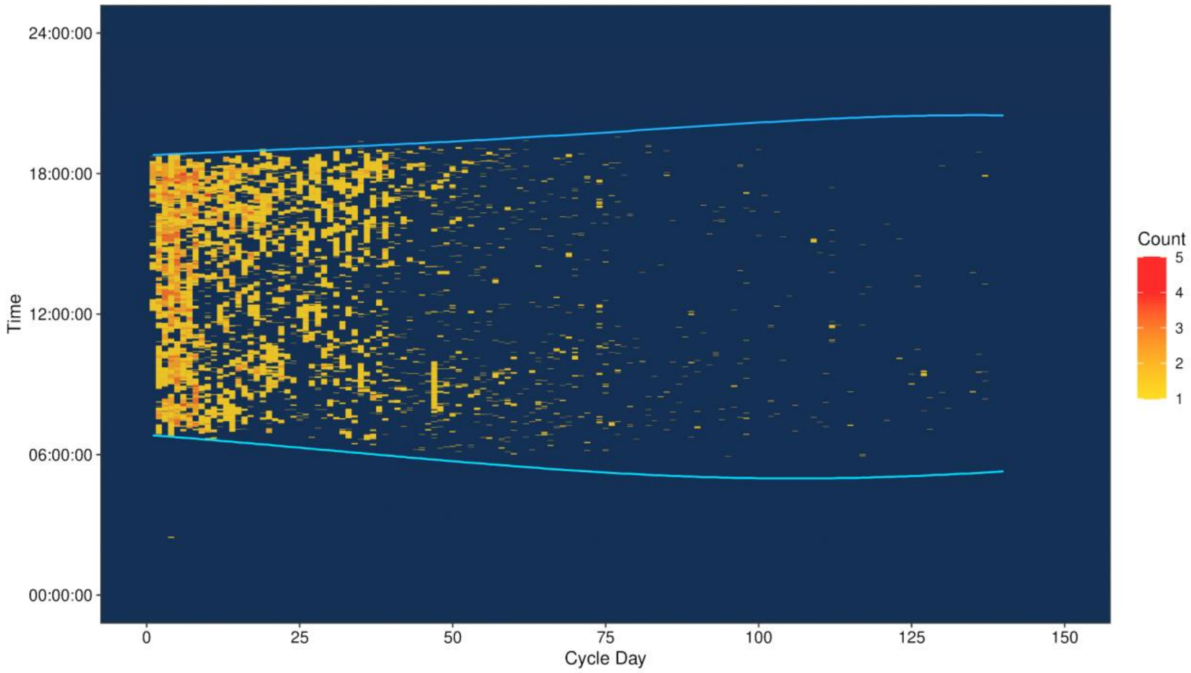

Figure 3.18: Intensity map of all individual scavenger visits to winter carcasses, with light blue lines representing civil dawn and civil dusk. Red indicates an overlap of multiple visits to individual carcasses occurring at the same time of day. Note: in this graph, the minimum time of a visit has been defined as 1 minute for illustrative purposes.

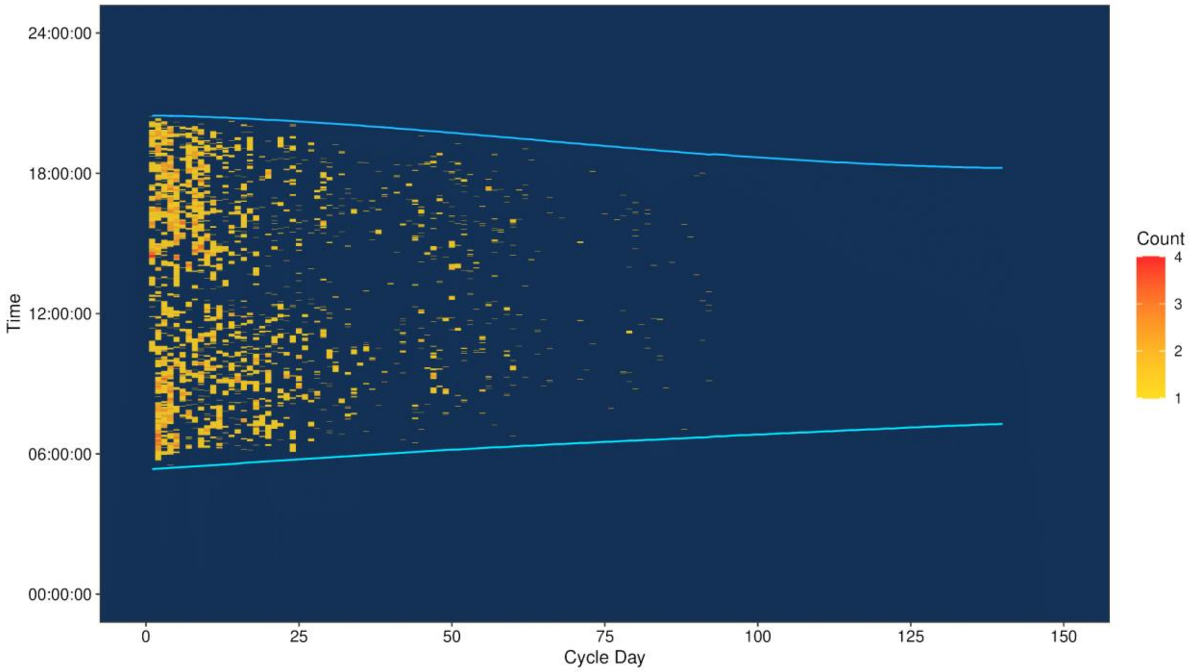

Figure 3.19: Intensity map of all individual scavenger visits to summer carcasses, with light blue lines representing civil dawn and civil dusk. Red indicates an overlap of multiple visits to individual carcasses occurring at the same time of day. Note: in this graph, the minimum time of a visit has been defined as 1 minute for illustrative purposes.

The average number of total visits across all carcasses was 388, but when compared across seasons, Table 3.19 shows a greater number of visits occurred on average in winter at 467 compared to 308 visits in summer. Along with increased visit number, total winter visit duration was more than double that of summer, at 49 hours compared to 23 hours. This pattern was also primarily followed at the level of individual mass loss percentiles, as shown in Table 3.20. Winter carcasses were visited on average 200 times before 17% mass loss, compared to a summer mean of 80; 112 visits versus 22 to reach 34% loss; 64 visits versus 25 to reach 52% loss, and 53 visits compared to a mean visit number of 45 to reach 68% mass loss in summer. Visit duration was similarly higher in winter than in summer for all mass loss percentiles except that of 68%. Winter carcasses were visited for an average duration of 31 hours before reaching 17% mass loss, compared to a summer mean of 10 hours; a duration of 10 versus 3 hours to reach 34% loss; 5 versus 2 hours to reach 52% loss, and 1 hour compared to a mean visit duration of 4 hours to reach 68% mass loss in summer.

Table 3.19: Maximum, mean, and minimum seasonal total scavenging visit number and duration.

Season	Measure	Total visit number	Total visit duration (h:m:s)	Multi-mongoose duration (h:m:s)	% Multi-mongoose
Winter	Max	797	97:41:41	02:53:48	3
	Mean	467	48:53:56	01:04:33	2
	Min	299	15:17:10	00:01:07	<1
Summer	Max	474	46:36:04	10:20:01	24
	Mean	308	23:34:28	04:21:16	14
	Min	114	3:53:38	00:14:47	4

h:m:s = hours: minutes: seconds; % = percentage.

Table 3.20: Maximum, mean, and minimum seasonal scavenging visit number and duration (h:m:s) in parentheses for each mass loss percentile.

Season	Measure	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End
Winter	Max	271 (43:35:44)	165 (32:51:56)	142 (21:57:37)	109 (4:26:47)	110 (1:21:58)
	Mean	200.6 (31:17:55)	111.6 (10:29:54)	64 (5:06:53)	52.6 (1:25:30)	38.4 (0:33:44)
	Min	159 (13:54:43)	60 (0:49:21)	24 (0:17:02)	28 (0:09:35)	0 (0:00:00)
Summer	Max	103 (14:02:27)	32 (9:02:52)	53 (5:36:01)	138 (13:52:29)	276 (11:04:03)
	Mean	80.4 (9:44:21)	22 (3:08:37)	24.6 (2:08:30)	45 (3:42:18)	136.2 (4:50:42)
	Min	46 (3:25:56)	2 (0:01:39)	3 (0:10:40)	2 (0:01:24)	36 (0:13:59)

h:m:s = hours: minutes: seconds; % = percentage.

The seasonal differences in the median number of mongoose visits and duration of visits were significant only in the early stages of decomposition, as shown in Table 3.21. Mongoose activity in later percentiles was not significantly different in the number or duration of visits across seasons. Visits to 17% mass loss: median visit number of 88 for summer, 190 visits for winter; visits to 34% mass loss: median visit number of 29 for summer, 107 visits for winter. Only median visit duration up to 17% mass loss was significantly different between seasons: median visit duration of 10 hours for summer, and 37 hours for winter.

Table 3.21: Kruskal-Wallis tests for seasonal differences in scavenger visit number and visit duration within each mass loss percentile.

Measure		***H*-statistic (1)**	***p*-value**
Visit number	17% mass loss	6.82	**0.009**
	34% mass loss	6.86	**0.009**
	51% mass loss	3.19	0.074
	68% mass loss	0.54	0.463
	Total	1.84	0.175
Visit duration	17% mass loss	5.77	**0.016**
	34% mass loss	1.84	0.175
	51% mass loss	0.27	0.602
	68% mass loss	0.27	0.602
	Total	1.32	0.251

H = statistic from Kruskal-Wallis test for nonparametric data, with degrees of freedom denoted in parenthesis; significant differences ($p < 0.05$) are denoted by bold type; % = percentage.

Figure 3.20 visually depicts the seasonal differences in visit number and duration, highlighting the greater mean number and duration of visits in winter compared to summer. This figure also clearly presents how most visits and time are spent at the beginning of the decomposition cycle. The proportion of overall visit number and duration per mass loss milestone is depicted in Figure 3.21. This figure more clearly shows that although most mongoose visits and time spent scavenging was clustered in the first percentile, the summer cohort experienced a more equal distribution of visit number and duration compared to the carcasses scavenged in winter, where comparatively more time was spent in the early decomposition period.

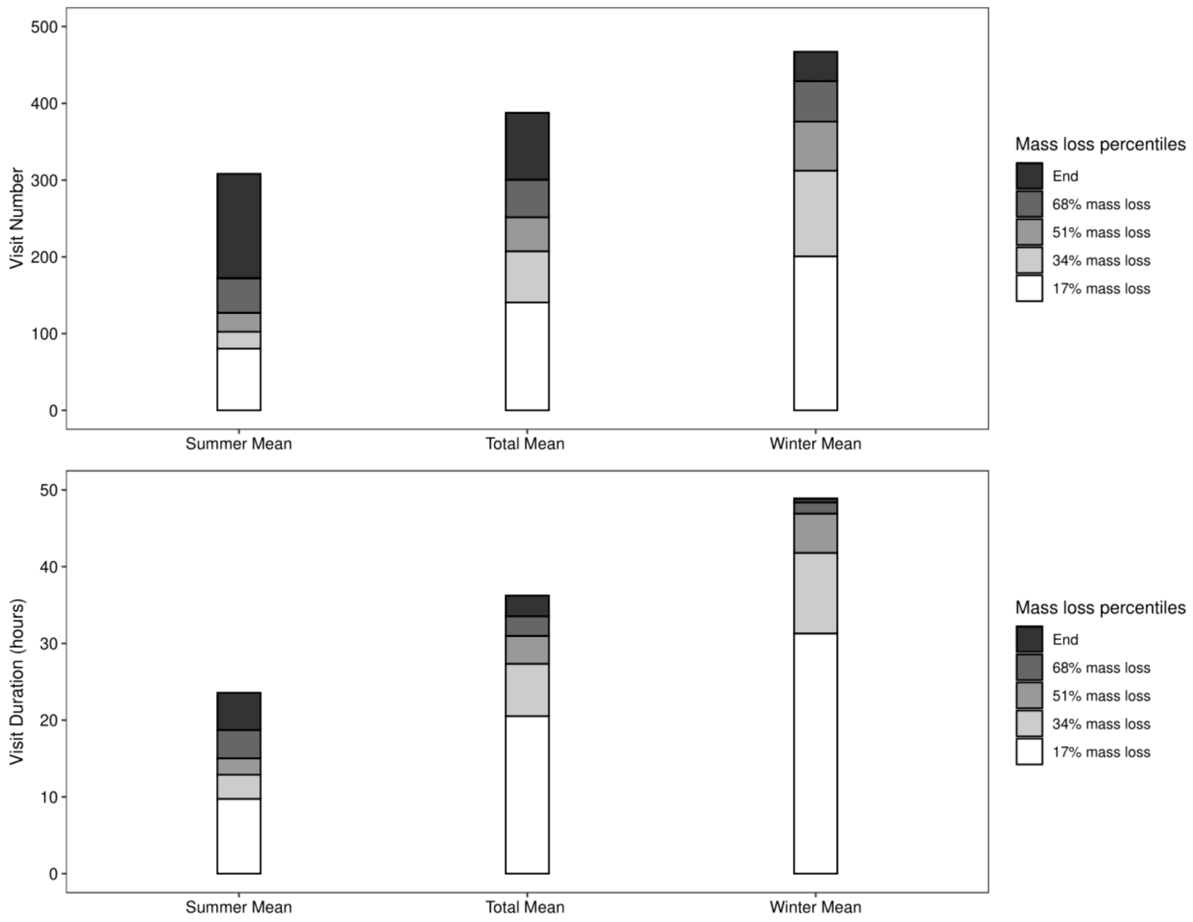

Figure 3.20: The seasonal and total mean scavenger visit number (top panel) and visit duration (bottom panel) to reach each mass loss percentile. % = percentage.

There is a large observable difference in simultaneous scavenging by multiple mongooses across seasons: visits by multiple mongooses were more prevalent in summer than in winter, with a summer total mean duration of 4 hours (14%), ranging from 15 mins (4%) to 10 hours (24%), as shown in Table 3.19. By contrast, winter carcasses experienced a total mean multi-mongoose duration of 1 hour (2%) and a range from 1 min (<1%) to 3 hours (3%). Table 3.22 provides the visit duration of multiple simultaneous mongooses and the percentage of the total duration made up by these visits for each mass loss percentile. In summer, simultaneous scavenging by multiple mongooses was more prevalent, with a greater duration and proportion of the total evident across the mass loss percentiles. Summer carcasses were visited by more than one mongoose for an average of 2 hours compared to a winter mean of 36 mins before 17% mass loss; 36 mins versus 16 mins to reach 34% loss; 27 mins visits versus 9 mins to reach 52% loss, and 43 mins compared to a mean visit multi-mongoose visit duration of 0 mins to reach 68% mass loss in winter. Similarly, the percentage of total visit duration made up by the simultaneous activity of multiple mongooses was greater in summer than in winter across all milestones. Summer carcasses saw an average of 18% of total visit duration made up by more than one mongoose before 17% mass loss, compared to a winter mean of 2%; 14% versus 1% to reach 34% loss; 13% versus 7% to reach 52% loss, and 12% compared to a mean visit multi-mongoose visit duration of less than 1% to reach 68% mass loss in winter.

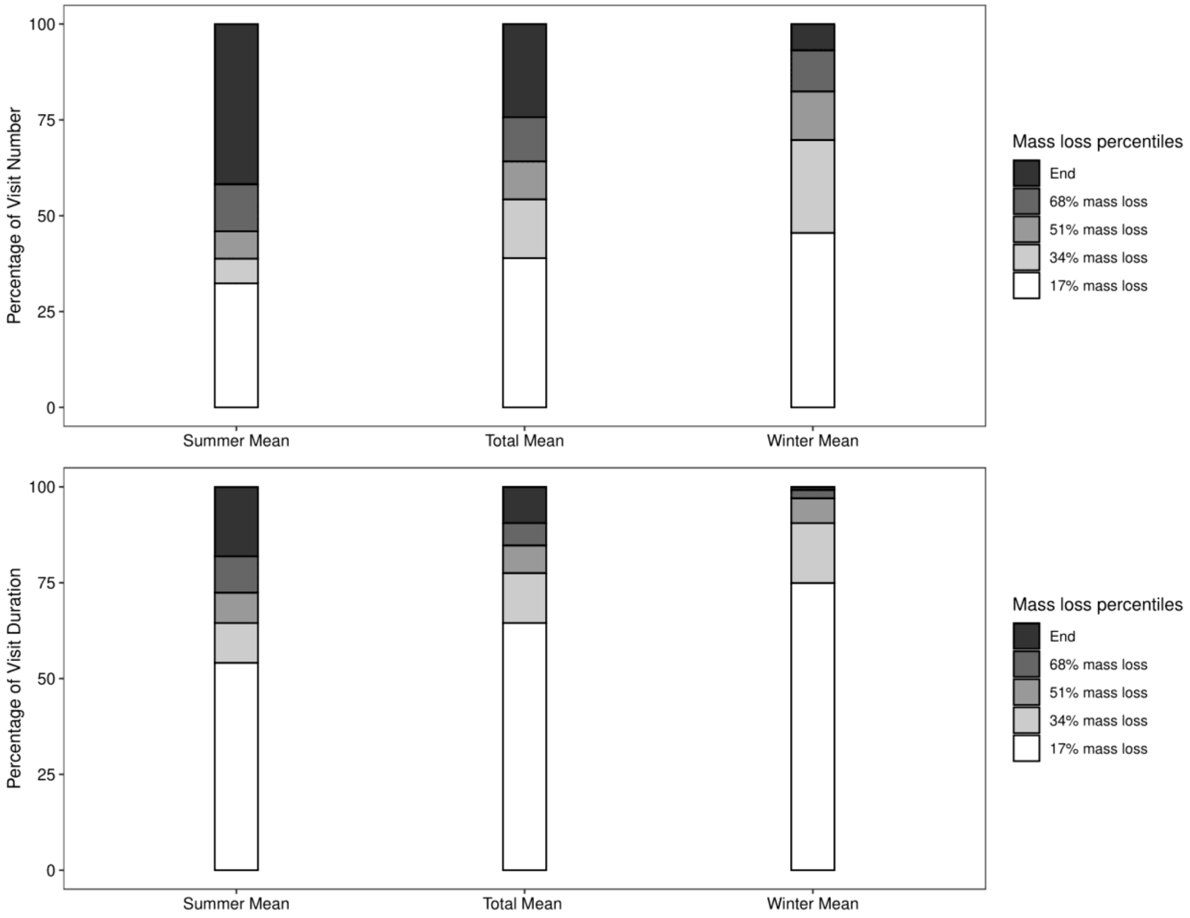

Figure 3.21: The seasonal mean percentage visit number (top panel) and visit duration (bottom panel) per mass loss percentile. % = percentage.

Table 3.22: Maximum, mean, and minimum seasonal visit duration (h:m:s) by multiple mongooses simultaneously and percentage in parentheses for each mass loss percentile.

Season	Measure	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End
Winter	Max	1:21:25 (3%)	1:15:19 (4%)	0:41:30 (34%)	0:00:01 (<1%)	0:02:49 (4%)
	Mean	0:36:33 (2%)	0:16:36 (1%)	0:09:27 (7%)	0:00:00 (<1%)	0:00:34 (<1%)
	Min	0:01:02 (<1%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)
Summer	Max	4:44:05 (34%)	1:38:37 (30%)	1:39:20 (30%)	2:41:27 (24%)	1:10:33 (18%)
	Mean	2:02:19 (18%)	0:35:57 (14%)	0:27:34 (13%)	0:43:09 (12%)	0:32:17 (9%)
	Min	0:14:47 (5%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)	0:00:00 (0%)

h:m:s = hours: minutes: seconds; % = percentage.

The seasonal differences in simultaneous visit duration by multiple mongooses were only significantly different in the median values at 68% mass loss: median visit duration of 4 mins for summer and 0 mins for winter, as presented in Table 3.23. However, the median percentage of visit duration of more than one mongoose was significantly different between seasons in the early and late stages of decomposition and the total. The median percentage of multi-mongoose visit duration was 16% for summer vs 2% for winter to reach 17% mass loss; median of 16% for summer vs 0% for winter to reach 68% mass loss; and median percentage of multi-mongoose duration of 16% for summer vs 2% for winter for the total period.

Table 3.23: Kruskal-Wallis tests for seasonal differences in visit duration and percentage by multiple mongooses simultaneously for each mass loss percentile.

Measure		*H*-statistic (1)	*p*-value
Multi-mongoose visit duration	17% mass loss	1.84	0.175
	34% mass loss	0.29	0.590
	51% mass loss	0.74	0.389
	68% mass loss	4.48	**0.034**
	Total	1.32	0.251
Multi-mongoose visit percentage	17% mass loss	6.82	**0.009**
	34% mass loss	0.94	0.332
	51% mass loss	1.16	0.281
	68% mass loss	4.48	**0.034**
	Total	6.82	**0.009**

H = statistic from Kruskal-Wallis test for nonparametric data, with degrees of freedom denoted in parenthesis; significant differences ($p < 0.05$) are denoted by bold type; % = percentage.

Figures 3.22, 3.23, 3.24, and 3.25 present the daily weight lost, mongoose visit duration and the associated temperature and rainfall data for each carcass in each deployment. These figures reiterate that scavenging activity was largely focused during the initial stages of decay and occasionally showed a slight increase in activity following rainfall later in the cycle. Increased mongoose activity usually correlated with an increased amount of weight lost but did not appear to be visually associated with fluctuations in temperature. However, weight loss did increase with increased temperature and decreased during periods of lower temperature. The amount of weight loss decreased during rainfall events, often becoming negative in the figures, but was quickly followed by an increase in weight loss.

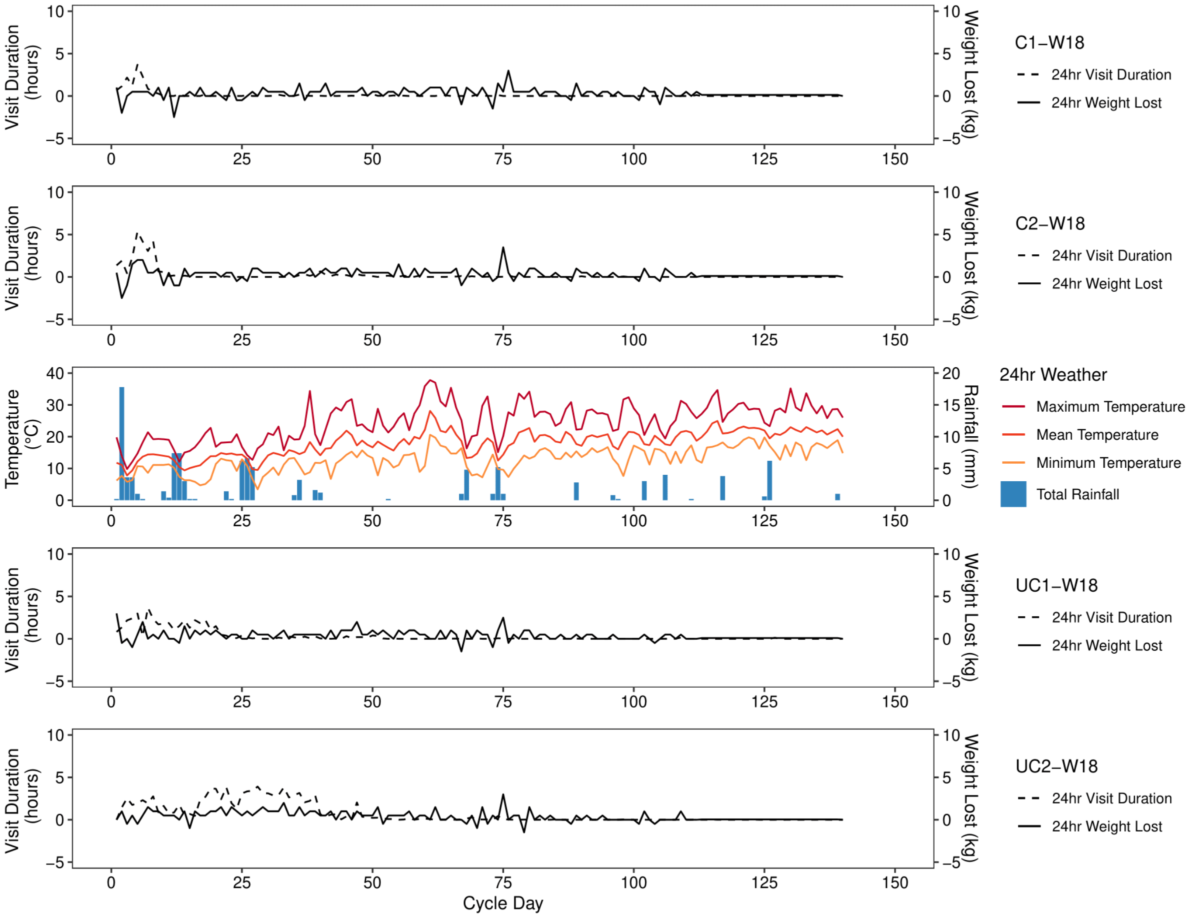

Figure 3.22: Daily weight lost, and total scavenger visit duration for each carcass in cycle 1, Winter 2018, with the associated temperature and rainfall data. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram; °C = degrees Celsius; mm = millimetres; hr = hour.

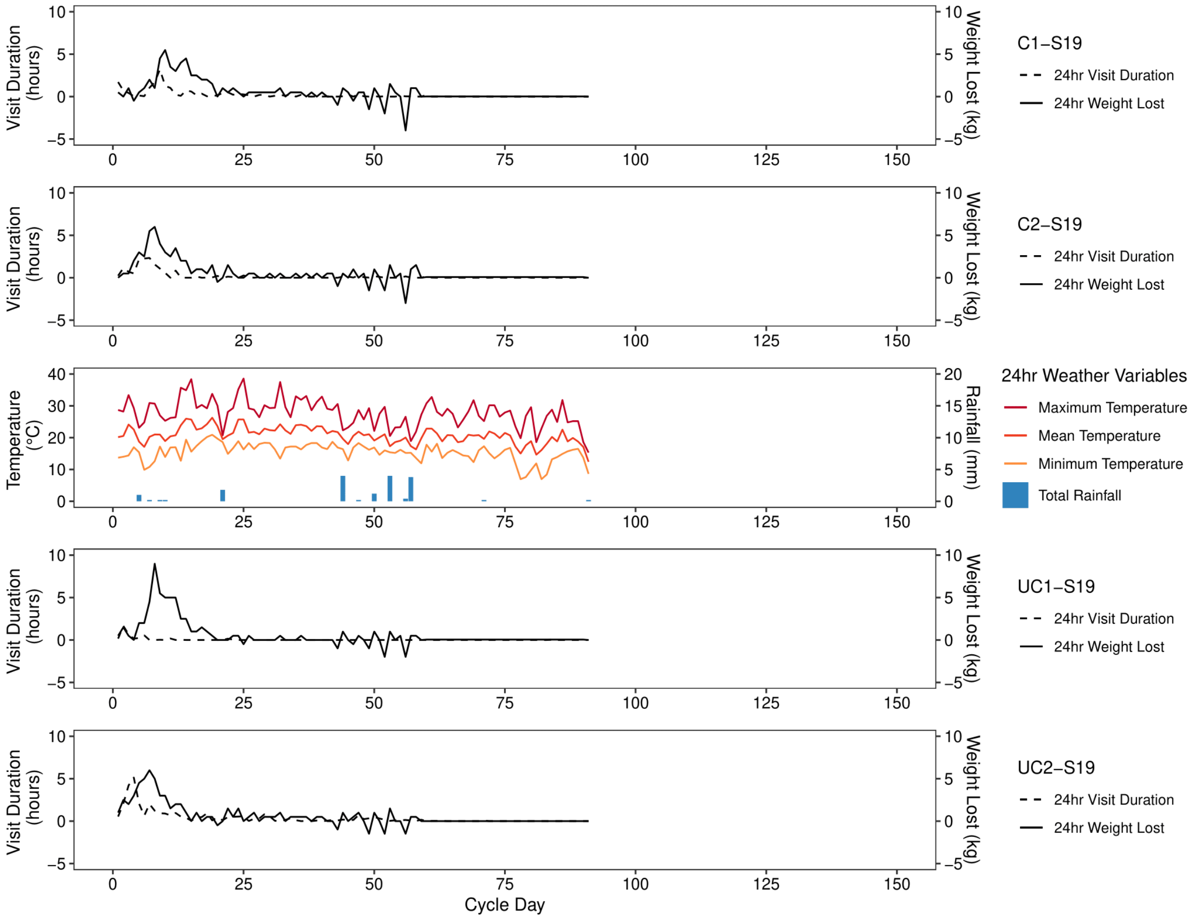

Figure 3.23: Daily weight lost, and total scavenger visit duration for each carcass in cycle 2, Summer 2019, with the associated temperature and rainfall data. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram; °C = degrees Celsius; mm = millimetres; hr = hour.

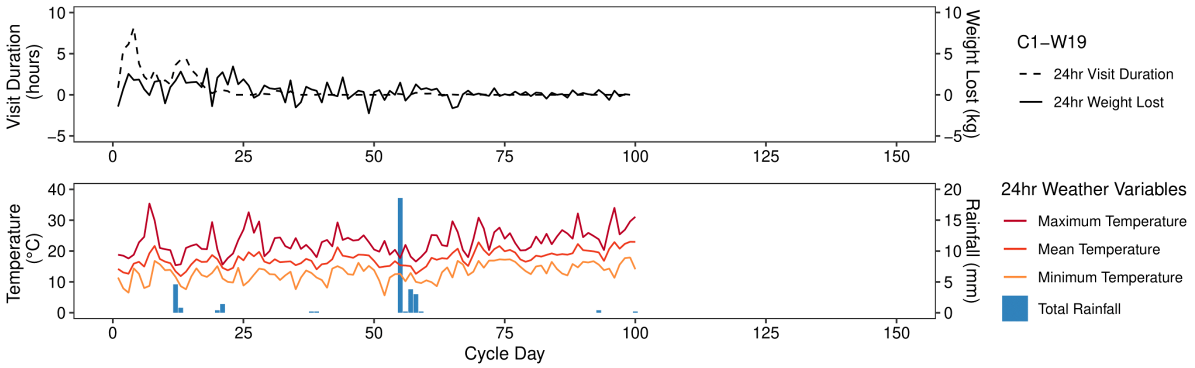

Figure 3.24: Daily weight lost, and total scavenger visit duration for the single clothed carcass in cycle 3, Winter 2019, with the associated temperature and rainfall data. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram; °C = degrees Celsius; mm = millimetres; hr = hour.

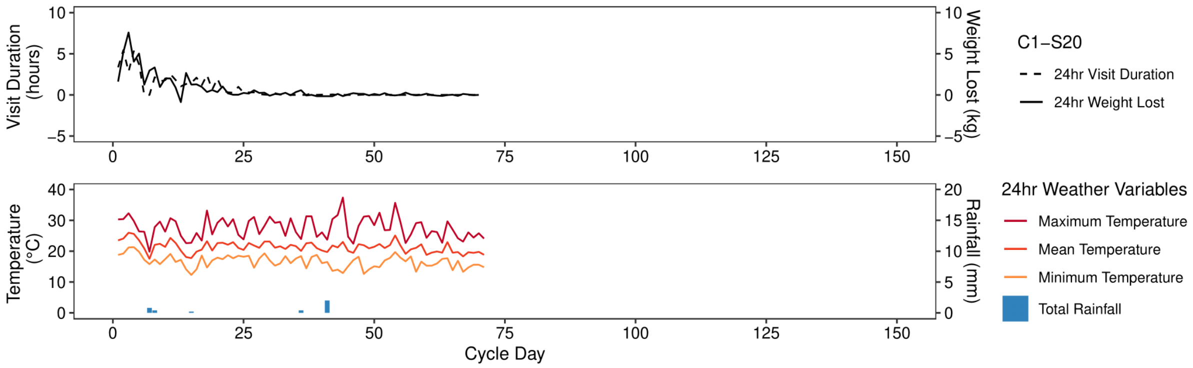

Figure 3.25: Daily weight lost, and total scavenger visit duration for the single clothed carcass in cycle 4, Summer 2020, with the associated temperature and rainfall data. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram; °C = degrees Celsius; mm = millimetres, hr = hour.

3.3.4 Summary

The winter cycles were significantly colder and wetter on average, with greater atmospheric pressure compared to the summer cycles. However, the four cycles experienced similar solar radiation, humidity, and wind speed levels. These seasonal differences resulted in winter decomposition progressing significantly slower than summer as measured by the rate of weight loss, as well as winter carcasses having a delayed bloat onset and longer duration than the summer group. Mongoose scavenging activity also showed some significant differences between seasons: winter carcasses were visited more often and for longer than summer carcasses in the initial stages of decomposition. Simultaneous visits by multiple mongooses were significantly longer in the early stages of summer decomposition and made up a significantly greater percentage of total mongoose scavenging hours across all mass loss milestones in summer compared to winter. Mongoose activity did not appear to be visually associated with temperature changes, unlike the rate of mass loss, which increased with increased temperature, as well as with increased scavenging activity. Some instances of increased mongoose activity after rainfall occurred.

3.4 The effect of carrion biomass load

The previous results sections highlighted a demonstrable difference in the decay rate between clothed and unclothed carcasses, as well as a significant difference between seasonal decomposition rates. To determine the effect increasing carrion availability may have on mass loss, single clothed carcasses were deployed in summer and winter and compared to the previous deployments of multiple carcasses. The analyses were completed using data only from clothed carcasses, but crucially, the single clothed carcass used in cycle 3 (winter) and in cycle 4 (summer) was the only available carrion source respectively at the time of each deployment. In contrast, cycle 1 (winter) and cycle 2 (summer) each comprised four carcasses deployed simultaneously, two of which were unclothed.

3.4.1 The effect of carrion biomass load on decomposition

Regardless of the season, there is a noticeable overall difference in weight loss rate between the single clothed carcass mean and the clothed multi-carcass mean. This is shown in Figure 3.26, which provides a clear visual comparison of the rate of weight loss experienced by the different cohorts broken down by season. In winter, the single clothed carcass lost weight more rapidly than the multi-carcass clothed mean and even the unclothed mean, with a large difference in trajectory. The difference was less pronounced in summer, but the single clothed carcass showed an immediate sharp decline in weight, without the initial lag present in both the clothed and unclothed multi-carcass summer means. Both single clothed carcasses plateaued earlier in the cycle but with slightly more weight than their multi-carcass seasonal counterparts.

The onset and duration of bloat in the head and neck was also influenced by carrion biomass load, with data presented in Table 3.24. The single clothed carcasses began to bloat in the head and neck earlier, starting on day four on average, with a shorter mean duration of six days, compared to the multi-carcass deployments which first showed evidence of bloat on day 10 and lasted 20 days on average. In winter, this was exaggerated, with the single clothed carcasses first bloating on day five, lasting only 10 days, whereas the multiple carcasses started bloating on day 17 and lasted 35 days on average. In summer, the two groups were more similar, but still distinct: bloat began on day two for the single carcass and lasted only two days, whereas bloat first started on day 4 on average for the multiple carcass deployment and lasted an average of five days.

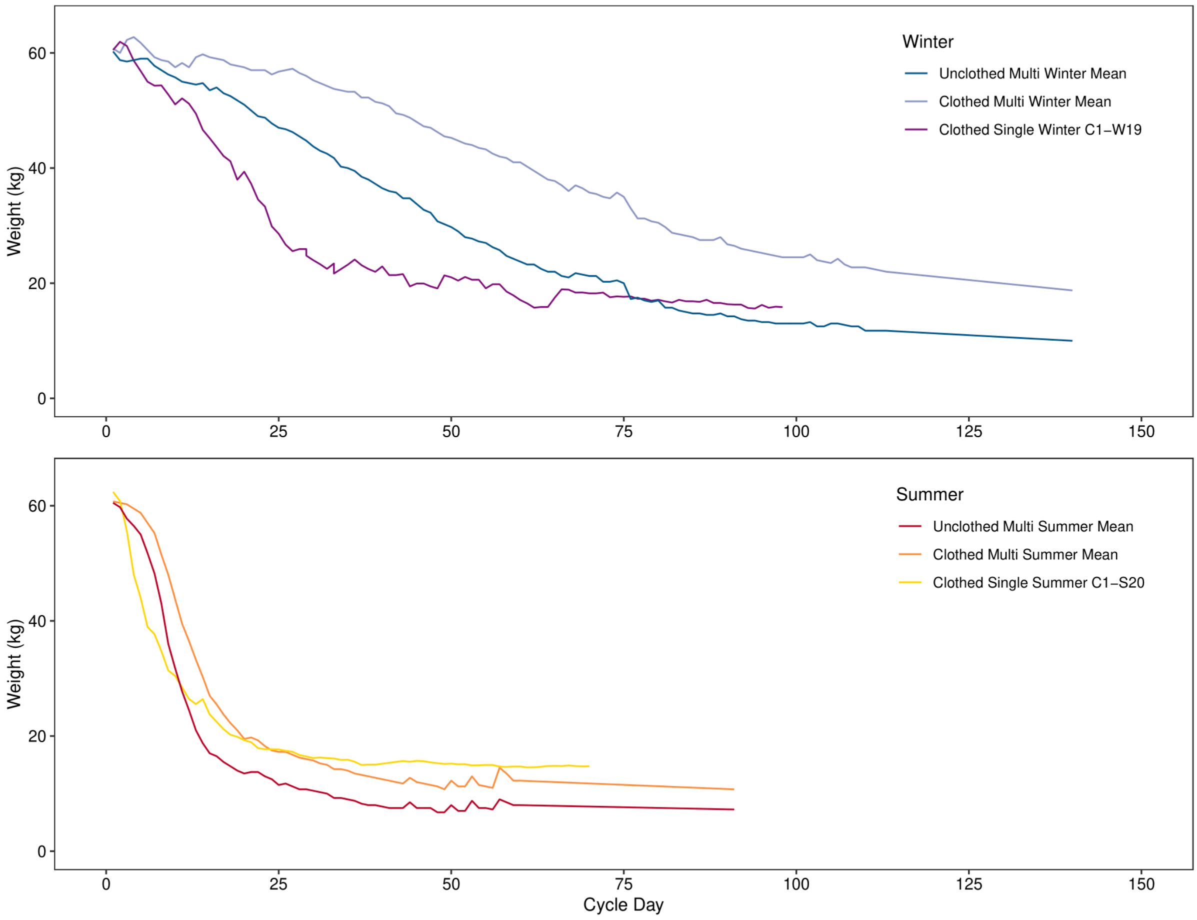

Figure 3.26: Weight loss plotted over time for clothed single carcasses and means for clothed and unclothed multi-carcass deployments in winter (top panel) and summer (bottom panel). C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram.

Table 3.24: The start, end, and duration of bloat in the head and neck, measured in days, for clothed single and multiple carcass deployments per season.

Clothing	Measure	Bloat Start	Bloat End	Length of Bloat
Single carcasses	Winter	5	15	10
	Summer	2	4	2
	Mean	4	10	6
Multi-carcass mean	Winter	17	52	35
	Summer	4	9	5
	Mean	10	30	20

Table 3.25 adds further detail to Figure 3.26: the two single carcasses took on average 8 days to reach 17% mass loss, compared to 25 days for the multiple carcasses; 13 days versus 36 to reach 34% loss; 17 days versus 47 to reach 51% loss; and 31 days versus 80 days to reach 68% mass loss. Similarly, the single carcasses required less thermal energy, as measured by ADD, to reach each percentile, also presented in Table 3.25. The single carcasses needed 139 ADD to reach 17% mass loss, compared to 366 ADD for the multi-carcass deployments; 231

ADD versus 567 to reach 34% loss; 304 ADD versus 790 to reach 51% loss; and 567 ADD versus 1477 to reach 68% mass loss. Despite these differences, the average percentage weight lost by the end of the cycle was very similar; 75% lost for the single carcasses compared to 76% for the multi-carcasses.

Table 3.25: Number of days and accumulated degree days (ADD) in parentheses to reach mass loss percentiles for clothed single and multiple carcass deployments per season.

Deployment	Season	17% mass loss	34% mass loss	51% mass loss	68% mass loss	Total	Weight loss %
Single carcass	Winter	13 (203.56)	20 (318.91)	24 (380.12)	45 (740.92)	99 (1738.58)	73.81
	Summer	3 (73.56)	6 (143.59)	10 (226.93)	18 (393.49)	70 (1495.08)	76.61
	Mean	8 (138.56)	13 (231.25)	17 (303.52)	32 (567.21)	85 (1616.83)	75.21
Multi-carcass mean	Winter	42 (557.60)	60 (905.75)	81 (1284.88)	140 (2512.45)	140 (2512.45)	69.14
	Summer	9 (173.91)	11 (227.42)	14 (295.24)	20 (440.65)	91 (1886.19)	82.30
	Mean	25 (365.76)	36 (566.58)	47 (790.06)	80 (1476.55)	116 (2199.32)	75.72

% = percentage.

Delving a little deeper, the effect of seasonality is emphasised in Figure 3.27, which provides a visual aid in the form of bar charts for each seasonal cohort. This figure portrays the large difference between the single and multi-carcass deployments in the total mean number of days and ADD to reach mass loss percentiles. Although both single carcasses in summer and winter showed increased decay rates across all mass loss milestones, this effect was more pronounced in winter, with greater differences in the number of days and ADD to each milestone between single and multiple clothed deployments. By contrast, the summer single and multi-carcass mean deployments were more similar.

The single clothed winter carcass experienced 17% mass loss in 13 days compared to an average of 41 days for the multiple winter carcasses; 20 days versus 60 to reach 34% loss; 24 days versus 80 to reach 51% loss; and 45 days versus 140 to lose 68% mass (Table 3.25). The comparison of thermal energy follows a similar pattern, with large differences in ADD values between the single winter carcass and the multi-carcass winter deployment, as depicted in Table 3.25. The single winter carcass reached 17% mass loss in 204 ADD compared to 558 for the multi-carcass mean; 319 ADD versus 906 to reach 34% loss; 380 ADD versus 1285 to reach 51% loss; and 741 ADD versus 2512 ADD to reach 68% mass loss.

In summer, the number of days and ADD to reach mass loss percentiles for both single and multiple carcasses were similar. However, the single carcass was still the quickest, with only 3 days to reach 17% mass loss compared to 9 for the multi-carcass mean; 6 days versus 11 to reach 34% loss; 10 days versus 14 to reach 51% loss; and 18 days compared to 20 days to lose 68% mass. Similarly, summer single clothed decomposition required less thermal energy than the multi-carcass clothed deployment, with 74 ADD required to reach 17% mass loss compared to 174; 144 versus 227 ADD to reach 34% loss; 227 ADD versus 295 to reach 51% loss; and 393 ADD versus 441 to reach 68% mass loss.

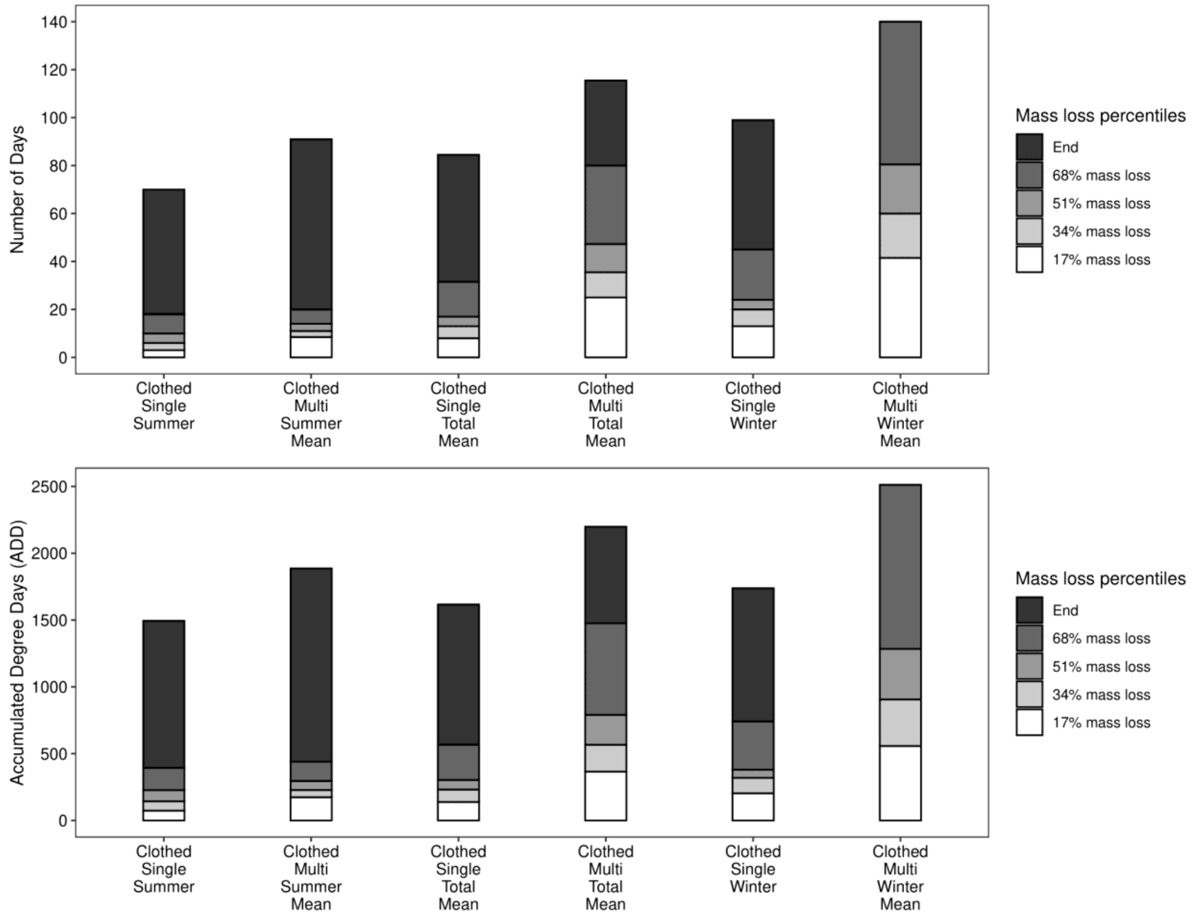

Figure 3.27: Number of days (top panel) and accumulated degree days (bottom panel) to reach mass loss percentiles for clothed single and multi-carcass deployments by season. % = percentage.

3.4.2 The effect of carrion biomass load on scavenging

In terms of scavenging, Table 3.26 shows that single carcasses had an average total mongoose visit number of 384 compared to 320 visits for the multi-carcass mean. However, individual mass loss percentiles were not always greater for single carcasses and showed more variability, with a mean of 103 mongoose visits for the single carcasses before 17% mass loss compared to 142 visits for the multi-carcass mean; 64 versus 54 visits to reach 34% loss; 39 versus 33 visits to reach 51% loss; and 92 versus 26 visits to reach 68% mass loss.

When assessing by season, there was a similar variation in mongoose visit number across the mass loss percentiles between single and multiple carcasses in winter. A total of 159 visits occurred to the single winter carcass by 17% mass loss compared to a mean of 186 to the multi-carcasses; an additional 98 visits versus a mean of 84 to reach 34% loss; 24 visits versus a mean of 48 to reach 51% loss; and a final 46 visits compared to a mean of 34 to reach 68% mass loss. In summer, the single carcass mongoose visits were more equally distributed across the mass loss percentiles than the multi-carcass deployment, which had a concentration of visits in the first 17% mass loss. The single carcass was visited 46 times before 17% mass loss compared to 99 times on average for the multi-carcass deployment; an additional 29 visits versus a mean of 24 to reach 34% loss; 53 visits versus a mean of 19 to reach 51% loss; and a further 138 visits compared to a mean of 19 to reach 68% mass loss.

Table 3.26: Mongoose visit number and duration (h:m:s) in parentheses by percentile for clothed single and multiple carcass deployments per season.

Deployment	Season	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End	Total
Single carcass	Winter	159 (43:35:44)	98 (12:32:11)	24 (1:01:21)	46 (1:57:12)	64 (1:08:45)	391 (60:15:13)
	Summer	46 (11:37:27)	29 (9:02:52)	53 (5:36:00)	138 (13:52:29)	111 (6:27:15)	377 (46:36:04)
	Mean	103 (27:36:35)	64 (10:47:31)	39 (3:18:41)	92 (7:54:50)	88 (3:48:00)	384 (53:25:38)
Multi-carcass mean	Winter	186 (19:33:00)	84 (2:04:18)	48 (0:34:26)	34 (0:12:50)	0 (0:00:00)	351 (22:24:34)
	Summer	99 (9:47:57)	24 (1:59:41)	19 (1:23:17)	19 (0:34:30)	129 (3:14:07)	288 (16:59:32)
	Mean	142 (14:40:29)	54 (2:02:00)	33 (0:58:51)	26 (0:23:40)	65 (1:37:03)	320 (19:42:03)

h:m:s = hours: minutes: seconds; % = percentage.

The total mean mongoose visit duration, also displayed in Table 3.26, shows that mongooses spent well over double the total time on the single carcasses with a mean of 53 hours compared to 20 hours for the multiple carcasses. Per weight loss percentile, single carcasses were visited consistently longer on average than the multiple carcasses. Single carcasses were visited by mongooses for 28 hours up to 17% mass loss compared to a mean of 15 hours for the multi-carcasses; 11 versus a mean of 2 hours to reach 34% loss; 3 versus a mean of 1 hour to reach 51% loss; and a further 8 hours compared to a mean of 23 min to reach 68% mass loss.

When examining mongoose visit duration by season, we see substantial differences within winter, as the single carcass experienced a duration of 44 hours up to 17% mass loss compared to a mean of 20 hours for the multi-carcass deployment; 13 versus a mean of 2 hours to reach 34% loss; 1 hour versus a mean of 34 min to reach 51% loss; and an additional 2 hours compared to a mean of 12 min to reach 68% mass loss. Although not as great as in winter, the single summer carcass similarly experienced a greater duration across all milestones, with 12 hours compared to a mean of 10 hours up to 17% mass loss; 9 versus a mean of 2 hours to reach 34% loss; 6 versus a mean of 1 hours to reach 51% loss; and a further 14 hours compared to a mean of 34 min to reach 68% mass loss.

The mongoose activity data is visually depicted in Figure 3.28, using bar charts to contrast the number of mongoose visits and duration to each percentile for single and multi-carcass deployments across both seasons and the total mean. This figure indicates that although the visit number was somewhat similar between deployments, vastly more time was spent at the single carcasses, regardless of the season. This figure also depicts the distributed nature of mongoose activity to the single summer carcass throughout the decomposition cycle. More visits of longer duration continued later into the summer cycle compared to the single winter carcass or both multi-carcass deployments. Figure 3.29 provides the percentage of visit number and duration within each mass loss percentile, indicating a slightly lower proportion of mongoose visits and duration occurring in the first 17% mass loss for the single carcasses on average, with a comparatively larger proportion spent later in the cycle. This dispersed mongoose activity throughout the cycle in single carcasses was exaggerated in summer, which showed the greatest proportion of mongoose visits and visit duration occurring in the final 68% mass loss.

Simultaneous scavenging by multiple mongooses was longer and contributed a greater proportion of the total visit duration in the single carcass deployments, as presented in Table 3.27. Single carcasses experienced a mean total multi-mongoose duration of 6 hours

(12%) compared to a mean of only 49 min (5%) for the multi-carcass deployment. As indicated in previous sections of the results, the summer cohort received more simultaneous attention from multiple mongooses; this was exaggerated for the single carcass, which received a total multi-mongoose visit duration of 10 hours (22%) compared to a mean of 2 hours (10%) for the multi-carcass deployment. By contrast, 2 hours (3%) was recorded for the single winter carcass and a mean of only 4 min (<1%) for the winter multi-carcass deployment. A similar pattern of little to no activity by multiple mongooses was observed throughout the decomposition cycle for both winter groups, despite the single carcass receiving more activity in total. The single winter carcass received a multi-mongoose visit duration of 1 hour (3%) for the first 17% of mass loss, compared to a mean of only 1 min (<1%) for the winter multi-carcass deployment; 7 min (1%) versus a mean of 0 min (0%) to reach 34% loss; 0 min (0%) versus a mean of 3 min (17%) to reach 51% loss; and 0 min (0%) for both groups to reach 68% mass loss. In contrast to this, the single summer carcass received 3 hours (27%) in the first 17% mass loss period compared to a mean of 1 hour (11%) for the multi-carcass deployment; 2 hours (18%) versus a mean of 17 min (11%) to reach 34% loss; 2 hours (30%) versus a mean of 4 min (5%) to reach 51% loss; and a further 3 hours (19%) compared to a mean of 2 min (10%) to reach 68% mass loss.

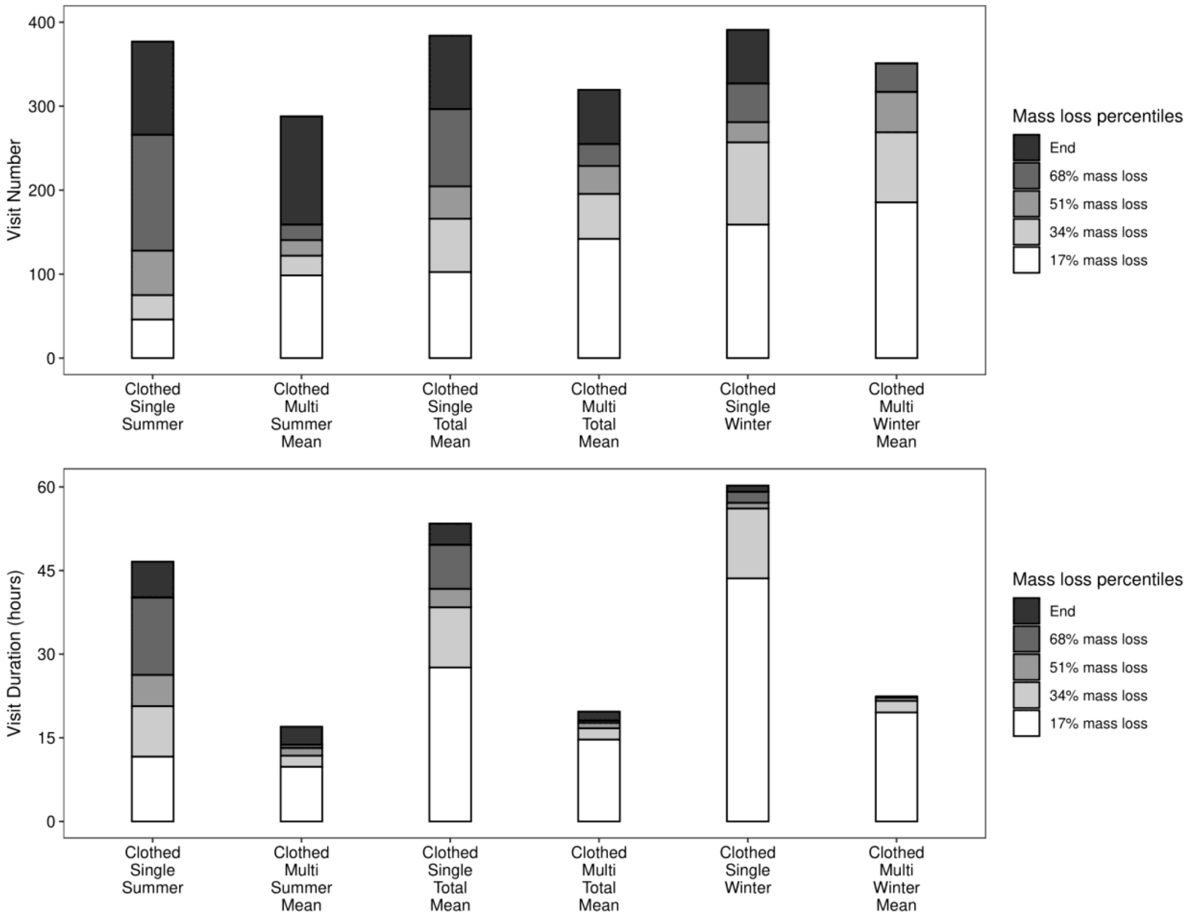

Figure 3.28: Number of mongoose visits (top panel) and visit duration (bottom panel) to reach mass loss percentiles for clothed single and multi-carcass deployments by season. % = percentage.

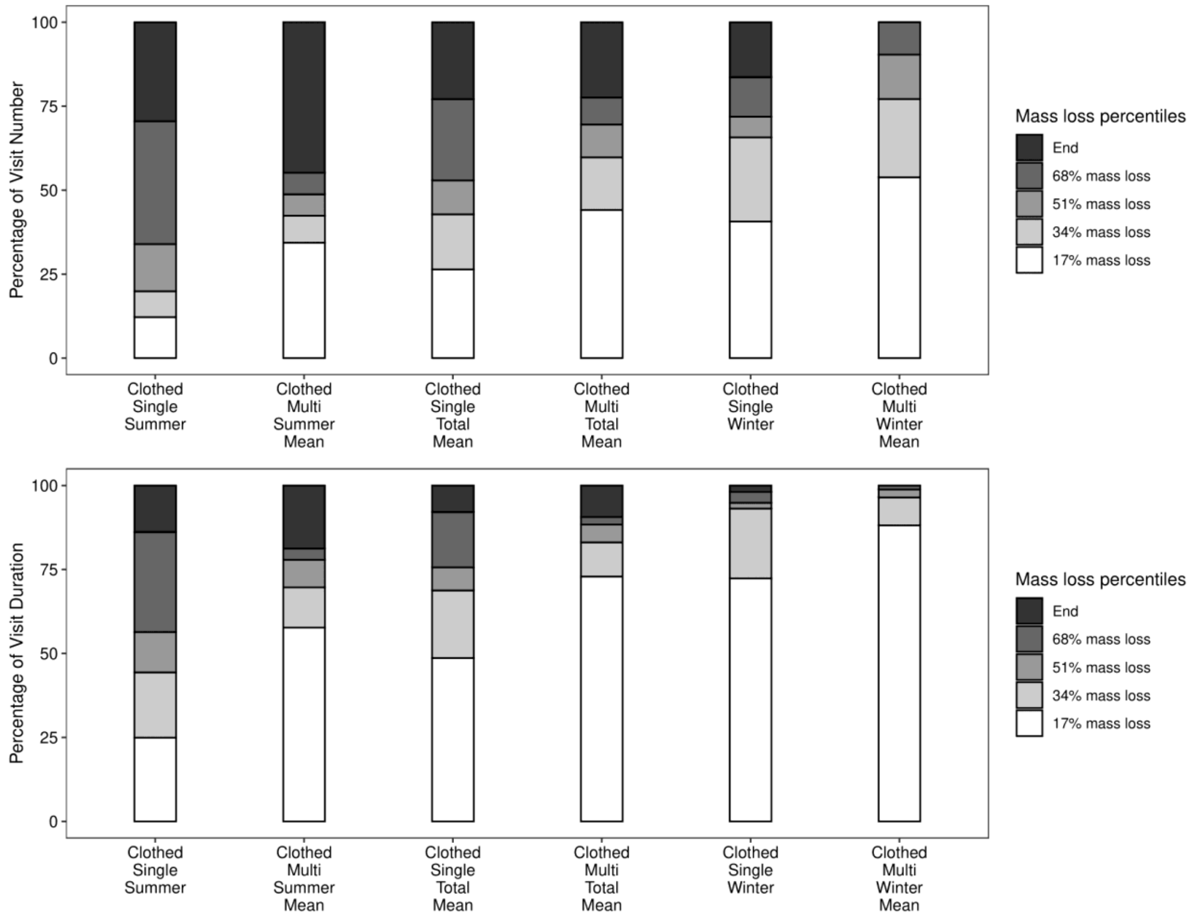

Figure 3.29: Percentage number of mongoose visits (top panel) and visit duration (bottom panel) to reach mass loss percentiles for clothed single and multi-carcass deployments by season. % = percentage.

Table 3.27: Multi-mongoose visit duration (h:m:s) and percentage in parentheses by percentile for clothed single and multiple carcass deployments per season.

Deployment	Season	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End	Total
Single carcass	Winter	01:21:25 (3%)	0:07:42 (1%)	0:00:00 (0%)	0:00:00 (0%)	0:02:49 (4%)	01:31:56 (3%)
	Summer	03:11:01 (27%)	01:38:37 (18%)	01:39:20 (30%)	02:41:27 (19%)	01:09:36 (18%)	10:20:01 (22%)
	Mean	02:16:13 (15%)	0:53:09 (10%)	0:49:40 (15%)	01:20:44 (10%)	0:36:13 (11%)	05:55:59 (12%)
Multi-carcass mean	Winter	0:01:05 (<1%)	0:00:00 (0%)	0:02:53 (17%)	0:00:00 (0%)	0:00:00 (0%)	0:03:58 (<1%)
	Summer	01:00:52 (11%)	0:17:05 (11%)	0:03:59 (5%)	0:02:35 (10%)	0:10:38 (8%)	01:35:09 (10%)
	Mean	00:30:58 (5%)	0:08:32 (5%)	0:03:26 (11%)	0:01:18 (5%)	0:05:19 (4%)	0:49:34 (5%)

h:m:s = hours: minutes: seconds; % = percentage.

3.4.3 Comparative analyses with existing data on a single clothed winter carcass

To provide a deeper level of analysis, the single winter clothed carcass data were compared with that collected by Du Toit (2019), who conducted a pilot study of a single clothed winter carcass in the same habitat in 2019 in collaboration with the author, Associate Professor Gibbon, and Dr Finaughty. The pilot study served as a proof of concept to test the automated weighing apparatus and the use of single clothed carcasses like those used in the current study. The Du Toit carcass was identically clothed but deployed earlier in the colder part of the year, and therefore, experienced differences in various weather variables compared to the winter weather previously documented in this study. These differences and the significance values are presented in Table 3.28. In general, the weather experienced by the Du Toit carcass was colder and more humid, with less solar radiation and wind but greater atmospheric pressure. Over 24-hours, Du Toit's average temperature was significantly colder with a maximum of 18 °C vs 24 °C, a mean of 13 °C vs 18 °C, and a minimum of 9 °C vs 13 °C. There was significantly less solar radiation with a max of 87 W/m^2 vs 361 W/m^2, and a mean of 15 W/m^2 vs 53 W/m^2. Humidity was significantly greater in Du Toit's cycle, with a maximum of 95% vs 91%, a mean of 84% vs 74%, and a minimum of 67% vs 52%. The atmospheric pressure was similarly significantly greater with a maximum of 1025 bar vs 1020 bar, a mean of 1022 bar vs 1017 bar, and a minimum of 1019 bar vs 1015 bar. Windspeed was significantly less for Du Toit's deployment with a maximum of 2 km/h vs 3 km/h, a mean of 0.7 km/h vs 1 km/h, but minimum windspeed was similar for both studies. Differences in 24-hour total rainfall were also insignificant, but a total of 65 mm fell over the whole of Du Toit's deployment and a mean total of 71 mm during the two winter deployments of the present study. Differences in the daytime and night-time weather variables followed similar patterns of significance. The data are provided in Table 3.28.

The line plots in Figure 3.30 provide a visual comparison of the rate of weight loss experienced by the various cohorts of winter carcasses, including Du Toit's carcass, which lost weight more gradually, at a rate between the multi-carcass clothed and unclothed groups of the present study. The single clothed carcass from the current investigation (C1-W19) decayed more rapidly by contrast. This discrepancy between the two single, clothed carcass deployments may be attributable to the difference in recorded weather variables.

Table 3.28: T-test differences in average weather variables between winter deployments and comparative data from Du Toit (2019).

Period	Weather Variable	Measure	Du Toit	Spies	Difference	*t*-statistic	*p*-value
24 Hours	Temperature (°C)	Max	17.55	24.06	-6.51	-13.97	**0.000**
		Mean	12.87	17.80	-4.92	-17.17	**0.000**
		Min	9.16	12.91	-3.75	-10.65	**0.000**
	Solar Radiation (W.m^{-2})	Max	86.55	360.51	-273.97	-14.97	**0.000**
		Mean	14.57	53.39	-38.82	-19.09	**0.000**
		Sum	349.60	1281.01	-931.40	-19.08	**0.000**
	Rainfall (mm)	Max	0.37	0.28	0.09	1.04	0.299
		Mean	0.03	0.03	0.01	0.88	0.379
		Sum	0.75	0.59	0.16	0.85	0.399
	Humidity (%)	Max	94.71	90.43	4.28	6.40	**0.000**
		Mean	84.47	74.11	10.36	9.63	**0.000**
		Min	67.22	51.89	15.33	8.06	**0.000**
	Pressure (bar)	Max	1024.52	1019.97	4.55	7.98	**0.000**
		Mean	1021.68	1017.27	4.41	7.51	**0.000**
		Min	1019.00	1014.98	4.02	6.47	**0.000**
	Windspeed (km.h^{-1})	Max	2.20	2.72	-0.53	-2.27	**0.025**
		Mean	0.67	1.06	-0.39	-3.44	**0.001**
		Min	0.07	0.08	-0.01	-0.15	0.880
Day	Temperature (°C)	Max	17.51	24.05	-6.54	-13.95	**0.000**
		Mean	14.30	19.50	-5.20	-16.48	**0.000**
		Min	9.74	13.29	-3.55	-9.27	**0.000**
	Solar Radiation (W.m^{-2})	Max	86.55	360.51	-273.97	-14.97	**0.000**
		Mean	31.06	89.25	-58.19	-18.22	**0.000**
		Min	0.08	29.84	-29.76	-16.53	**0.000**
		Sum	349.55	1280.87	-931.33	-19.08	**0.000**
	Rainfall (mm)	Max	0.21	0.13	0.08	1.25	0.215
		Mean	0.03	0.02	0.01	0.99	0.321
		Sum	0.29	0.24	0.05	0.45	0.651
	Humidity (%)	Max	93.64	88.99	4.65	5.60	**0.000**
		Mean	80.35	68.49	11.86	8.78	**0.000**
		Min	67.43	22.24	45.19	18.43	**0.000**
	Pressure (bar)	Max	1023.32	1018.73	4.58	7.48	**0.000**
		Mean	1021.63	1017.15	4.48	7.25	**0.000**
		Min	1020.04	423.42	596.62	18.42	**0.000**
	Windspeed (km.h^{-1})	Max	1.97	2.60	-0.62	-2.86	**0.005**
		Mean	0.92	1.35	-0.42	-3.12	**0.002**
		Min	0.19	604.95	-604.76	-18.58	**0.000**

°C = degrees Celsius; mm = millimetres; % = percentage; W.m^{-2} = Watts per square meter; km.h^{-1} = kilometres per hour; *t* statistic from Welch two sample *t*-test; significant differences ($p < 0.05$) are denoted by bold type.

Continued

Table 3.24 *Continued*

Period	Weather Variable	Measure	Du Toit	Spies	Difference	*t*-statistic	*p*-value
Night	Temperature (°C)	Max	14.67	17.81	-3.14	-11.87	**0.000**
		Mean	11.61	15.35	-3.74	-13.59	**0.000**
		Min	9.40	13.28	-3.88	-11.22	**0.000**
	Solar Radiation ($W.m^{-2}$)	Max	0.06	0.13	-0.08	-2.08	**0.038**
		Mean	0.00	0.01	-0.01	-2.36	**0.019**
		Sum	0.06	0.13	-0.08	-2.08	**0.038**
	Rainfall (mm)	Max	0.24	0.18	0.06	0.94	0.346
		Mean	0.04	0.03	0.00	0.30	0.767
		Sum	0.46	0.35	0.11	0.80	0.422
	Humidity (%)	Max	93.34	88.30	5.04	7.43	**0.000**
		Mean	88.11	82.24	5.87	6.87	**0.000**
		Min	78.56	74.28	4.28	3.38	**0.001**
	Pressure (bar)	Max	1024.28	1019.85	4.43	7.87	**0.000**
		Mean	1021.73	1017.46	4.27	7.55	**0.000**
		Min	1019.20	1015.43	3.77	6.11	**0.000**
	Windspeed ($km.h^{-1}$)	Max	1.25	1.57	-0.33	-1.50	0.135
		Mean	0.46	0.64	-0.18	-1.75	0.082
		Min	0.07	0.12	-0.05	-0.90	0.368

°C = degrees Celsius; mm = millimetres; % = percentage; $W.m^{-2}$ = Watts per square meter; $km.h^{-1}$ = kilometres per hour; *t* statistic from Welch two sample *t*-test; significant differences ($p < 0.05$) are denoted by bold type.

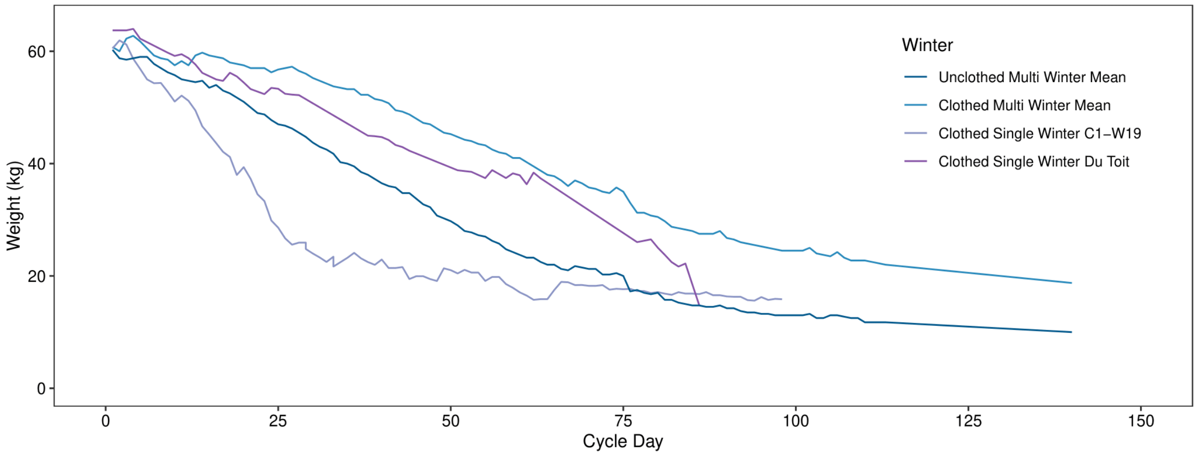

Figure 3.30: Weight loss plots over time for the winter clothed single carcass, comparative single clothed carcass studied by Du Toit (2019) and means for both clothed and unclothed multi-carcass deployments. C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; kg = kilogram.

Further information on the rate of weight loss for Du Toit's carcass, as measured in the number of days and ADD to the same mass loss milestones, is presented in Table 3.29. The single clothed winter carcass from the present study progressed more rapidly through the percentiles, requiring 13 days to lose 17% of its weight compared to 23 days for Du Toit's single carcass; 20 days versus 45 to reach 34% loss; 24 days versus 71 to reach 51% loss; and only 45 days compared to 85 to reach 68% mass loss. Similarly, less thermal energy was required to progress to each mass loss milestone, as C1-W19 required 204 ADD compared to 298 ADD to reach 17% mass loss; 319 ADD versus 584 to reach 34% loss; 380 ADD versus 905 to reach 54% loss; and 741 ADD compared to 1097 to reach 68% mass loss.

Table 3.29: Number of days and accumulated degree days to reach mass loss percentiles for the winter single clothed carcass and Du Toit's (2019) comparative single clothed carcass.

Measure	Deployment	17% mass loss	34% mass loss	51% mass loss	68% mass loss	Total	Weight loss %
Days	C1-W19	13	20	24	45	99	73.81
	Du Toit	23	45	71	85	85	68.00
ADD	C1-W19	203.56	318.91	380.12	740.92	1738.58	73.81
	Du Toit	297.78	584.19	905.37	1096.65	1107.12	68.00

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; % = percentage.

In terms of scavenging activity, there were some stark differences between C1-W19 and Du Toit's carcass, with C1-W19 receiving substantially less activity by mongooses. The single clothed carcass deployed by Du Toit was also only scavenged by the Cape grey mongoose but received comparatively more attention, as presented in Table 3.30, which provides the mongoose visit number and duration, along with the multi-mongoose visit duration and percentage. There were 159 mongoose visits to C1-W19 compared to 249 visits to Du Toit's carcass before 17% mass loss; 98 versus 274 visits to reach 34% loss; 24 vs 227 visits to reach 51% loss; 46 vs 51 visits to reach 68% loss; and a total of 391 mongoose visits to C1-W19 vs 802 visits to Du Toit's carcass across the study cycle. Visit duration was similarly less for C1-W19, with a duration of 43 hours compared to 59 hours for Du Toit's carcass until 17% mass loss; 12 vs 34 hours to reach 34% loss; 1 vs 23 hours to reach 51% loss; 2 hours vs 1 hour to reach 68% loss; and a total of 60 hours for C1-W19 compared to 117 hours Du Toit. The multi-mongoose visit duration for C1-W19 was 1 hour (3%) compared to 8 hours (13%) for Du Toit's carcass up to 17% mass loss; 8 min (1%) vs 5 hours (15%) to reach 34% loss; 0

min (0%) vs 7 hours (30%) to reach 51% loss; 0 min (0%) for both carcasses to reach 68%; for a total of 1.5 hours (3%) vs 19.5 hours (17%) over the total deployment.

Table 3.30: Mongoose visit number and duration (h:m:s) by mass loss percentiles for the winter single clothed carcass (C1-W19) and Du Toit's single clothed carcass.

Measure	Deployment	17% mass loss	34% mass loss	51% mass loss	68% mass loss	End	Total
Visit number	C1-W19	159	98	24	46	64	391
	Du Toit	249	274	227	51	1	802
Visit duration	C1-W19	43:35:44	12:32:11	1:01:21	1:57:12	1:08:45	60:15:13
	Du Toit	59:17:29	34:13:20	22:46:16	1:17:09	0:00:02	117:34:16
Multi-visit duration	C1-W19	1:21:25	0:07:42	0:00:00	0:00:00	0:02:49	1:31:56
	Du Toit	7:47:57	4:58:47	6:45:02	0:00:00	0:00:00	19:31:46
Multi-visit percentage	C1-W19	3	1	0	0	4	3
	Du Toit	13	15	30	0	0	17

C = clothed; UC = unclothed; W = winter; S = summer; 18/19/20 = year of deployment; % = percentage; h:m:s = hours: minutes: seconds.

3.4.4 Summary

Single clothed carcasses lost weight more rapidly than clothed carcasses deployed simultaneously with other available carrion sources, even when compared to unclothed multi-carcass deployments. Single clothed carcasses also experienced a quicker and shorter bloat period than the clothed multi-carcass deployments. This increased decay rate was exaggerated in winter but less evident in summer. Single carcasses required fewer days and accumulated degree days (ADD) to reach defined mass loss milestones. Although mongoose visit numbers were usually greater to begin with for multi-carcass clothed deployments, the visits to single carcasses remained high later in the decay cycle, unlike the visit drop-off seen during multi-carcass deployments. This resulted in a greater total number of visits to single carcasses for both seasons. Mongoose visit duration was always greater for single carcasses than multi-carcasses across both seasons and all mass loss percentiles, with more than double the total time spent at single carcasses. The single clothed summer carcass experienced the most evenly distributed mongoose activity throughout the decomposition cycle in terms of visit number, duration, and relative proportion. A comparison of the single clothed winter carcass (C1-W19) to a comparative dataset of another clothed single winter carcass, examined by Du Toit (2019), revealed some notable differences between the two: C1-W19 decayed more rapidly, as measured by the visual weight loss curve and the number of days and ADD to reach mass loss milestones. However, several weather variables were significantly different between the deployments, namely Du Toit’s winter cycle was significantly colder, with less solar radiation and wind, but with more humidity and greater pressure. Scavenging activity was also vastly different between the two single carcass deployments, with Du Toit’s carcass receiving more mongoose visits of longer duration, for nearly double the total visit number and duration. Similarly, visits by multiple mongooses also occurred more for Du Toit’s carcass for a greater percentage of total mongoose visit duration.

Chapter 4: Discussion

This study was designed to investigate several key questions that arose during previous taphonomic studies in the Western Cape province, South Africa. Primarily, how the rate and process of decomposition are affected by clothing and whether clothing would interfere with vertebrate scavenger activity under different experimental conditions. These included the influence of season, as weather variables are known to affect decay, and carrion biomass load, as an understudied aspect in the taphonomic literature. This investigation was also designed to address whether common taphonomic research practices, like using large samples of unclothed, caged remains, are forensically realistic and appropriate to feasibly generate accurate measures of decay progression for PMI estimation. Accurate, regional PMI methods, based on common forensically realistic scenarios and incorporating the effects of frequently encountered variables like clothing, scavenging, and season, are crucial for identifying remains to provide justice and closure to loved ones.

The discussion chapter is divided into five sections, starting with statements on the novelty and the technological advancements of this investigation, highlighting the contribution to the taphonomic literature. The decomposition and scavenging results are discussed next, covering some general observations before delving into the effect of clothing, seasonality, and carrion biomass load, respectively. Finally, the chapter concludes with a section on this study's limitations before highlighting the forensic implications and recommendations for future researchers.

4.1 Novelty statement

This research project was the first investigation into the influence of clothing on decomposition in the Western Cape, aimed at identifying novel factors impacting post-mortem interval estimation. The project used seasonally appropriate clothing, based on evidence from forensic casework, which was tailored to fit the carcass mimicking clothing on a human to prevent unrealistic vertebrate scavenger access. Although previous research has investigated clothing (Cahoon, 1992; Kelly, 2006; Kjorlien, Beattie & Peterson, 2009; Matuszewski et al., 2014; Capobianco & Christensen, 2017), the methods of tailoring, which improved the robusticity and forensic relevance of the project, has not previously been documented in the literature. This study was the first to investigate the effect of carrion biomass load on the rate of decomposition by directly comparing deployments of single and multiple carcasses in the same season and environment. This aspect stemmed from carrion ecology theory and has not been previously reported in the taphonomy and forensic anthropology literature. This research is globally innovative and is helping to push international and national boundaries in taphonomic study design and standards of best practice for establishing accurate, quantitative, and less disruptive data collection techniques.

4.2 Technological advancements

Weight loss measures were first conducted manually every day with a block and tackle, but in the latter half of the study, an automated weighing apparatus was utilised to increase measurement accuracy, decrease human disturbance to the environment and scavengers, and decrease costs and travel-time associated with daily site visits. The automated system (Finaughty, Spies, et al., 2020; Finaughty et al., 2021), developed by the team outlined in the Materials and Methods Chapter, was the first of its kind internationally. The device was field-tested once in June 2019 independently of this investigation (Du Toit, 2019) before updated iterations were implemented in this study's third and fourth cycles (September 2019 and January 2020). The system lifted and recorded weight readings automatically once every night, reducing the necessary researcher site visits for data collection from daily to weekly and preventing weight lifts during the day when scavengers were active. Nightly manual weight lifts in cycles 1 and 2 were not possible for access and safety reasons. This method caused a reduction of missing data. In cycles 1 and 2, there was a combined total of 25% (59/232) missing manual weight readings due to site access issues, but in cycle 4 only 7% (5/70) of the automated weight readings were missing due to five single-recording unanticipated system errors. This represents a vast improvement in the completeness of the data set compared to the first taphonomic study in the Western Cape conducted by Finaughty (2019) during 2014-2016, who manually collected data using a staggered approach, resulting in a cumulative total of 38% (600/1562) of the data requiring imputation. Although requiring an initial investment and perhaps some external expertise, similar systems are recommended for future taphonomic research, as the automated weighing apparatus reduced the amount of missing data, researcher disturbance to the environment, and the time and travel costs associated with data collection (Finaughty, Spies, et al., 2020; Finaughty et al., 2021). The next section of this chapter will discuss the analysed data on decomposition and scavenging collected during this study in more detail.

4.3 Decomposition and scavenging

4.3.1 General observations on decomposition and scavenging

Decomposition was quantitatively measured via weight loss to reduce researcher bias and circumvent logistical challenges of assessing visual states of decay of carcasses obscured by clothing. In addition, the visual stages approach to measuring decomposition has been criticised for being qualitative, subjective, and ignoring the continuous and mosaic nature of the decomposition process (Carter, Yellowlees & Tibbett, 2007; Matuszewski et al., 2010; Michaud, Schoenly & Moreau, 2015). Therefore, the methodology in this study focused on the use of weight loss as a quantitative measure of the active decay rate, with visual methods only used as a guide when estimating the onset and end of bloat in the head and neck, confirmed via calibrated photographic measurement, as additional data to support the measures of weight loss. The rate of weight loss and onset and duration of bloat was highly variable across the sample, with some distinct differences between the clothing, season, and carrion biomass load groups. These are discussed in more detail in the subsequent sections of this chapter.

Total body score methods, which rely on visual body changes correlated with ADD or temperature and humidity to estimate PMI, such as those developed by Megyesi, Nawrocki & Haskell (2005) and Vass (2011), respectively, have produced significantly different results for the actual and calculated PMI in different habitats (Myburgh et al., 2013; Spencer, 2013; Marhoff et al., 2016; Suckling, Spradley & Godde, 2016; Forbes et al., 2019). Although these methodologies were not directly assessed in this study, the collected ADD data supports previous researchers' assertions of inaccuracy, as different individual carcasses required vastly differing amounts of accumulated thermal energy to reach the same weight loss milestones, depending on the season, clothing, and carrion biomass load. The aforementioned TBS/ADD methods remain reliant on qualitative visual interpretations of states of decay (Hayman & Oxenham, 2020) and constants for environmental variables developed using data from specific regions. Although researchers have indicated that the TBS scoring method is reliable for trained users, it is less accurate in mosaic and late-stage decomposition (Nawrocka, Frątczak & Matuszewski, 2016). Therefore, the method continues to suffer from the same shortcomings of subjectivity. The environmental variables and constants used in these formulae, namely ADD, temperature, and humidity, are regionally specific, vary with season, and cannot be universally applied; additional variables also need to be considered, and regional formulae developed (Cockle & Bell, 2015, 2017; Giles et al., 2020). Therefore, these methods can be of little help in forensic cases from environments other than those in which the methods were developed (Pittner et al., 2020). The results from this study, as well as others, indicate that the exclusion of scavenging activity from PMI estimation methods may also lead to inaccuracies given the extent that scavengers can alter the decay rate and how widespread carrion use is in the animal kingdom (DeVault, Rhodes & Shivik, 2003; Spies, Gibbon & Finaughty, 2018; Steadman et al., 2018; Barton et al., 2019; Beasley et al., 2019; Benbow et al., 2019; Olea, Mateo-Tomás & Sánchez-Zapata, 2019). As such, scavenging must be incorporated into future PMI estimation methods (Giles et al., 2020). Multiple methods should be used in conjunction, along with interdisciplinary collaboration, to improve the accuracy of PMI estimation and the chances of correct identification (Pittner et al., 2020; García et al., 2021). Although insect activity is a known and significant contributor to tissue breakdown and was evident in the current study, this investigation focused on the relatively understudied influence of vertebrate activity, with a similar focus on invertebrates outside the scope of this study. Given the importance of vertebrate scavenging, general observations on the observed scavenging activity are discussed next.

As expected from previous research in this region conducted by Finaughty (2019) followed by the author's Honours thesis (Spies, 2017; Spies, Finaughty & Gibbon, 2018; Spies, Gibbon & Finaughty, 2018) and that of Du Toit (2019), the Cape grey mongoose was the only vertebrate scavenger species observed in this habitat. There are few alternative species in and around Cape Town that could scavenge remains, apart from domestic dogs and cats were they able to gain access. Additional species that may foreseeably scavenge opportunistically and be of forensic interest in rural or mountainous regions around Cape Town include caracal (*Caracal caracal*), the Cape leopard (*Panthera pardus*), the honey badger (*Mellivora capensis*), the Cape fox (*Vulpes chama*), genets (Genetta spp.), Chacma baboons (*Papio ursinus*), and pied crows (*Corvus albus*) (Finaughty, 2019). Scavenging by the Cape grey mongoose was recorded prolifically on all carcasses, in line with recent work, despite previous research indicating a diet consisting predominantly of small vertebrates and insects in varying proportions, with only a small percentage consisting of carrion (Smithers, 1983; Cavallini & Nel, 1990a). Mongoose activity was recorded near exclusively during the day, supporting the diurnal nature of the species previously observed (Smithers, 1983; Cavallini & Nel, 1990b; Finaughty, 2019). Activity usually began within a few minutes to hours following deployment in the morning, as seen in the intensity maps, Figures 3.7, 3.18, and 3.19. This may indicate the species is readily able to detect carrion in the environment but may also signify the mongooses becoming accustomed to carrion appearing in the area given the previous years of research. This point is reiterated as a necessary area of future research.

The scavenging activity of the Cape grey mongoose was affected by the presence of clothing, the season, and the carrion biomass load; these aspects are discussed in more detail in the sections to follow. The sequence that the mongoose scavenged regions of the remains followed similar patterns to that observed by Finaughty (2019) during 2014-2016, the author during 2017 (Spies, 2017; Spies, Gibbon & Finaughty, 2018), and Du Toit during 2019 (Du Toit, 2019; Finaughty et al., submitted). Scavenging activity typically began very soon after deployment at the head/snout and then the anus in unclothed individuals or the abdomen when clothed. French (2020) also found the head and abdomen to receive the highest frequency of mongoose scavenging activity. A comparison of mongoose feeding behaviour is best made with other opportunistic scavengers of comparable size, namely the common or northern racoon, the striped skunk, and the Virginia opossum from North America. The mongooses' initial behaviour is similar to the racoon, which also begins porcine scavenging at the snout (Steadman et al., 2018). However, the racoon and the striped skunk both prefer to feed by making a small hole in the skin to remove tissue, leaving behind a layer of skin that rapidly desiccates (Morton & Lord, 2006; Synstelien, 2015; Jeong, Jantz & Smith, 2016; Pokines & Pollock, 2018; Steadman et al., 2018; Smith & Connor, 2020; Smith & Wankmiller, 2020; Smith, 2021). This is unlike the mongoose, which would remove larger sections of abdominal skin, but both mongoose and racoon appear to target skeletal muscle as the preferred food source (Steadman et al., 2018). The quick onset of mongoose feeding is similar to the racoon but differs from the opossum and skunk, which both prefer tissue that is beginning to putrefy and soften or has been previously softened by the activity of an alternative scavenger such as the racoon (Morton & Lord, 2006; Synstelien, 2015; Jeong, Jantz & Smith, 2016; King et al., 2016; Steadman et al., 2018; Smith, 2021). Similar to the mongoose, skunks climb atop remains or dig beneath and around them to consume maggots (Smith & Wankmiller, 2020; Smith, 2021).

Scavenging activity on and around carrion is known to cause the scatter of skeletal elements, obscuring the context of the remains. This phenomenon was only observed once in the present study, following the same pattern of movement into denser undergrowth away from the carcass, described in previous research (Spies, 2017; Spies, Finaughty & Gibbon, 2018). A hypothesised reason for the limited scattering observed in the current study compared to previous work is the use of a greater number of larger carcasses deployed simultaneously, as the previous pilot study utilised only two 20 kg carcasses accessible to scavengers, which may be considered child-sized (Morton & Lord, 2006; Spies, 2017; Spies, Finaughty & Gibbon, 2018). The smaller, more juvenile bones of the previous study may be more readily disarticulated by small scavengers like mongooses than larger, more developed bones of the carcasses used in the present study. Additionally, the dramatic increase in the available soft tissue on which to feed in the present study may have limited competition and the need to relocate segments of the skeletal remains for continued feeding in a more secure environment. Moleón et al. (2015) observed decreased competition between scavengers consuming large carcasses (>100 kg). Although not on the same individual scale as the large carcasses examined by Moleón et al. (2015), the difference in total biomass between the previous study (40 kg) and the present study (240 kg per multi-carcass deployment) represents a substantial increase in the total available carrion, and a similar effect is likely. As such, decreased disarticulation and scattering is a logical outcome of reduced competition, given the abundance of carrion to preferentially consume first. As indicated by Spies, Finaughty & Gibbon (2018), the bones of the hands and feet of adult human remains were predicted, and observed in casework, to be the most common skeletal elements to be scattered by small vertebrate scavengers like a mongoose – this is supported by the current findings, as the rear left hoof was the only element scattered after the shoe had been removed by mongoose activity.

Other scavengers similar to the mongoose are also known to scatter skeletal elements. King et al. (2016) reported opossums scattering metapodials and phalanges at a similar distance of between 6 - 10 m away from the carcass, as well as to cache small elements.

Raccoons appear to scatter remains only minimally (Hannigan, 2015). The movement of small skeletal elements by the small Indian mongoose has been reported by Dibner, Valdez & Carter (2019), although distances were not recorded. These scavengers appear to have little impact on weight loss progression and feed mainly on insect larvae (Dibner, Valdez & Carter, 2019). Red foxes (*Vulpes vulpes*), although larger than mongooses, are relatively small canids and appear to scatter remains linearly towards areas of high vegetation, fallen tree branches or dens to cache them, similar to the mongoose, between 10 - 45 m away (Young, Márquez-Grant et al., 2015). Elsewhere in South Africa, the Cape grey, slender, water, yellow, and banded mongoose species have been observed to scavenge on remains, to scatter goose remains, but cause relatively little movement of larger porcine skeletal elements (Shaw et al., 2015; Keyes, Myburgh & Brits, 2021a,b). Other larger animals, such as domestic dogs, coyotes, vultures, foxes, and badgers, can disperse remains over vastly larger areas (Haglund, Reay & Swindler, 1989; Kjorlien, Beattie & Peterson, 2009; Cameron & Oxenham, 2012; Beck et al., 2015; Young, Márquez-Grant et al., 2015; Keyes, Myburgh & Brits, 2021b). It is important to note that not all post-mortem movement is a consequence of vertebrate scavengers; body position may be vastly altered by insect activity and the baseline natural decomposition process such as bloating in the early phase and ligaments and other tissues contracting due to moisture loss later in the cycle (Wilson et al., 2020). However, vertebrate scavenging activity can cause drastically more post-mortem movement and scatter skeletal elements over varying distances, accelerate the decomposition rate and lead to early skeletal exposure. To prevent inaccurate PMI estimates, methods to estimate the time since death need to be developed to account for scavenging activity. Clothing is an additional variable that needs to be considered for PMI estimation methods and is subsequently discussed.

4.3.2 How does clothing affect decomposition and scavenging?

Most forensic cases, both locally and abroad, involve decedents that are partially or wholly clothed, which can modulate the effect of weather (Galloway et al., 1989; Komar, 1998, 2003; Miller, 2002; Steadman, 2015; Juglan et al., 2016; Baliso, 2018, 2020; Baliso, Finaughty & Gibbon, 2019; Alfsdotter & Petaros, 2021). Although the effect of clothing has been previously investigated elsewhere, environments and methodologies are inconsistent: as indicated in the introduction chapter, most taphonomic research has simply not incorporated clothing, but when clothing has been investigated, seasonally appropriate clothing types are not utilised, differing animal and human models are used, or the clothing is not tailored to fit non-human samples (Kjorlien, Beattie & Peterson, 2009; Phalen, 2013; Matuszewski et al., 2014; Capobianco & Christensen, 2017). These differences in methodology, along with differences in climate, weather, geography, and inherent differences between porcine and human decomposition, have produced inconsistent results, highlighting the need for regionally specific research conducted using a standardised protocol of forensic realism. Baliso (2020) found that most local forensic anthropology cases involved clothed remains (58%). This is supported by the retrospective analysis of FACT case files conducted during the present study; up to 70% are clothed when cases with no clothing information were excluded. Similar data may be found elsewhere with many historical case files lacking information on clothing, but those that do contain information, or more recent cases indicate clothing is prevalent (Marks, 1995; Galloway, 1997; Komar, 1998, 2003; Young, Márquez-Grant et al., 2015). Therefore, an investigation into the effect of clothing on the local decomposition process was required. This was the first study in the Western Cape to compare clothed and unclothed decomposition and the first internationally to use tailored clothing for an animal model, to the best of the author's knowledge.

The clothing in this study was tailored to fit the pigs appropriately, accounting for differences in human and pig anatomy. Specifically, the trouser legs and jersey arms were shortened and tapered to mimic realistic clothing worn by humans and prevent a large leg opening for unrealistically easy vertebrate and invertebrate access to the hind limbs. Although the limbs themselves were not a major target for scavenging activity in this study, a large, loose trouser leg opening would have allowed the mongoose direct access to the anal region, which was a preferred initial feeding site on unclothed carcasses in this study as well as previous studies (Spies, Gibbon & Finaughty, 2018; Finaughty, 2019). Therefore, the tailored clothing acted as a realistic barrier for small mammal scavengers, as would be expected from clothed human remains. The altered clothing ensured the fit of the clothes was appropriate and realistic, increasing the forensic realism of the research. Without information on the date-of-death and rarely any corroborating evidence for PMI estimates, the clothing worn by individuals in these forensic case reports may not represent clothing for a specific season but rather be a consequence of unseasonably hot or cold weather on a particular day. Additionally, a common behaviour amongst possibly homeless, indigent, or transient people observed by FACT members during casework and documented in the case files is to wear multiple layers of clothing for ease of transport, even during relatively warm temperatures. These issues were addressed by extracting the most common clothing types observed from case files and anecdotal evidence and creating seasonally appropriate variations of this wardrobe for the study that are likely to be worn during a given set of weather conditions, in turn, associated with a given season. This ensured that the clothing used in each season was forensically realistic, however, it did result in differences in the weight and moisture absorption capabilities of the different clothing sets used in the summer and winter clothed groups. The absolute value of the winter clothing weight should not impact the interpretation of the results directly, as the rate of weight loss was the most crucial aspect examined, not the weight itself. The percentage weight loss was calculated using the starting weight of each carcass, which included any clothing. The winter clothing would allow for increased moisture absorption compared to the summer clothing, and this may have impacted the rate of decay. However, figures 3.22, 3.23, 3.24, and 3.25 indicate that although weight increased after a rainfall event, it rapidly decreased again once rainfall ceased. This was true for both clothed and unclothed carcasses, indicating that the increased moisture absorbed by the more heavily clothed winter carcasses still evaporated quickly.

In both hotter, drier summer months and cooler, wetter winter months, the presence of clothing appears to inhibit the rate of decay and limit total weight loss. Clothing also prolonged the bloating of the head and neck regardless of the season but did not appear to influence its onset. However, this inhibiting effect was more prominent in winter, where weight loss was considerably more gradual in clothed rather than unclothed carcasses (Spies et al., 2020a), and bloating was more prolonged. In winter, clothed carcasses took substantially longer across all benchmarks compared to unclothed winter carcasses. In summer, the single layer of a cotton T-shirt and double layer of cotton blend underwear and trousers had a comparatively negligible effect on the decay rate in terms of both bloat duration and mass loss, although still present. This generally supports Galloway et al. (1989), Voss, Cook & Dadour (2011), and Capobianco & Christensen (2017), who reported a general reduction in the decay rate of clothed human or porcine remains in Arizona, USA (BWh – arid, desert, hot), Western Australia, (Csb – temperate, dry and warm summer), and Tennessee, USA (Cfa – temperate, without dry season, hot summer) respectively. Capobianco & Christensen (2017) indicated that the delaying effect might vary with the season but found no significant difference between warmer and cooler weather. The authors also highlighted that increasing the amount of clothing may have an effect, which supports the results of the present study, as winter clothed carcasses were dressed in an additional, thicker polyester layer over the torso. The current study's results also partially agree with the work done by Matuszewski et al. (2014) in Western Poland (Dfb – cold, without dry season, warm summer), indicating the effect of moderate, single-layer clothing on porcine decomposition is negligible in the warmer months. Thicker clothing in colder weather was not investigated (Matuszewski et al., 2014, 2016).

The results of the current investigation do not support the conclusions of Cahoon (1992), who indicated that clothing accelerated decomposition, and of Miller (2002), who found clothing delayed decomposition in spring and summer but not in winter. Both studies were conducted on human remains in the humid subtropical climate of Tennessee, USA (Cfa – mild temperate, fully humid, hot summer). Mann, Bass & Meadows (1990) also reported that clothing accelerates decomposition by protecting maggots during forensic casework across the USA, which was not found in this investigation. Despite finding a statistically significant difference between clothed and unclothed porcine decomposition in North West England (Cfb – temperate, without dry season, warm summer), Card *et al*. (2015) concluded no practical difference was observed when a 95% confidence interval was applied to the dataset. However, the carcasses used were all under 40 kg, and multiple seasons were not investigated. Phalen (2013) concluded that clothing accelerated human decomposition in the early summer in Central Texas (Cfa – mild temperate, fully humid, hot summer) by trapping moisture, preventing mummification, and promoting invertebrate activity, thereby hastening skeletonisation. These results also do not correspond with those of the current investigation. In a retrospective study of 96 exposed terrestrial human death investigations across Canada, the influence of clothing appeared negligible on average, contrary to the current results (Cockle & Bell, 2017). Similarly, the current findings do not support the conclusions of Kelly (2006), who reported that clothing had no impact on porcine decomposition or insect succession patterns in the hot, arid (BSk) environment of the Free State, South Africa, regardless of season, but that it did facilitate maggot movement in autumn, spring, and summer, but not winter. These inconsistencies in the literature emphasise that variations in seasonality and geography underpin the impact of clothing, and no global effect may be established. This necessitates region-specific, locally relevant data that forensic anthropologists and taphonomists can draw upon. In a local context, clothing appears to be forensically relevant, especially in the winter months.

The material in which the clothing is made can have a great effect on the decomposition process. Many modern fabrics incorporate synthetic fibres to increase clothing stretch, retain shape, and decrease drying time. These fibres have different properties that cause them to degrade at different rates and may differentially affect the decomposition process; similarly, the decomposition process may differentially alter the breakdown of the material (Cahoon, 1992; Canetta, Montiel & Adya, 2009; Mitchell et al., 2012; Lowe et al., 2013; Ueland et al., 2015, 2017; Ueland, Forbes & Stuart, 2019). Synthetic fibres may increase heat retention and repel water, thereby limiting the effect of fluctuations in ambient temperature and tissue hydration, potentially altering human remains' decay compared to those clothed in only natural fibres. The range of fibre compositions used in this study was chosen to be most representative of those found in casework and in affordable clothing available to the average consumer in South Africa. Investigating the specific interactions between different fibre types and the decomposition ecosystem should be considered for future research.

The clothing used in this study altered mongoose scavenging behaviour; clothed carcasses were visited less often and for a shorter duration than unclothed ones on average, regardless of the season. This preferential scavenging behaviour has been reported previously in Edmonton, Canada, with coyotes showing a preference for unclothed rather than clothed pig carcasses (Kjorlien, Beattie & Peterson, 2009). However, the influence of clothing appears to modulate mongoose scavenging behaviour differently in summer and winter. Winter clothed carcasses saw a reduction in scavenger visit number and duration compared to unclothed carcasses. In summer, clothed carcasses showed a slightly greater number of longer duration visits by scavengers across the percentiles than unclothed summer carcasses. This may indicate that the clothing acted to preserve the freshness of the tissue during summer or that the unclothed carcasses were putrefied so quickly that they were not appetising to the mongooses. However, the difference in visitation data between clothed and unclothed carcases in summer was slight, so repeat studies investigating this would be required to determine whether this observation is consistently present and whether it creates a meaningful difference in decay rate.

The pattern of mongoose feeding on carcasses was altered by the presence of clothing, as the rump of a clothed carcass was inaccessible to scavengers. Although activity began near the head, as was commonly seen in the unclothed carcasses, feeding then occurred at the abdomen. The mongooses exhibited a necessary level of dexterity to push or pull the clothing out of the way enabling access to the abdomen. Synstelien (2015) reported similar behaviour by racoons slightly displacing loose pant cuffs for feeding. The opening of the abdominal cavity by mongooses appeared to occur more quickly in clothed rather than unclothed winter carcasses, presumably as fewer areas were accessible to scavenge in the former. The abdominal feeding likely contributed to the considerable delays in decay seen by clothed winter carcasses by reducing the available internal tissue for consumption by maggots and the external skin for their protection from the environment. The visible constriction of the abdomen by the belt during bloating may also have facilitated a more rapid rupture of the abdominal cavity of clothed winter carcasses. In summer, clothed and unclothed carcasses showed little distinction in abdominal rupture timing due to the rapid onset of bloating compared to winter. Similar changes to the feeding behaviour of red foxes on clothed human remains have been suggested compared to studies on unclothed deer remains (Young, Márquez-Grant et al., 2015); however, Willey & Snyder (1989) have previously likened thick, hairy deer hide to clothing on humans. Forensic case reports have indicated that scavenging dogs could open the thoracic and abdominal cavities of clothed human remains, leaving the lower limbs mostly intact similar to the mongoose (Willey & Snyder, 1989). Heavy clothing has also been suggested to prevent canid and marine scavenging (Haglund, Reay & Swindler, 1989; Introna, Di Vella & Campobasso, 2013).

The influence of vertebrate and invertebrate activity on clothed remains may mimic the patterns of perimortem sexual assault (Komar & Beattie, 1998), and similar such patterns may be seen here with the displaced T-shirt and jersey covering the torso. Mongooses were unable to remove or displace the denim trousers, as previously suggested for heavy clothing (Haglund, 1997), but lighter fabrics or different clothing types may present less of a challenge to displace for small mammal scavengers like the mongoose. Komar & Beattie (1998) used adult-sized clothing not tailored to fit their porcine subjects, often resulting in loose or ill-fitting clothing on the smaller carcasses, possibly exaggerating the effect of movement by maggot masses. Care should be taken when examining clothed remains in forensic cases and the entire scene analysed in context to prevent drawing inaccurate conclusions regarding the possibility of perimortem sexual assault. The effect of clothing on scavenging activity and decomposition in general would be incomplete without analysing the considerable role both weather and season play in altering the decay rate and scavenger behaviour.

4.3.3 How does seasonality affect decomposition and scavenging?

One of the primary questions this thesis was designed to address is how seasonally appropriate clothing impacted the rates and process of porcine decomposition in warmer and cooler weather. The inclusion of seasonality in this investigation was crucial, as temperature and other weather variables fluctuate between seasons and are known to affect the decomposition process. This was evident in the current study, as winter weather was significantly colder and wetter, resulting in significantly slower decomposition, and substantially delayed and prolonged head and neck bloat, compared to summer. This weather difference resulted in winter carcasses taking on average more than five times longer than summer carcasses to reach the same final benchmark of 68% mass loss, with significantly more time spent in each of the preceding mass loss percentiles: 17%, 34%, and 51% mass loss. Winter decomposition also required significantly more thermal energy in accumulated degree days (ADD) to reach each milestone compared to decomposition in summer. This may be considered counterintuitive, as equivalent ADD values ostensibly correlate with equivalent decomposition levels regardless of the season. However, as Finaughty (2019) described, the manner of thermal energy application is vitally important – the shorter, cooler winter days result in less thermal energy input each day, which is required for the metabolic processes of biological agents of decay. This means there are longer periods of relative inactivity, resulting in greater total thermal energy required over a longer time to break down the winter carcasses. This was evident in the delayed onset and prolonged duration of bloat in winter, compared to the more rapid onset, shorter duration, and more extensive bloat seen in summer.

Differences in decomposition rate between seasons have been established in the literature, with higher summer temperatures often cited as the primary cause for more rapid decay, as chemical processes occur more quickly and microbial and invertebrate decomposers are more active as temperatures rise (Mann, Bass & Meadows, 1990; Campobasso, Di Vella & Introna, 2001; Kelly, 2006; Carter, Yellowlees & Tibbett, 2007; Kelly, van der Linde & Anderson, 2008, 2009; Giles et al., 2020). Finaughty (2019) previously showed that summer decomposition was accelerated in the same environment under study, with higher summer temperatures contributing to the more rapid decay. This is likely the case in the current study, as the 24-hour mean temperature differed significantly between seasons: summer cycles were 3.2 °C warmer on average.

Other significant differences between seasons included greater rainfall in winter, accompanied by greater atmospheric pressure. Archer (2004) showed that increased rainfall accelerates the decay rate of neonatal porcine remains, possibly by leaching, providing moisture to bacteria and insects, decreasing temperature through evaporative cooling, or rehydrating tissue for maggot recolonisation. Early & Goff (1986) conversely showed rain to cause waterlogging of remains, delaying weight loss. Precipitation has also been reported to have no impact on human decomposition (Cockle & Bell, 2017) and inhibit dehydration when accompanied by cooler temperatures (Galloway et al., 1989). Solar radiation and wind speed were not different between seasons, likely due to the dense thickets of invasive Port Jackson (*Acacia saligna*) and Rooikrans (*Acacia cyclops*), limiting sunlight and wind penetration. In this habitat, Finaughty (2019) reported the thickets to reduce solar radiation by up to 90%, wind by 20%, and rainfall by 50% compared to an adjacent, unsheltered area.

Relative humidity, recently reported to potentially play a greater role than the temperature in decomposition (Giles et al., 2020), also showed no significant differences between seasons. Increased humidity is suggested to delay the onset of mummification, increase insect activity (Mann, Bass & Meadows, 1990), and increase carcass moisture, essential for internal autolysis and putrefaction (Cockle & Bell, 2015). Since Cape Town is a coastal city and the research area is covered in dense vegetation, the relative humidity did not fluctuate but remained at a considerable mean level of 74% over 24-hours during both summer and winter cycles. This indicates that at least in the Western Cape, the temperature plays a greater role than humidity. Periods of low humidity, high temperature, and high wind speed can rapidly initiate desiccation, termed precocious natural mummification when occurring early in the decomposition cycle (Finaughty & Morris, 2019). This phenomenon was not observed despite clearly visible tissue desiccation due to high summer temperatures, as humidity remained high and wind penetration into the thickets was low.

Just as changes in weather variables may alter decay rates, changes in climate, *i.e.* the same factors usually averaged over a period of 30 years, may also impact decomposition trends. Work by Strack (2020) on the impact of climate change trends on decomposition indicates accelerated decay is likely, due to the predicted increases in temperature and slight decreases in humidity in current climate change models. Environmental changes due to climate change are already affecting the distribution and range of various insect species, including those forensically relevant (Turchetto & Vanin, 2004; Parella, 2018). Such long-term trends in temperature, humidity or invertebrate dynamics due to climate change may have contributed in the short-term to some of the significant differences between the weather variables and subsequent decay rates recorded in this study and those recorded four years prior by Finaughty (2019). Another possible contributor to the differences in weather variables between the two studies is the warm phase of the El Niño-Southern Oscillation (ENSO) climate pattern in the Pacific Ocean, known simply as El Niño. This climate pattern, affecting both ocean and atmospheric temperatures, occurs irregularly at two- to seven-year intervals and can alter local and distant weather events during that period (National Geographic Society, 2015). Although each study occurred during an El Niño event (and not during La Niña, its counterpart, the cooling phase), Finaughty's investigations took place from 2014-2016, which was one of the strongest El Niño periods on record (Becker, 2015; United States National Oceanic and Atmospheric Administration Climate Prediction Center, 2021), resulting in a severe drought in Cape Town at the time. However, another factor affecting the differences in weather variables, particularly in winter, is the mismatch in the study period between the two investigations. Finaughty's winter cycles started and ended earlier than those conducted for this study, meaning the winter cycles of the current investigation continued into spring and arguably ended at the onset of summer. This may explain the observed significant increase in winter temperature and humidity and decrease in rainfall compared to Finaughty's winter recordings as, when averaged, the seasonal changes later in the cycle may have altered the final values for the whole cycle. The relative reduction in winter rainfall, wind speed, and solar radiation between the two studies may be explained by the growth of the surrounding vegetation in the intervening years. The effect of the thickets at limiting the penetration of these weather variables was established by Finaughty (2019) and an increase in thicket growth over time will have exaggerated this effect. The differences in seasonal weather variables limit the value of a direct comparison between the two investigations, but the slight changes over time in weather variables within the same season, due to the factors outlined above, although significant, appear to have changed the decay process only slightly. By contrast, the difference in weather variables between the warm, dry summer and cool, wet winter have a much more drastic effect.

Just as seasonal weather affects microbial decomposition, so too is the activity and composition of vertebrate scavengers (Turner et al., 2017; Walker et al., 2021). Multiple researchers have shown that carrion consumption by vertebrates decreases in frequency, duration, or intensity with increasing temperatures (DeVault, Brisbin & Rhodes, 2004; Selva et al., 2005; Parmenter & MacMahon, 2009; O'Brien et al., 2010; Young, Márquez-Grant et al., 2015; Moleón et al., 2019). This is likely a consequence of increased microbial and invertebrate activity during warmer periods, resulting in greater levels of putrefaction as well as a host of unappetising or toxic amine and sulphur compounds secreted into the surrounding tissues (Janzen, 1977). Increased winter scavenging has also been attributed to fewer alternative food sources and cold conditions increasing the energy demands and, therefore, risk-taking behaviour of animals (Shaw et al., 2015; O'Malley et al., 2018). Gathering at carrion sources may be risky for smaller species as they may be out-competed by larger species or more dominant individuals in the same species or simply preyed upon by larger predators (Allen, Elbroch & Wittmer, 2021; Walker et al., 2021). The present study recorded winter carcasses receiving more mongoose visits of longer duration compared to the summer carcasses. Despite summer carcasses appearing to have longer visits towards the end of the cycle up to 68% mass loss than in winter, visit number and duration in the early phases of mass loss were significantly greater in winter. This supports the findings of Hannigan (2015), Smith (2015), Synstelien (2015), and Steadman et al. (2018), who reported more intense or longer racoon scavenging (and possibly opossum and skunk scavenging in the case of Steadman et al. (2018)) during winter, possibly related to the mating season or simply the prolonged freshness of carrion in colder weather. The increased winter mongoose scavenging differs from the results of Jeong, Jantz & Smith (2016), who found racoon scavenging to increase in frequency during summer but have a longer duration in winter after a delayed start. Hannigan (2015) found racoon activity to only begin approximately four months after deployment during winter and occur strictly at night with up to five individuals present at a time. Scavenging by fishers has also been reported as more frequent and for longer during winter (Allen, Elbroch & Wittmer, 2021), similarly for skunks (Smith, 2021) and red foxes (O'Malley et al., 2018). By contrast, opossums show no seasonal preference in scavenging behaviour (King et al., 2016). Keyes, Myburgh & Brits (2020) report an increased number and diversity of scavenging species during summer, along with quicker scavenging onset and more rapid skeletonisation.

A dip in mongoose scavenging activity to carcasses appeared during the middle of the day, possibly due to disturbance by the researcher during data collection. However, this reduced activity was more evident in summer, when midday temperatures are high, supporting Cape grey mongoose daily activity patterns described by Dorst & Dandelot (1970 as cited in Finaughty 2019, p. 146) and Smithers (1983). Beyond this, scavenging activity does not appear to be well associated with fluctuations in temperature over the whole cycle. A slight increase in mongoose visit duration was occasionally observed following a rainfall event. This has been reported in the literature and is likely due to the rehydration of desiccated tissues increasing the mongooses' ability to feed (Suckling, 2011; Spies, 2017; Spies, Gibbon & Finaughty, 2018; Collins, 2019; Finaughty, 2019). From a climate perspective, vertebrate scavenging activity has been observed to increase in intensity during periods of ecosystem stress when fewer alternative food options are available, such as below-average rainfall in south-eastern Australia linked to El Niño (DeVault, Rhodes & Shivik, 2003; Brown, Field & Letnic, 2006). During periods of increased rainfall and greater prey species abundance, carrion was less fully utilised (Brown, Field & Letnic, 2006). Although mongoose activity in the current study was more prominent during winter, when rainfall was greater than in summer, both winter deployments took place during 2018 and 2019, when annual cumulative rainfall was well below that recorded in previous years in the area (Climate System Analysis Group (CSAG), n.d.), lending support to the findings of Brown, Field & Letnic (2006). This phenomenon may also help explain the high duration of mongoose visits recorded by Finaughty (2019) in his 2015 and 2016 deployments that took place during a drought.

Simultaneous visits by more than one mongoose occurred substantially more in summer, significantly so by some measures, despite overall visit numbers being greater in winter. Summer visits by multiple mongooses were, on average, over four times the duration and seven times the percentage of multi-mongoose visits in winter. A contributing factor may be the relative abundance of carrion available compared to other food sources in summer, such as a reduction in prey species, but it is likely a consequence of the mongoose breeding season. In the summer months of January and February, pups born in the previous year may be old enough to accompany their parents when feeding. Once the winter deployments began later in the year, most adolescent animals may have matured sufficiently to leave their home range and begin the solitary lifestyle typical of the species. When simultaneous feeding was observed, there were often smaller, adolescent-looking mongooses present, lending weight to the above hypothesis and supporting previous observations of parental association (Smithers, 1983; Cavallini & Nel, 1990b; Labuscagne, 2018). However, identifying and ageing individual animals was beyond the scope of this investigation. Little else is known about the reproduction and pup rearing of the Cape grey mongoose, and these areas of the biology and ecology of the species require further research (Do Linh San et al., 2016). Although mongooses were more active during winter and showed a preference for unclothed over clothed carcasses, how did their behaviour and the subsequent decay rate change when only a single clothed carcass was available?

4.3.4 How does carrion biomass load affect decomposition and scavenging?

The decay rate comparison of single carcasses and multiple carcasses deployed simultaneously arose from a need to increase the forensic realism of local taphonomic research. This stemmed from an increased awareness of the ecology of carrion food webs and scavenger behaviour in the local environment, typically lacking from most forensic anthropology and taphonomy research. Although the use of large sample studies is a common and recommended practice in taphonomy studies to align with the standards of best practice established by the *Daubert* guidelines and those of Henssge & Madea (2007) previously discussed, these appear, at first glance, to conflict with carrion ecology theory and forensic realism. An increase in the frequency or magnitude of carrion resources can alter the structure and composition of the local scavenger assemblage and result in increased scavenger attendance, species variety, or scavenger swamping, altering the decay rate of carrion and human remains (Smallwood, 2007; Moleón et al., 2014; Shaw et al., 2015; Baruzzi et al., 2018). Multiple carrion sources in close proximity to each other may also be affected by adjacent invertebrate activity preventing assumptions of subject independence (Tessmer & Meek, 1996; Lewis & Benbow, 2011; Perez, Haskell & Wells, 2016; Matuszewski et al., 2020). Additionally, since most forensic cases involve single clothed decedents (Baliso, Finaughty & Gibbon, 2019; Baliso, 2020), large samples for taphonomic study do not accurately represent common realistic forensic scenarios. These reasons, along with initial evidence of scavenger preference for unclothed carcasses, resulted in the subsequent investigations of single clothed carcasses.

There was a considerable difference in decomposition rate as measured by mass loss and the onset and duration of bloat, depending on the amount of available carrion: single clothed carcasses decomposed quicker than carcasses deployed simultaneously in the same season. This was due to the combined influence of vertebrate and invertebrate activity and was especially evident in winter, where the single clothed carcass showed a substantially faster rate of weight loss and a quicker onset and shorter duration of bloat in the head and neck than both clothed and unclothed multi-carcass groups in the winter deployment. In summer, the weight loss curves, measures of bloat, and the number of days and ADD to reach mass loss percentiles for both single and multiple carcasses were more similar, as summer decomposition progresses rapidly in this environment, regardless of the presence of clothing or carrion biomass availability. However, the summer weight loss chart still demonstrates a noticeable difference between single and multi-carcass clothed deployments: the single clothed summer carcass experienced a rapid decline in weight from the first day of deployment, with no evident lag phase at the beginning like that experienced by the other carcasses. Similarly, the single clothed summer carcass experienced quicker onset and shorter duration of bloat compared to the muti-carcass summer deployment. This may be due to possibly increased maggot activity accelerating natural putrefaction since there was only a single carrion option for insect oviposition.

The influence of scavenging activity is integral to the analysis of the effect of carrion biomass load on the rate and process of decomposition. Given the ephemeral nature of carrion, altering the availability or quality of this precious nutrient resource is known to change the density and diversity of scavengers in a particular area (DeVault, Rhodes & Shivik, 2003; Wilson & Wolkovich, 2011; Barton et al., 2013; Selva et al., 2019). The single clothed carcasses in this study experienced greater mongoose scavenging activity than the multi-carcass means for each season. Similarly, Finaughty's (2019) carcasses, deployed in pairs, also experienced greater scavenging activity than the multi-carcass deployments. Although the number of mongoose visits to single carcasses was not always greater than to the multi-carcasses for each mass loss percentile, the duration of visits to single carcasses was substantially and consistently greater than the multi-carcass means. Mongooses spent more than double the amount of time at single carcasses as they did at carcasses deployed simultaneously. In addition, a noticeable pattern of prolonged feeding on single carcasses is evident, as the mongoose visit number and duration for single carcasses remained high late into the cycle, compared to the more rapid decline in mongoose activity after 17% mass loss observed in the multi-carcass deployments. The single carcasses were also scavenged by multiple mongooses simultaneously for a greater duration and percentage of total scavenging time compared to the multi-carcass deployments. This is indicative of scavenger swamping occurring in the multi-carcass deployments; scavengers having too many carrion sources available and being unable to adequately process them all (Smallwood, 2007; Schutgens, Shaw & Ryan, 2014; Shaw et al., 2015; Costantini et al., 2017; Bernardino et al., 2020). Scavenger swamping results in the mongooses dividing their time amongst the various carrion options available or choosing to focus on only a few carcasses leaving the others alone, thereby altering the true decomposition rate of any individual carcass. This preferential scavenging behaviour resulted in more activity to unclothed than clothed carcasses during multi-carcass deployments; similar preferential scavenging for either unclothed remains, a particular species or particular individuals, has been recorded in other contexts (Kjorlien, Beattie & Peterson, 2009; Olson, Beasley & Rhodes, 2016; Steadman et al., 2018). Maggot feeding, although not the focus of this study, plays a considerable role in the decay rate, and was observed at all carcasses, and may have accelerated the decay of the single carcasses as they were the only available option for oviposition. However, the vast distinction in mongoose scavenging behaviour, both as individuals and as groups, between single and multi-carcass deployments is believed to be the primary reason for the more rapid decline in weight seen by the single carcasses, especially evident in winter.

To the best of the author's knowledge, no other researcher has explored the decomposition of single vs multiple individuals besides Du Toit (2019), who, in collaboration with the author as part of Gibbon's research group, conducted a pilot study using a prototype automated weighing apparatus with a single clothed carcass in the same habitat. The comparison between the single clothed winter carcass investigated in this study (C1-W19), and that examined by Du Toit (2019), revealed some distinct differences – Du Toit's single clothed carcass did not proceed as quickly through the mass loss milestones as C1-W19. However, a comparison of the weather variables recorded during the two investigations showed that Du Toit's study was significantly colder and more humid, with less solar radiation and wind. As indicated previously, differences in weather can substantially alter the decomposition process, which likely contributed to the difference in decay rate between these two similar deployments. The carcass examined by Du Toit (2019) experienced more mongoose visits of longer duration across most of the mass loss percentiles compared to C1-W19. The increased scavenging activity present at Du Toit's carcass may be due to the same factors previously discussed, such as the mongoose breeding season and resource availability, but exaggerated based on the time of year of the Du Toit deployment in late autumn or early winter. However, as indicated previously, establishing a more robust definition of scavenging behaviour delineating feeding from other activities in the vicinity of a carcass would facilitate better comparisons across scavenging circumstances.

The observed stark difference in across-season mean decay rate between single and multiple carcasses of 32 vs 80 days (567.21 vs 1476.55 ADD) to reach 68% mass loss, although preliminary, supports the hypothesis that research forgoing forensic realism, with large samples of subjects simultaneously deployed near each other, may inadvertently alter the decay rate, creating inaccurate data. When designing future taphonomic studies, care should be taken to balance the need for statistical robusticity and forensic realism, especially in environments where vertebrate scavenging activity is prevalent. Although these results are noteworthy, the study does have some limitations, which are addressed next.

4.4 Study limitations

Although care was taken to ensure this study would generate reliable, replicable, and forensically realistic results, aspects of the study design should be highlighted as potential limitations to their interpretation. The use of pigs as proxies for human decomposition remains an ongoing debate in the literature as to the applicability of the obtained results. Although data developed by researching a non-human model cannot be directly applied to humans, this does not render the data irrelevant or without value. As indicated in Chapter 1, the domestic pig carcass is viewed as the best analogue for human decomposition, despite differences in the anatomy and decay process, as the use of human remains for taphonomic research, although perceived to be more applicable than a non-human model, is not without its problems. These include notable differences between the average age, body mass, and health status of cadaver donor populations and those usually seen in forensic casework. In addition, in many countries, including South Africa, researchers are unable to conduct human decomposition research. Although the findings derived from animal models are helpful, they are limited and cannot be directly extrapolated to human decay and should ideally be validated using human cadavers (Matuszewski et al., 2020; Miles, Finaughty & Gibbon, 2020).

Although many studies, particularly those using human remains, have relatively short inter-carcass distances, recent recommendations have indicated that a distance of at least 50 m between individuals is necessary for use in both taphonomic and entomological studies to prevent the overlap and cross-competition of insects and ensure subject independence (Tessmer & Meek, 1996; Lewis & Benbow, 2011; Perez, Haskell & Wells, 2016; Matuszewski et al., 2020). Given the limited research area available for this study, compromises had to be made during the initial multi-carcass deployments, with a minimum distance of approximately 20 m used between carcasses, although some carcasses were more than the recommended 50 m away from others. This may have resulted in certain carcasses either sharing or competing for entomological activity, thus altering the decay rate – neighbouring carcasses may have received a diluted, shared supply of invertebrate species, or a more enticing carcass may have attracted more insects, resulting in another being underrepresented, or the abundant insects at an attractive carcass may have spilt over to a relatively unattractive, perhaps clothed, neighbour. Although a limitation of the present study, these factors are further arguments for the use of single, isolated carcasses for improved forensic realism.

An additional limitation is the small sample size of this study and the lack of more true replicates due to constraints on time, budget, and study design. The single carcasses were required for the latter research question on whether an increased quantity of available carrion biomass would influence scavenger activity and thereby alter the decay rate. However, additional single clothed and single unclothed carcasses in both summer and winter seasons would have been ideal for further comparison and corroboration. The small sample precluded the use of some statistical analysis. Although the results of exploratory research of this nature are not nullified, a larger total sample and more true replicates within each treatment group would have been valuable to increase the reliability of the conclusions derived from the data (see Michaud, Schoenly & Moreau, 2012). Validation of these results with additional deployments in future research is recommended.

Another potential limitation of the study design was the use of a metal grid and weighing apparatus. In an attempt to examine any effect caused by the weighing system's metal grid, the author previously compared the decay of two small carcasses in 2017, one on open ground and one on a grid identical to those used in the current study (Spies, Gibbon & Finaughty, 2018). Both carcasses decomposed at very similar rates. However, the current methodology included lifting the carcasses off the ground to measure daily weight loss. Although this method allowed a more quantitative measure of the decay rate, less prone to researcher bias compared to a more qualitative method reliant on visual indicators of decay like TBS, it did result in disturbance to the carcasses. Although body position remained the same and contact with the ground was only broken for a very short period each day, the impact of this on the rate of decay is difficult to quantify and is acknowledged.

The use of different clothing types for the summer and winter deployments, although ensuring seasonal deployments were realistic, may also be considered a possible limitation for this research: the winter clothing was heavier and allowed for more moisture absorption compared to the summer clothing. This may have caused some discrepancies in weight loss when comparing clothed summer and winter cohorts.

4.5 Forensic implications and research recommendations

This investigation revealed three noteworthy findings that forensic practitioners and taphonomic researchers must consider in local and international contexts. Firstly, seasonally appropriate clothing delays decomposition in the Western Cape during winter but has less impact in summer, specifically in a thicketed microhabitat. This novel finding is essential for local forensic investigators to consider for PMI estimation. Future investigations should validate these findings and expand the type and variety of clothing and fabric fibres used to investigate their possible impact on the clothed decomposition process. The method of tailoring the clothes, unreported in the literature, prevented unrealistic scavenger access increasing the forensic realism of the research. Future taphonomic researchers should include seasonally appropriate clothing into their study designs, tailored to fit appropriately when using a porcine model, as a standard experimental condition to improve the forensic realism of the derived data since most forensic cases involved clothed individuals.

Secondly, vertebrate scavengers play a critical role in the local environment, specifically the Cape grey mongoose, as previously suggested (Spies, 2017; Spies, Finaughty & Gibbon, 2018; Finaughty, 2019). The mongoose may not leave clearly identifiable taxon-specific taphonomic indicators of scavenging activity on tissue or bone, which is a critical area of further research outside the scope of this investigation, but evidence of scavenger attendance can be corroborated by the presence of spoor or scat (Spies, Finaughty & Gibbon, 2018; Finaughty, 2019; and Stuart & Stuart [2013 as cited in Finaughty 2019, p. 150]). Since mongoose visit number and duration did not necessarily equate to time spent feeding, including behaviour such as grooming on and around the carcass, a new modified definition of scavenging activity is advised for future investigations similar to that used by Dibner, Valdez & Carter (2019) and proposed by Du Toit (2019). This, coupled with the implementation of video recording alongside still photography, will improve understanding of carrion-associated mongoose behaviours. Although research on small mammal scavenging has been conducted in the recent past, this topic has been historically overlooked within the decomposition ecosystem for taphonomic and forensic anthropology research, resulting in a relative lack of small mammal scavenging focused literature. This study adds to the literature, confirming previous research that small mammal scavengers may drastically influence the decay process in this habitat and possibly others, necessitating further investigations of this nature across the globe. With the lack of obvious scavenging indicators, compared to scavenging by canid or avian species, small mammal scavenging may go unnoticed during forensic casework. Further region-specific studies need to be conducted to investigate the small mammal vertebrate scavenger assemblages present in the region and methods developed to identify whether such animals have scavenged remains. The frequent practice of caging remains to prevent vertebrate scavenger access is not encouraged for taphonomic studies investigating decay rates in a given environment, unless as a control or for other specific purposes, as this may significantly impact rates of decay compared to human remains scavenged by local animals in forensic casework. Additionally, the possibility of scavenger species habituation to carrion repeatedly and frequently deposited by researchers should be explored, as this may alter the accuracy and relevance of the generated data. Ecological surveys of scavenger species variety, abundance, and behaviour before and after carrion deposition are recommended. The interaction between vertebrates and invertebrates should also be more closely examined, as invertebrate activity also plays a prominent role in carrion breakdown and the two may influence each other.

Thirdly, single carcasses experience more scavenging activity and decompose quicker than deployments of larger samples of multiple carcasses. This is a novel finding, with no previous investigations of this nature, directly comparing single and multiple carcass deployments, in the literature. This result is crucial to incorporate into the design of future forensically realistic taphonomic investigations, as large samples deployed simultaneously may alter the ecological dynamics of vertebrate and invertebrate assemblages, influencing the decay rate and causing the generated data to be unrealistic and not applicable in forensic casework. Replication of subjects for statistical purposes may be obtained via temporal separation of repeat deployments, *i.e.*, deployed at the same time the following year, or via simultaneous deployment in an adjacent but sufficiently distant location within the same habitat (suggested minimum distance between carcasses of 100-500 m apart; see Costantini et al., 2017, and Bernardino et al., 2020). Methods to estimate the PMI derived from data excluding vertebrate scavenging or from large samples deployed simultaneously may be inaccurate, especially in environments where small mammal scavenging is prevalent (Steadman et al., 2018). PMI estimation methods need to incorporate the influence of vertebrate scavenging and need to be developed with the effect of carrion biomass load under consideration.

Chapter 5: Conclusion

This research was designed to investigate the influence of clothing and carrion biomass load on seasonal decomposition and scavenging in the thicketed Cape Flats Dune Strandveld habitat of the Cape Town metropole. These topics were chosen to maximise forensic realism, done deliberately in opposition to the customary practice of deploying large samples of unclothed human or animal carcasses for improved statistical reliability when studying taphonomy. This study addressed a local need for clothed decomposition data and a global need for a decay rate comparison of single vs multiple carcasses.

Ten large domestic pig carcasses of approximately 60 kg each served as proxies for human decomposition and were quantitatively examined using daily weight loss as a measure of active decomposition progression. The study was conducted in four separate trials, occurring over two summers and two winters between 2018 and 2020, starting with comparisons of two clothed versus two unclothed carcasses in summer and winter and then examining a single clothed carcass each in summer and winter to compare the effect of carrion biomass load. Data on carcass weight loss was correlated and compared with scavenging activity by the Cape grey mongoose and seasonal weather variables. Continuing the theme of forensic realism, the clothing used in this study was chosen based on common seasonally specific clothing types identified from a retrospective analysis of local cases conducted by Forensic Anthropology Cape Town (FACT) and was tailored to fit the pigs appropriately based on measurements taken from a live pig before deployment. This ensured the clothing prevented unrealistic access by vertebrate scavengers, as would be expected in common local forensic scenarios.

Double-layer cool-weather clothing caused a notable decrease in decomposition rate and altered scavenging behaviour in winter, but single-layer warm-weather clothing had a comparatively negligible effect in summer. As expected from a temperate climate like Cape Town, regardless of the presence of clothing, carcasses deployed in the hotter, drier summers decomposed more rapidly than those in the colder, wetter winters. In addition, a previously unexplored result in the taphonomic literature, carrion biomass load had a notable effect on decomposition rate: single clothed carcasses lost weight more rapidly than either the clothed or unclothed groups in the multi-carcass deployments. This effect was more prominent in winter than in summer, as summer decomposition progressed rapidly, regardless of additional variables. The hypothesised reason for the increased decay of single carcasses was the greater number and duration of mongoose visits by both single and multiple mongooses visiting simultaneously.

These two aspects of the results, that clothing delays decomposition in the Cape during winter and that decomposition occurs more quickly in isolation than when a group of carrion sources are simultaneously available, have critical relevance for forensic practitioners and future taphonomic researchers. Although further validation is required, PMI estimates that do not account for the effect of clothing and vertebrate scavenging on decay rate will be inaccurate, especially in environments where scavengers are known to be highly impactful agents of decay, such as the habitat currently under study. Additionally, research forgoing forensic realism, with large, unclothed samples simultaneously deployed near each other, may inadvertently alter the decay rate, creating inaccurate data. Again, this is especially true in environments where small mammal scavenging occurs, as scavengers may become swamped with the available carrion and be unable to process it all, reducing the relevance and accuracy of the generated data.

In summary, the results of this study indicate that single carcasses dressed in season-specific, appropriately tailored clothing are recommended for realistic taphonomic research, with multiple temporally separated or sufficiently distant iterations to create sample sizes suitable for robust statistical analysis, rather than large samples deployed simultaneously. In addition, the further development of a standardised data collection methodology, using automated systems to limit researcher interference to the ecosystem and collect quantitative data on weight loss, vertebrate scavenging, invertebrate activity, local ambient weather variables, carcass-specific measures of temperature and moisture, as well as other variables, will provide a much-needed framework to better model the decomposition process. This would improve our understanding of decomposition and carrion breakdown from a forensic perspective. It would also allow for better comparison of data sets between the different environments under study around the globe and lead to the development of improved quantitative forensically realistic and region-specific PMI estimation techniques based on multiple variables. The postmortem interval is a crucial aspect of the forensic death investigation, and better estimation methods may increase the chances of correct identification of the deceased by narrowing the search window for police, ultimately improving social and criminal justice.

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Appendices

Appendix A: Köppen-Geiger climate symbols and map

Table A.1: Description of Köppen-Geiger climate symbols and defining criteria (adapted from Peel, Finlayson & McMahon [2007]).

Symbols			Description	Criteria
1st	2nd	3rd		
A			Tropical	$T_{cold} \geq 18$ °C
	f		- Rainforest	$P_{dry} \geq 60$ mm
	m		- Monsoon	Not Tropical Rainforest (Af) & $P_{dry} \geq 100 - MAP / 25$
	w		- Savannah	Not Tropical Rainforest (Af) & $P_{dry} < 100 - MAP / 25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$ °C
		k	- Cold	$MAT < 18$ °C
C			Temperate	$T_{hot} > 10$ °C & 0 °C $< T_{cold} < 18$ °C
	s		- Dry summer	$P_{sdry} < 40$ mm & $P_{sdry} < P_{wwet} / 3$
	w		- Dry winter	$P_{wdry} < P_{swet} / 10$
	f		- Without dry season	Not Temperate Dry summer (Cs) or Dry winter (Cw)
		a	- Hot summer	$T_{hot} \geq 22$ °C
		b	- Warm summer	Not Hot summer (a) & $T_{mon10} \geq 4$
		c	- Cold summer	Not Hot summer (a) or Warm summer (b) & $1 \leq T_{mon10} < 4$
D			Cold	$T_{hot} > 10$ °C & $T_{cold} \leq 0$ °C
	s		- Dry summer	$P_{sdry} < 40$ mm & $P_{sdry} < P_{wwet} / 3$
	w		- Dry winter	$P_{wdry} < P_{swet} / 10$
	f		- Without dry season	Not Cold Dry summer (Ds) or Dry winter (Dw)
		a	- Hot summer	$T_{hot} \geq 22$ °C
		b	- Warm summer	Not Hot summer (a) & $T_{mon10} \geq 4$
		c	- Cold summer	Not Hot summer (a), Warm summer (b), Very cold winter (d)
		d	- Very cold winter	Not Hot summer (a) or Warm summer (b) & $T_{cold} < -38$ °C
E			Polar	$T_{hot} < 10$ °C
	T		- Tundra	$T_{hot} > 0$ °C
	F		- Frost	$T_{hot} \leq 0$ °C

MAP = Mean annual precipitation; MAT = Mean annual temperature; T_{hot} = temperature of the hottest month; T_{cold} = temperature of the coldest month; T_{mon10} = number of months where the temperature is above 10; P_{dry} = precipitation of the driest month; P_{sdry} = precipitation of the driest month in summer; P_{wdry} = precipitation of the driest month in winter; P_{swet} = precipitation of the wettest month in summer; P_{wwet} = precipitation of the wettest month in winter; $P_{threshold}$ = threshold precipitation, varies according to the following rules (if 70% of MAP occurs in winter then $P_{threshold} = 2 \times MAT$, if 70% of MAP occurs in summer then $P_{threshold} = 2 \times MAT + 28$, otherwise $P_{threshold} = 2 \times MAT + 14$); Summer (winter) is defined as the warmer (cooler) six-month period of ONDJFM and AMJJAS; °C = degrees Celsius; mm = millimetres.

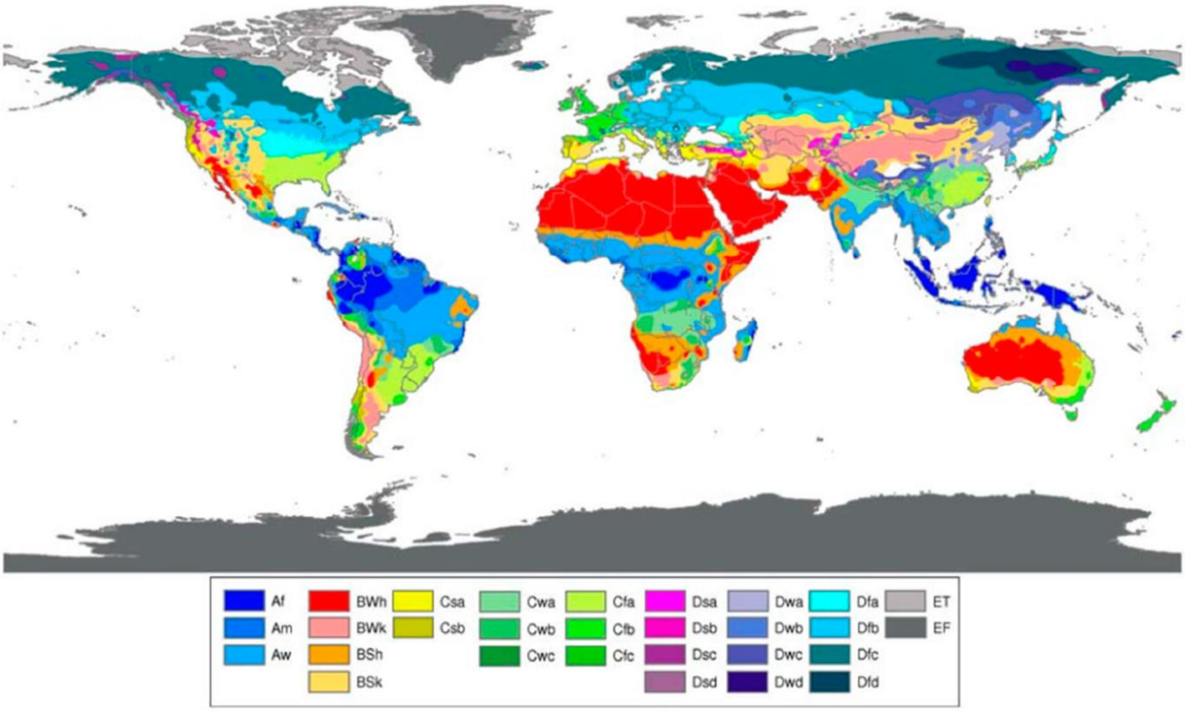

Figure A.1: Köppen-Geiger climate type map of the world (adapted from Peel, Finlayson & McMahon [2007]).

Appendix B: Publications derived from this study

Forensic Science International 309 (2020) 110197

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Technical Note

The effect of clothing on decomposition and vertebrate scavengers in cooler months of the temperate southwestern Cape, South Africa

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ARTICLE INFO

Article history:
Received 22 August 2019
Received in revised form 11 February 2020
Accepted 12 February 2020
Available online 14 February 2020

Keywords:
Post-mortem interval
Taphonomy
Porcine models
Cape Flats Dune Strandveld
Cape Town

ABSTRACT

With research providing conflicting results from different habitats across the globe, the effect of clothing on decomposition is unclear; some studies indicate clothing increases decomposition rate by facilitating increased insect activity, and others conclude clothing prolongs the decay process. In South Africa, such research is lacking, with no data for the Western Cape Province, which suffers from a high murder rate with many unclaimed, unidentified bodies. Improving post-mortem interval (PMI) estimates will increase chances of correct forensic identification of decedents by narrowing the search window for police. Since no current PMI estimation method accounts for the possible influence of clothing, this study was designed to examine the effect of seasonally appropriate common clothing on decomposition rate in the thicketed Cape Flats Dune Strandveld, Cape Town, a forensically significant region. Four ~60 kg domestic pig carcasses (*Sus scrofa domesticus*) were used as proxies for human decomposition, two were clothed and two unclothed. The clothing, altered by a seamstress to ensure an appropriate fit, caused a notable decrease in decay rate in this initial sample. Daily weight loss was used as a quantitative measure of decomposition progression, as the clothing prevented the use of visual decomposition scoring systems. Weight loss was closely associated with scavenging activity by the Cape grey mongoose (*Galerella pulverulenta*), with a clear scavenger preference for unclothed carcasses. This suggests that the effect of clothing on decomposition may be better assessed in this environment by examining how scavengers interact with only a single clothed carcass.

1. Introduction

Estimation of the post-mortem interval (PMI) is a crucial element of forensic death investigations. An accurate estimate of PMI reduces the potential pool of individuals that the remains may belong to, thereby increasing the chances of correct identification [1]. It also assists with understanding the context of a criminal case (for example, when a crime may have occurred), narrowing the search window for police. In the case of a homicide, this can be used to exclude possible perpetrators or corroborate witness testimony [2]. The estimation of PMI relies heavily on interpreting the state of decomposition, a continuous process influenced by multiple environmental factors, along with insect activity and vertebrate scavenging [1,3–6]. Since these factors can vary significantly by geographic area, local data is crucial for forensic validity [3,7]. Recent research has established the base rate of terrestrial decomposition for the locally relevant Cape Flats area in Cape Town, Western Cape Province, South Africa, using unclothed pigs (a median time to 75 % weight loss of 83.5 days, and mean ADD of 1126.06) [8]. However, this is not necessarily the most appropriate model for decomposition, given that most recovered individuals in forensic cases are clothed to some degree [9,10]. Therefore, the assessment of how clothing affects decomposition is essential for developing improved PMI estimation methods in our relevant biogeographical area.

Internationally, the effect of clothing on decomposition remains unclear; research has shown the presence of clothing on surface depositions may slow or accelerate decomposition, depending on other factors. These include the trapping of moisture, increasing temperature, slowing cooling to promote putrefaction, inhibiting scavenging and entomological processes essential in the natural decomposition cycle, allowing for new areas of increased oviposition for insects, or simply protecting larvae from the elements [11–14]. Some researchers have maintained that although the effect of clothing is measurable, it is only statistically significant when comparing winter and summer months or simply that the statistical significance does not equate to a practical affect [13,15,16]. Different fibre types can degrade at different rates

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http://dx.doi.org/10.1016/j.forsciint.2020.110197
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Figure B.1: A copy of the first page of a publication derived from this study, published in *Forensic Science International* (Spies et al., 2020a).

ABSTRACTS

biomedical sciences and palaeopathology, providing major insights regarding the complex bone-muscle interactions at entheses and associated novel approaches for tracing neurodegenerative disorders in the human skeleton. Reviewing pathophysiological pathways and the effects of inhibited neuron-to-muscle signalling indicates a distinct role of oxidative stress in the formation of entheseal changes as an effect of allostatic disturbances. It is hypothesised that the combination of biochemical and neurological factors with biomechanical stressors not only delivers a potential explanation for a well-described yet relatively poorly understood phenomenon, but facilitates enhanced comprehension of disease mechanisms and particularly the analysis of neurodegenerative disorders from the skeleton, as this synthesis of clinical and skeletal data allows for a first mapping of skeletal manifestations of ALS in the palaeopathological record. Engaging bone-muscle cross-talk effectively connects clinical and palaeopathological perspectives and creates new directions in palaeopathology towards a holistic understanding of rare diseases and their experience in bioarchaeological frameworks.

Body Composition and Skeletal Acquisition in a Model of Chronic Stress

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In industrialized humans, skeletal robusticity has declined and obesity has risen globally, but urban communities are disproportionately affected. Similarly, age at menarche has declined globally, while happening earlier for Black girls. Although higher body fat, earlier menarche, and lower bone density are seen in children of all socioeconomic statuses, children of color in urban environments bear a higher cumulative allostatic load, for which the biological effects have largely been ignored. We hypothesize that high allostatic load in subadults causes interrelated physiological and metabolic changes that lead to obesity, earlier age at menarche, and reduced skeletal acquisition. We examined the effects of chronic stress on body mass, body fat, bone mineral density (BMD), and bone mineral content (BMC) in a mouse model. We predicted that chronic stress would increase body mass and body fat and decrease skeletal acquisition. Female C57BL/6J mice were subjected to varying stressors (S) or were not stressed (N) (n=8/group) from 3-6 wks of age. Stressors included exposure to music or mouse distress sounds, dim light during sleep, social isolation, and frequent group changes. Results indicated no significant differences in body mass, BMD, or BMC. S mice gained less body fat (48%) than N mice (64%) ($p<0.05$ for all). Food intake increased by 46% for S mice and 123% for N mice ($p<0.001$). These findings don't support the hypothesis that chronic stress increases body fat. This short-term study shows that stress can affect food intake, but longer studies are needed to understand how chronic stress impacts skeletal acquisition.

The effect of clothing on decomposition in the cooler months in Cape Town, South Africa

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No clear, universal effect of clothing on decomposition has been established, with conflicting results from research conducted in various habitats across the world. Little data are available from South Africa, especially the Western Cape where many victims of the province's high murder rate remain unclaimed and unidentified. Better methods of estimating the post-mortem interval (PMI) will narrow the search window for police and improve chances of correct identification of the deceased. Currently, no known PMI method explicitly accounts for clothing's possible effect on decay rate, therefore, this study assessed the influence of common, seasonally-appropriate clothing on porcine decomposition in the forensically-significant thicketed Cape Flats Dune Strandveld habitat, Cape Town. The clothes were tailored to ensure an appropriate fit, preventing unrealistic access by biotic agents of decay. The initial trial consisted of four ~60 kg domestic pig carcasses (Sus scrofa domesticus) as proxies for human decomposition, two of which were clothed and two unclothed. Since clothing limits the use of visual decomposition scoring methods, daily weight loss was used as a quantitative measure to track decomposition progression. Weight loss was closely linked with scavenging activity by the Cape grey mongoose (Galerella pulverulenta). Clothing caused a notable decrease in decay rate, possibly mediated by scavenger preference for unclothed carcasses. Since scavengers targeted unclothed carcasses and multiple decedents at scenes are rare, the influence of clothing on decay may be more accurately and realistically assessed with only a single clothed carcass in environments where scavengers play a substantial role in the taphonomic process.

South African National Research Foundation

It's elementary: Extending the teaching of anthropology to elementary schools

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Anthropology is usually confined to college classrooms, limiting to the subject. Anthropology is important for all humans to understand because it fosters understanding of human differences and similarities. We attempt to challenge this norm in the Tuscaloosa community with our program Anthropology is Elemental (AIE). Through the program, anthropology students have been teaching local elementary schoolers the basics of anthropology for the past 9 years. Through a service-learning course, undergraduates learn from doctoral students how to team teach. For each topic, one of the undergraduate students plans and teaches a lesson to elementary students in local schools and guides a group activity inspired by the lesson. All of the resources are uploaded to the AIE website for open access. To determine the effectiveness of the approach for the elementary children, we collect free-listing responses from them about main ideas relating to the lesson and the previous lessons. As well as providing feedback on the program, this also helps to reinforce the new ideas for the students. Projects like this can help foster a greater understanding of the nuances of anthropology, including controversial topics like evolution, from a young age when kids are more accepting of new ideas, allowing students to develop critical thinking skills and a greater appreciation for science and culture at an earlier age.

From the Bay to Belize: changes in genetic diversity over time

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European colonization during the 17th and 18th centuries significantly altered the population demography of the Bay of Honduras (now Belize) as Spanish and British colonists formed permanent settlements, displacing or subjugating Indigenous populations and bringing enslaved Africans to the region to labor in agricultural industries. Today, the population of Belize is considered a creole society with cultural and genetic roots in Indigenous, African, and European populations. In 2009, the St. George's Caye (SGC) Archaeological Project was established to learn more about a prominent British colonial settlement located on one of the nation's cayes. Ten years of archaeological excavations at the British cemetery at SGC have identified 76 burials in varying states of preservation. When possible, osteological and genetic analyses were undertaken for each burial to explore the demographic makeup of the settlement's inhabitants. A total of 54 individuals were sampled for ancient DNA analysis of mitochondrial haplotypes and estimation of genetic ancestry based on genome-wide SNPs. In addition, to assess changes in genetic diversity

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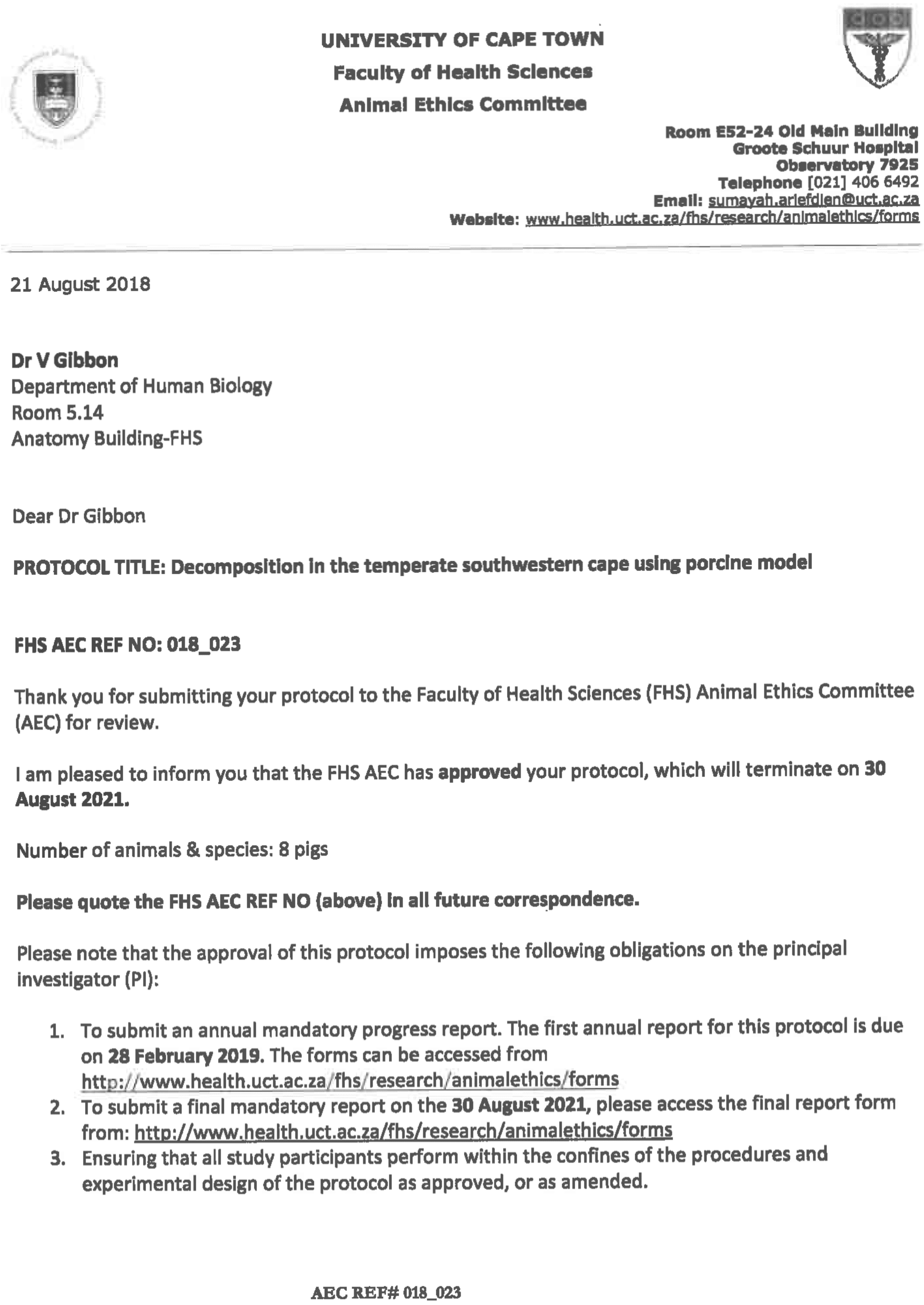
Figure B.2: A copy of a conference presentation abstract derived from this study, published in the *American Journal of Physical Anthropology* (Spies et al., 2020b).

Appendix C: UCT FHS AEC ethical approval (2018)



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Animal Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: sumayah.ariefdien@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/animalethics/forms

21 August 2018

Dr V Gibbon
Department of Human Biology
Room 5.14
Anatomy Building-FHS

Dear Dr Gibbon

PROTOCOL TITLE: Decomposition in the temperate southwestern cape using porcine model

FHS AEC REF NO: 018_023

Thank you for submitting your protocol to the Faculty of Health Sciences (FHS) Animal Ethics Committee (AEC) for review.

I am pleased to inform you that the FHS AEC has **approved** your protocol, which will terminate on **30 August 2021.**

Number of animals & species: 8 pigs

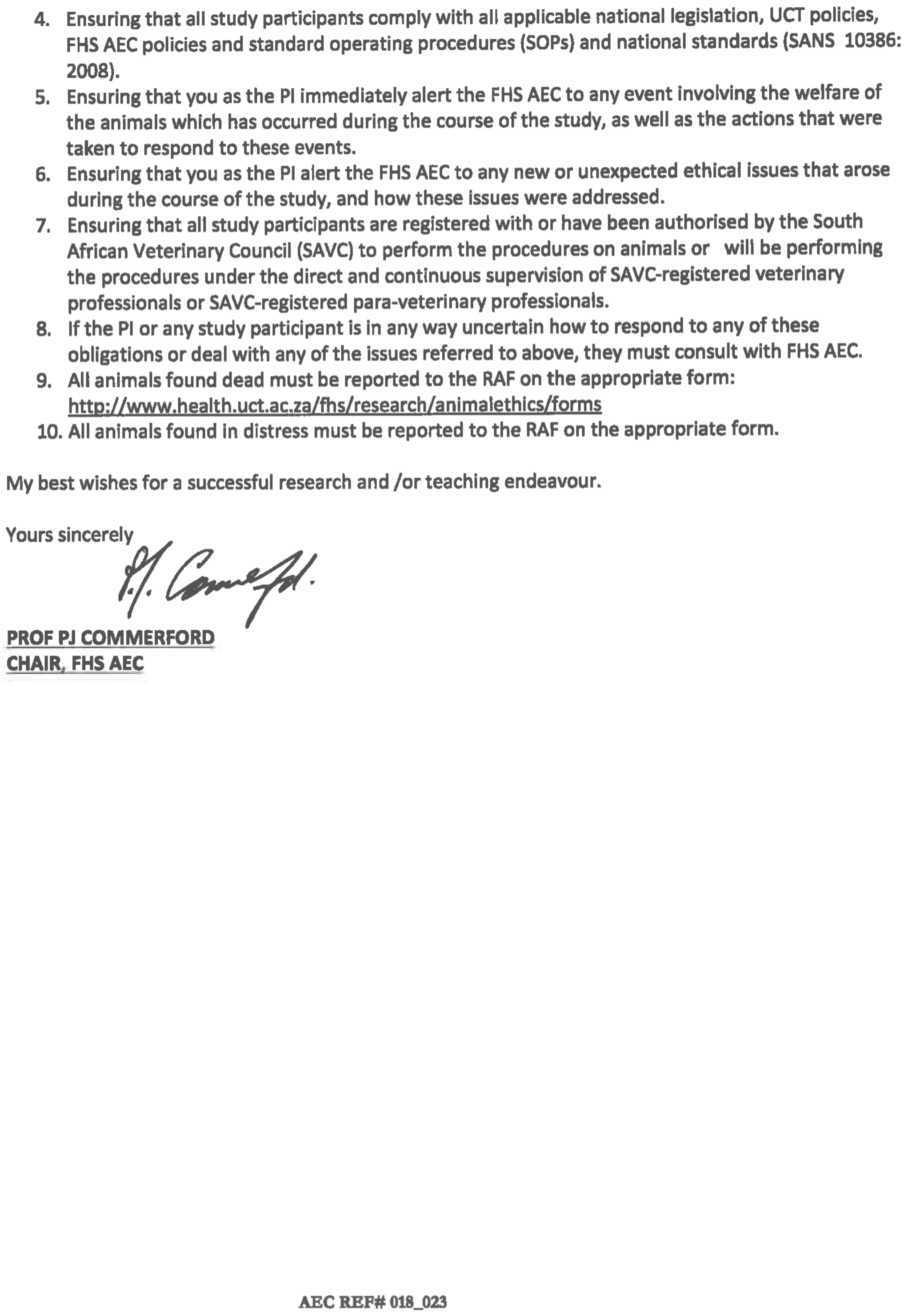
Please quote the FHS AEC REF NO (above) in all future correspondence.

Please note that the approval of this protocol imposes the following obligations on the principal investigator (PI):

1. To submit an annual mandatory progress report. The first annual report for this protocol is due on **28 February 2019.** The forms can be accessed from http://www.health.uct.ac.za/fhs/research/animalethics/forms
2. To submit a final mandatory report on the **30 August 2021,** please access the final report form from: http://www.health.uct.ac.za/fhs/research/animalethics/forms
3. Ensuring that all study participants perform within the confines of the procedures and experimental design of the protocol as approved, or as amended.

AEC REF# 018_023

Figure C.1: A copy of page one of the approval letter for application 018_023 from the University of Cape Town Faculty of Health Sciences Animal Ethics Committee.



4. Ensuring that all study participants comply with all applicable national legislation, UCT policies, FHS AEC policies and standard operating procedures (SOPs) and national standards (SANS 10386: 2008).
5. Ensuring that you as the PI immediately alert the FHS AEC to any event involving the welfare of the animals which has occurred during the course of the study, as well as the actions that were taken to respond to these events.
6. Ensuring that you as the PI alert the FHS AEC to any new or unexpected ethical issues that arose during the course of the study, and how these issues were addressed.
7. Ensuring that all study participants are registered with or have been authorised by the South African Veterinary Council (SAVC) to perform the procedures on animals or will be performing the procedures under the direct and continuous supervision of SAVC-registered veterinary professionals or SAVC-registered para-veterinary professionals.
8. If the PI or any study participant is in any way uncertain how to respond to any of these obligations or deal with any of the issues referred to above, they must consult with FHS AEC.
9. All animals found dead must be reported to the RAF on the appropriate form: http://www.health.uct.ac.za/fhs/research/animalethics/forms
10. All animals found in distress must be reported to the RAF on the appropriate form.

My best wishes for a successful research and /or teaching endeavour.

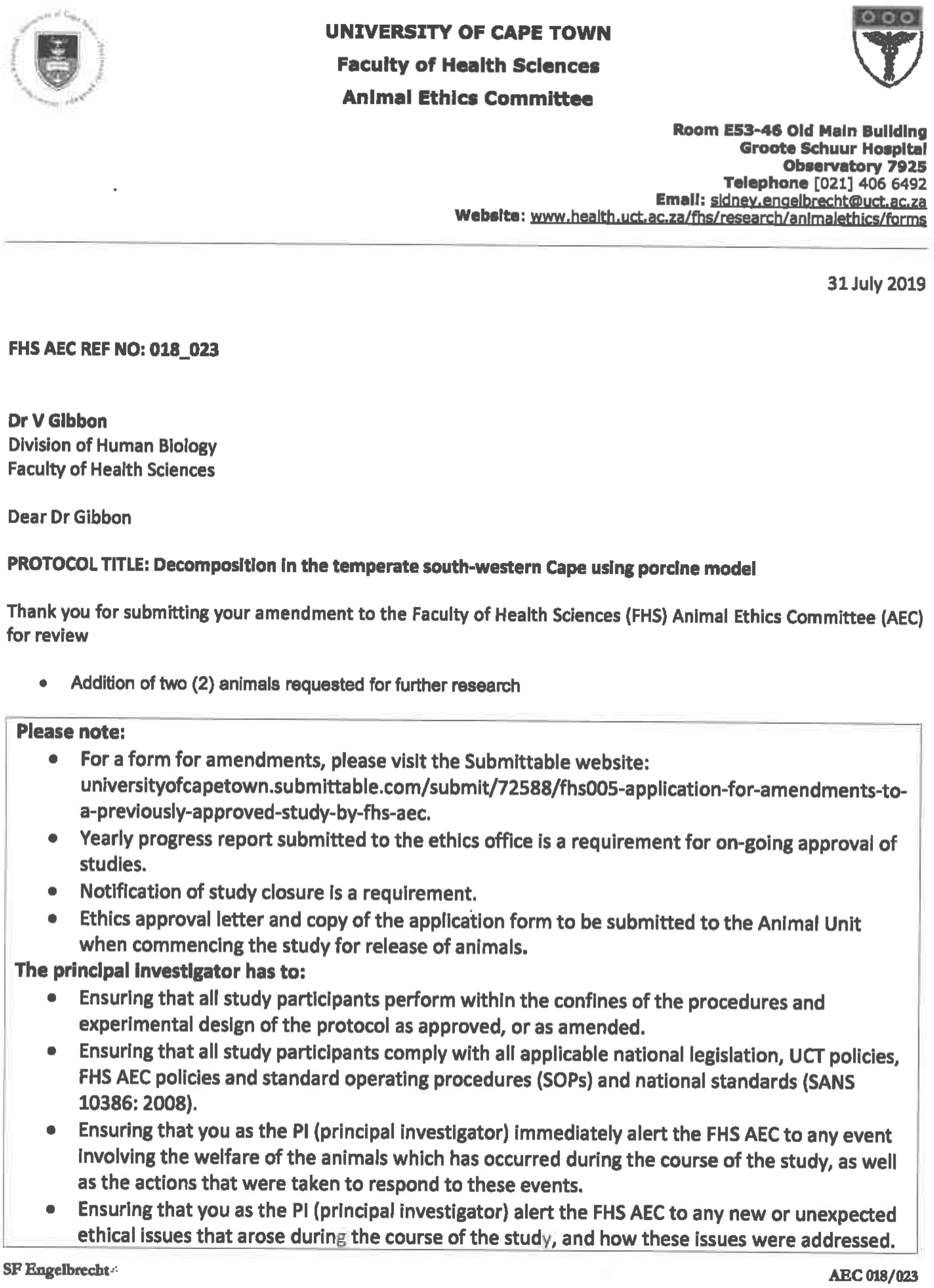
Yours sincerely

PROF PJ COMMERFORD
CHAIR, FHS AEC

AEC REF# 018_023

Figure C.2: A copy of page two of the approval letter for application 018_023 from the University of Cape Town Faculty of Health Sciences Animal Ethics Committee.

Appendix D: UCT FHS AEC amendment approval (2019)



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Animal Ethics Committee

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31 July 2019

FHS AEC REF NO: 018_023

Dr V Gibbon
Division of Human Biology
Faculty of Health Sciences

Dear Dr Gibbon

PROTOCOL TITLE: Decomposition in the temperate south-western Cape using porcine model

Thank you for submitting your amendment to the Faculty of Health Sciences (FHS) Animal Ethics Committee (AEC) for review

- Addition of two (2) animals requested for further research

Please note:

- For a form for amendments, please visit the Submittable website: universityofcapetown.submittable.com/submit/72588/fhs005-application-for-amendments-to-a-previously-approved-study-by-fhs-aec.
- Yearly progress report submitted to the ethics office is a requirement for on-going approval of studies.
- Notification of study closure is a requirement.
- Ethics approval letter and copy of the application form to be submitted to the Animal Unit when commencing the study for release of animals.

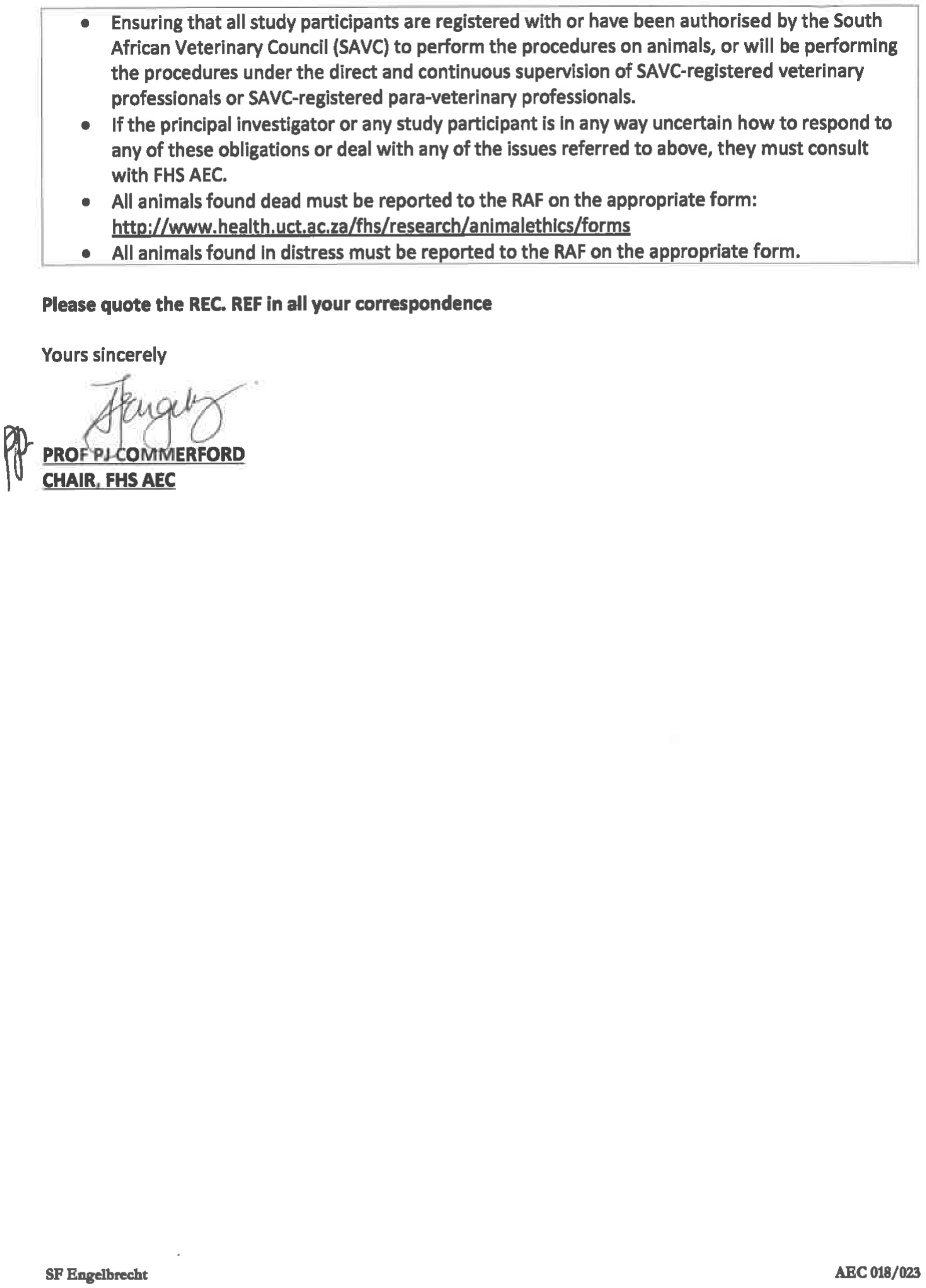
The principal investigator has to:

- Ensuring that all study participants perform within the confines of the procedures and experimental design of the protocol as approved, or as amended.
- Ensuring that all study participants comply with all applicable national legislation, UCT policies, FHS AEC policies and standard operating procedures (SOPs) and national standards (SANS 10386: 2008).
- Ensuring that you as the PI (principal investigator) immediately alert the FHS AEC to any event involving the welfare of the animals which has occurred during the course of the study, as well as the actions that were taken to respond to these events.
- Ensuring that you as the PI (principal investigator) alert the FHS AEC to any new or unexpected ethical issues that arose during the course of the study, and how these issues were addressed.

SF Engelbrecht

AEC 018/023

Figure D.1: A copy of page one of the approval letter for the amendment to application 018_023 from the University of Cape Town Faculty of Health Sciences Animal Ethics Committee.



- Ensuring that all study participants are registered with or have been authorised by the South African Veterinary Council (SAVC) to perform the procedures on animals, or will be performing the procedures under the direct and continuous supervision of SAVC-registered veterinary professionals or SAVC-registered para-veterinary professionals.
- If the principal investigator or any study participant is in any way uncertain how to respond to any of these obligations or deal with any of the issues referred to above, they must consult with FHS AEC.
- All animals found dead must be reported to the RAF on the appropriate form: http://www.health.uct.ac.za/fhs/research/animalethics/forms
- All animals found in distress must be reported to the RAF on the appropriate form.

Please quote the REC. REF in all your correspondence

Yours sincerely

PROF PJ COMMERFORD
CHAIR, FHS AEC

Figure D.2: A copy of page two of the approval letter for the amendment to application 018_023 from the University of Cape Town Faculty of Health Sciences Animal Ethics Committee.

Appendix E: Termination of life protocol

Mariendahl Farm, where the pig carcasses used in this study were purchased, follows the Producers Organisation code of best practise and is subject to Stellenbosch University ethics inspectors, veterinary inspections from the Animal Science Department, as well as National Society for the Prevention of Cruelty to Animals (NSPCA) inspections. In addition, the farm was inspected by two veterinarians from the UCT Animal Ethics Committee, and the following termination of life protocol was developed in consultation with them and ultimately approved by the broader committee (AEC 018_023).

The procedure involves individually loading the selected animal onto an appropriate vehicle, transporting them a short distance before termination via gunshot to the base of the brain. The chosen pigs are not separated from their counterparts until it is time for the termination protocol to commence. The animals are individually enticed up a portable loading ramp and onto the vehicle with food and allowed to feed for the short drive (~200m) on the farm away from the other animals to the termination site. This is done to reduce any undue stress to the selected animal as well as other animals on the farm. The vehicle is enclosed with rails to prevent any injury to the animal, and transport is conducted per standard commercial farming practices.

At the termination site, the animal is given food and allowed to achieve a state of relaxation and relative positional stasis, at which point termination of life is accomplished via a single gunshot of appropriate calibre (0.22 LR for pigs) delivered to the base of the brain by the farm manager, Mr John Morris, using his legally owned firearm (0.22 Mauser long rifle serial 205700, license: 6307185060087 1833). The site is out of earshot and sight of all other animals and humans present on the farm. The termination method does not elicit any pain that the animal would sense, given the immediacy of the destruction of the brain by gunshot, and it is unlikely to be aware of the impending termination given the setting in which it occurs. As such, anaesthetics or sedatives are not required.

Death is certified by a state veterinarian following satisfaction of four prerequisites, including confirmation of cessation of heart rate and breathing function, lack of corneal reflex, and the onset of cyanosis and *rigor mortis*. Should the protocol need to be repeated in the event multiple terminations are required, the dead animal is washed and removed, and the transport vehicle is also washed, where after the protocol is repeated. No live animals on the farm are exposed in any way to the termination practice or any deceased animals.

This method of life termination has been chosen over purchasing a pig from an abattoir, as the standard practice of exsanguination at abattoirs is more stressful to the animal and will drastically alter the natural decomposition process, and therefore, is not suitable for this study. This particular method has been selected as it has the least impact on the decomposition process. Termination via anaesthetics, or sedation before termination, will introduce drugs into the animal's system which have an unknown effect on decay and will confound the experiment in an immeasurable way. In addition, the potential effects these drugs may have on the animals which will subsequently consume the dead animal in a natural setting (including, but not limited to, insects and small mammalian scavengers such as the Cape grey mongoose) cannot be accounted for.

Appendix F: Scavenging activity patterns

The following figures provide visual and written descriptions of the patterns of scavenging activity to each carcass except for UC2-W18, C1-W18, UC2-S19, and C1-S19, which were previously presented as examples in the main body of the document in section 3.1.3 of the Results chapter.

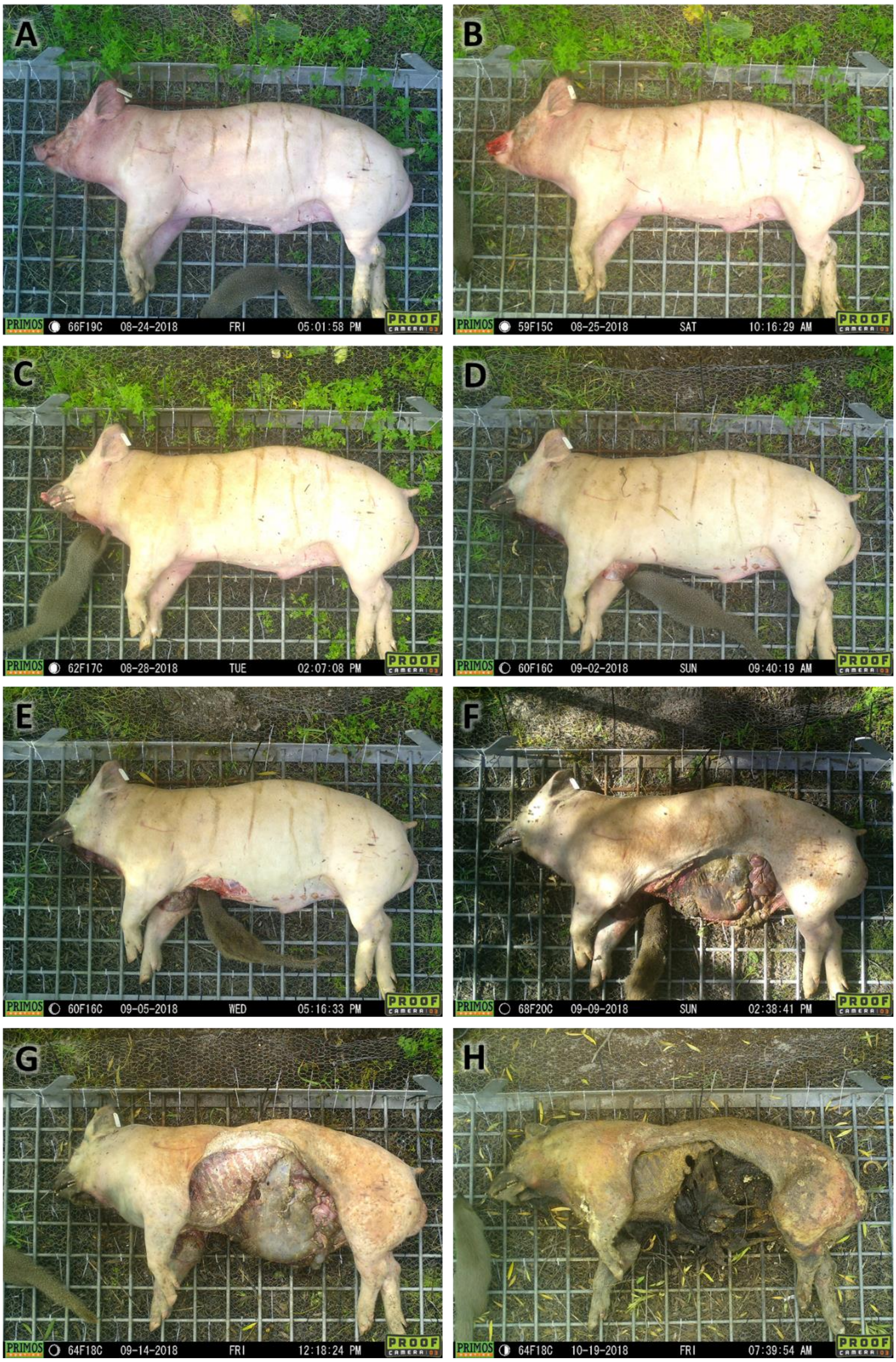


Figure F.1: Mongoose scavenging sequence of Unclothed 1 Winter 2018 (UC1-W18). A) Scavenging activity begins within a few hours, with nipples removed. B) Feeding begins at the nose/mouth on day two. C) Feeding on the mouth continues down the neck. D) Feeding continues to the sternum and inner surface of the upper forelimbs. E) Ribs and sternum exposed before abdomen opened. F) Abdominal opening expanded. G) Further expansion of the abdomen and feeding on the intercostal muscles, exposing the rib cage. H) Desiccation of remaining superficial tissue prevents most mongoose feeding from continuing.

Figure F.2: Mongoose scavenging sequence of Clothed 2 Winter 2018 (C2-W18). A) Scavenging activity begins on day one near the mouth and nose, with the left eye removed on day two. B) The abdominal cavity is then quickly accessed on day three, with the clothing displaced. C) Feeding continues on the abdomen, expanding the site. D) Some additional feeding on the viscera. E) Limited scavenging occurs, with the remains having a sunken appearance as desiccation begins. F-H) Little to no activity occurring in the remaining months with further desiccation.

Figure F.3: Mongoose scavenging sequence of Clothed 1 Winter 2019 (C1-W19). A) Scavenging activity begins on the eye, mouth, and nose, and the clothing is displaced. B) The abdomen is accessed on day two C) Feeding continues at the abdomen skin, subcutaneous fat, and muscle and the abdominal cavity is opened. D) The abdominal opening is expanded further. E) Feeding continues up the chest, exposing some rib ends on day five. F) Maggot activity hinders much further scavenging. G) Internal organs putrefy, exposing the spinal column, with desiccated skin covering the skull. H) Mostly skeletonised and disarticulated remains three months after deployment.

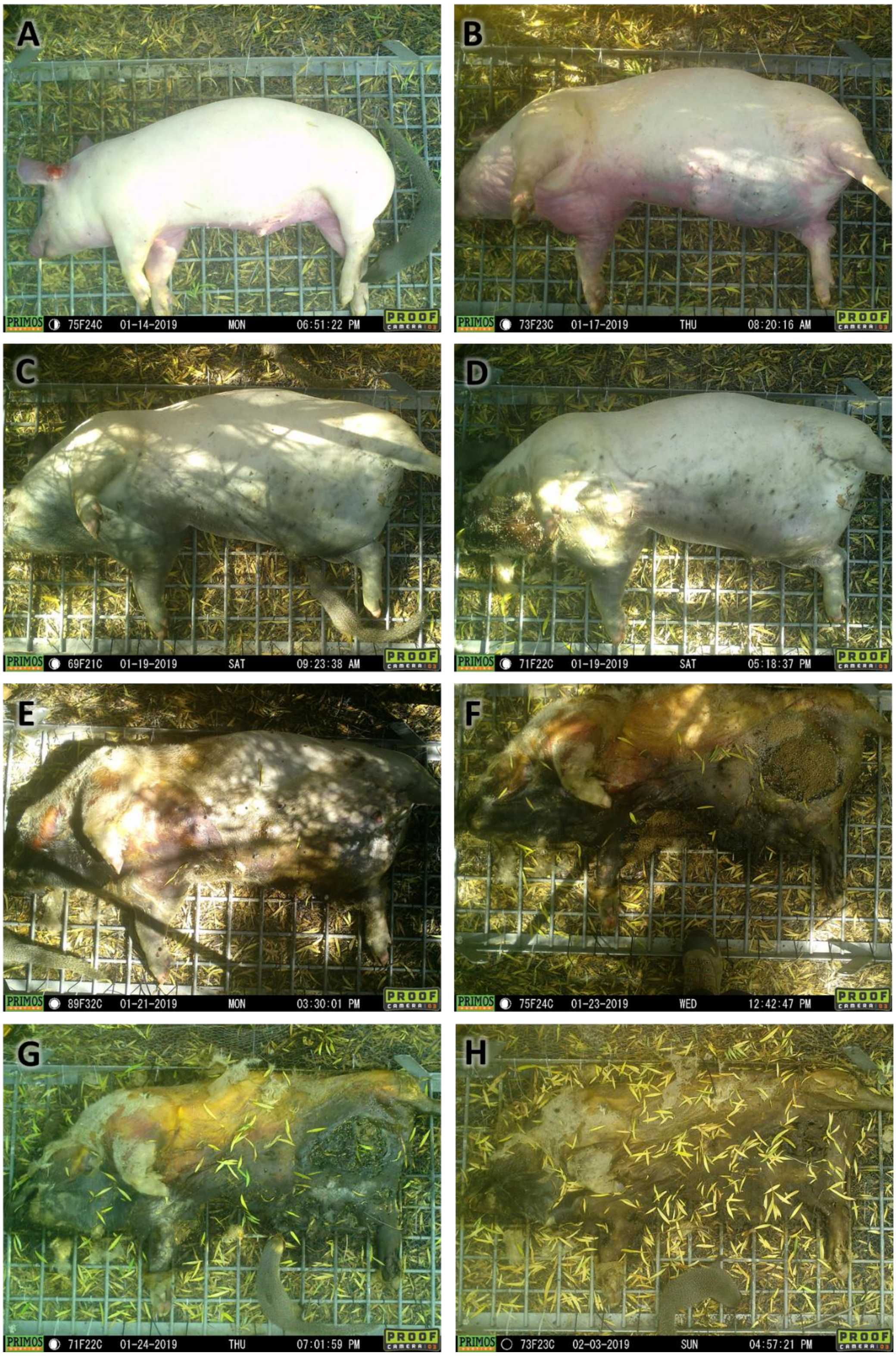


Figure F.4: Mongoose scavenging sequence of Unclothed 1 Summer 2019 (UC1-S19). A) Scavenging activity begins on day one on the ear, with some activity near the anal region. B) Extensive bloat overnight from day two to day three. C) Stomach ruptures on day five, with some feeding occurring there. D) Later on day five, maggots are visible on and around the head. E) Maggots colonise the whole carcass by day seven, with very limited scavenging occurring. F) Post-bloat, a large maggot mass is visible in the abdomen, as desiccation sets in at the head on day nine. G) Mongooses continue to visit, with little visible feeding. H) Desiccated skin covering moist bones after 20 days.

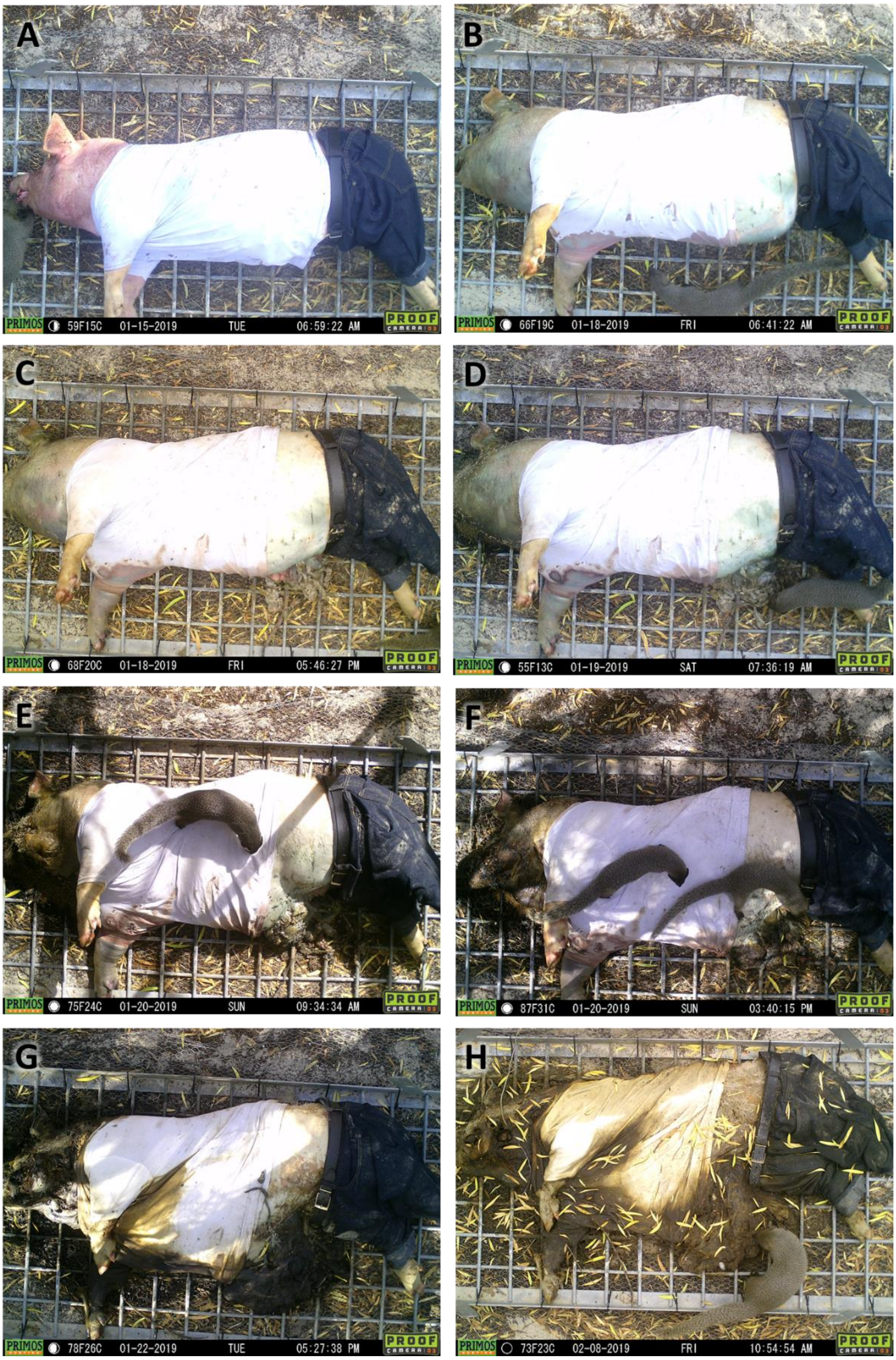


Figure F.5: Mongoose scavenging sequence of Clothed 2 Summer 2019 (C2-S19). A) Scavenging begins on day two with the removal of the tongue. B) Some feeding on the mouth and displacement of the T-shirt, with bloating underway by day four. C) The abdomen ruptures later on day four. D) The abdominal opening is expanded, with mongooses pulling out tissue, and maggot activity is evident on the head. E) The head attains a sunken appearance, and some additional scavenging occurs to the abdomen. F) Maggot activity is evident at the abdomen, with limited scavenging. G) Little to no scavenging occurring. H) Approaching a month after deployment, desiccated skin covering the cranial bones and much of the remains.

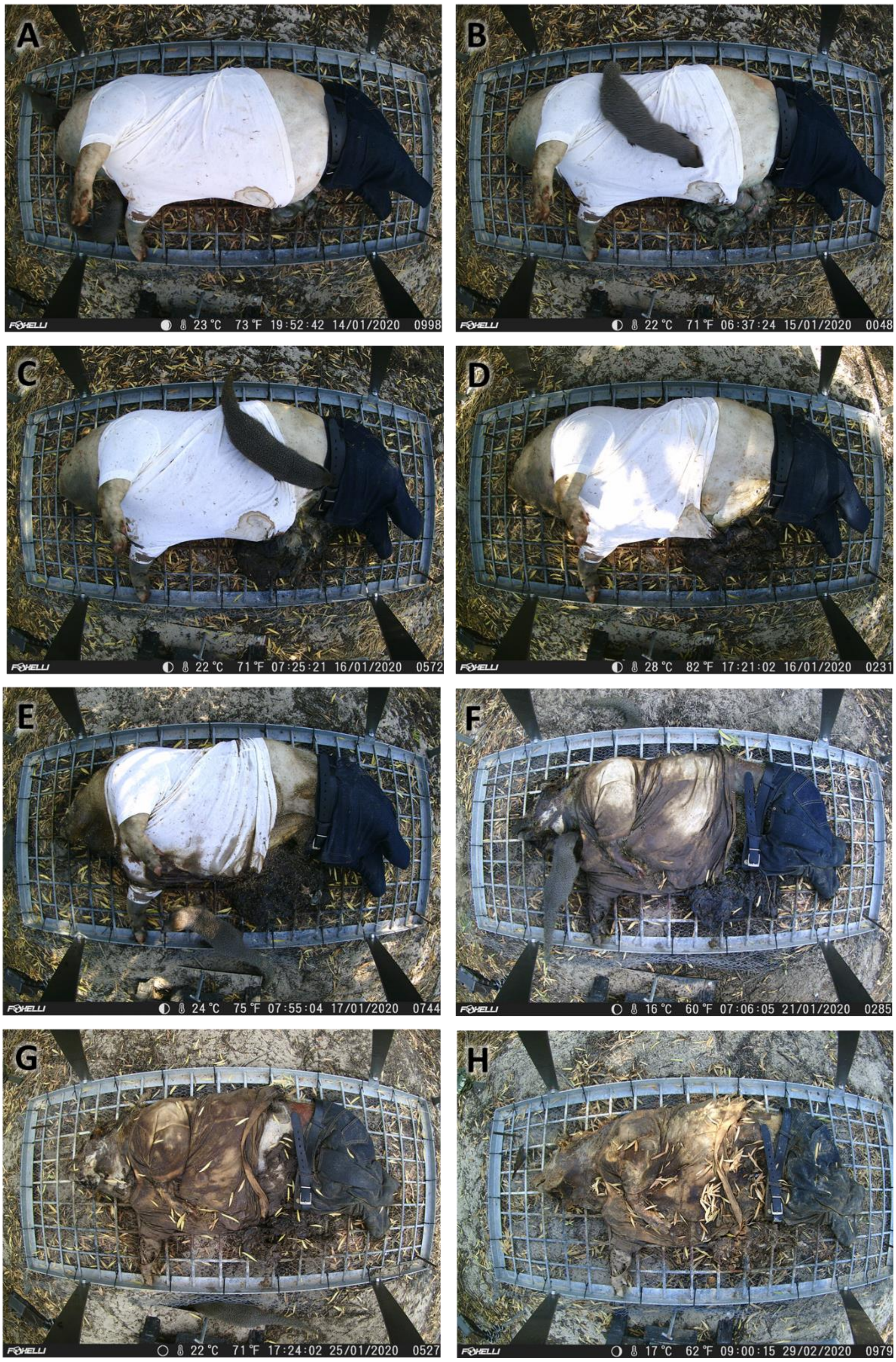


Figure F.6: Mongoose scavenging sequence of Clothed 1 Summer 2020 (C1-S20). A) Scavenging activity begins early on day one on the eye and ear, and the T-shirt displaced. Bloat is evident on day two, and the abdomen ruptures that evening. B) Feeding occurs at the abdomen rupture site. C) Feeding continues at the abdomen and head. D) The abdominal opening is expanded, with mongooses on subcutaneous tissue. E) Post-bloat, large maggot masses are evident at the abdomen with reduced mongoose activity. F) The cranial skin begins to desiccate. G) Mongooses return briefly, but little to no feeding occurs as desiccation sets in. H) Only dry tissue and bones remain after 17 days.

Appendix G: Scavenging visit data for each carcass

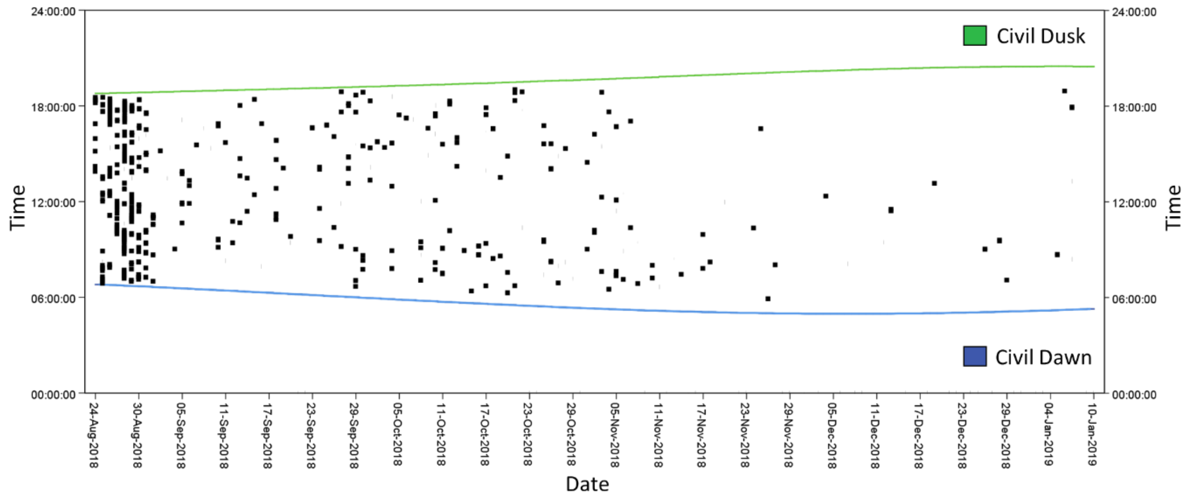


Figure G.1: Mongoose visit duration for Clothed 1 Winter 2018 (C1-W18) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

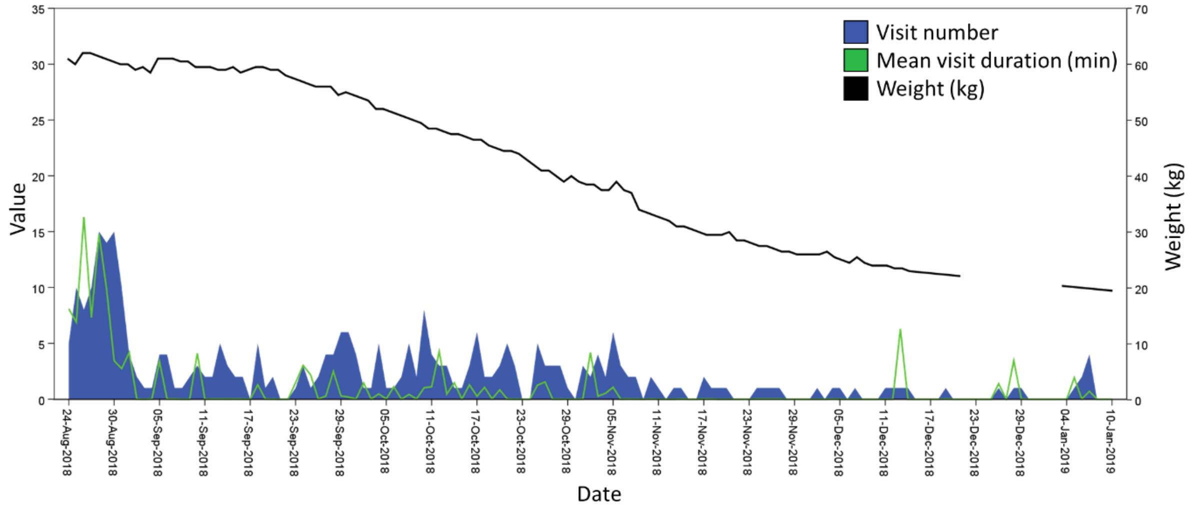


Figure G.2: Mongoose visit number and mean duration for Clothed 1 Winter 2018 (C1-W18) plotted against date overlaid with carcass mass loss.

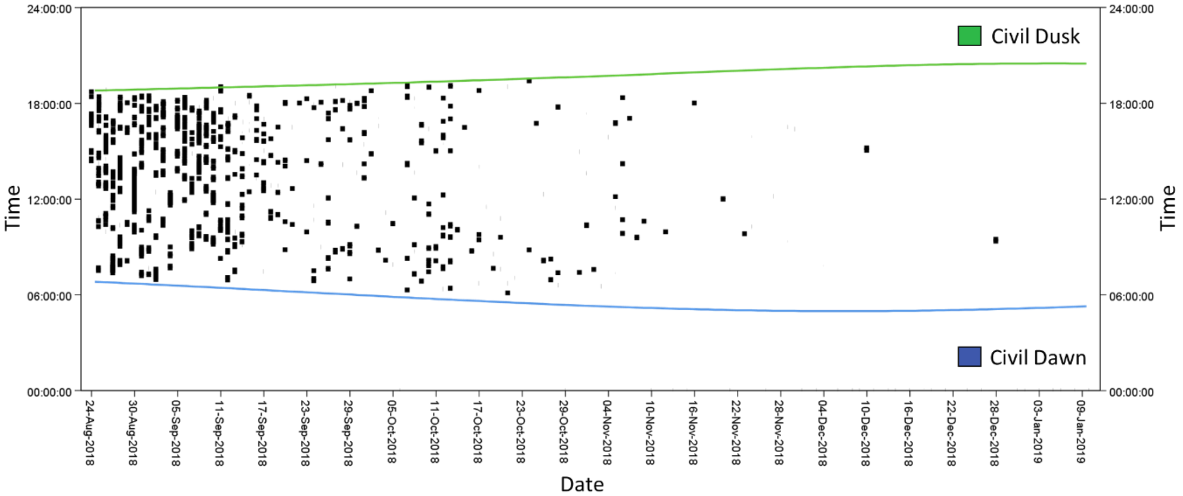


Figure G.3: Mongoose visit duration for Unclothed 1 Winter 2018 (UC1-W18) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

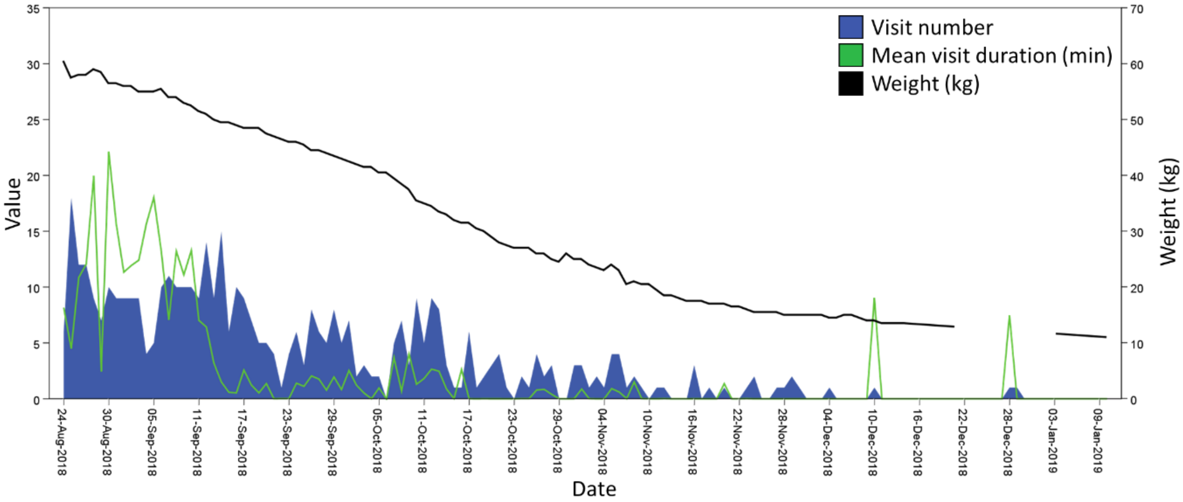


Figure G.4: Mongoose visit number and mean duration for Unclothed 1 Winter 2018 (UC1-W18) plotted against date overlaid with carcass mass loss.

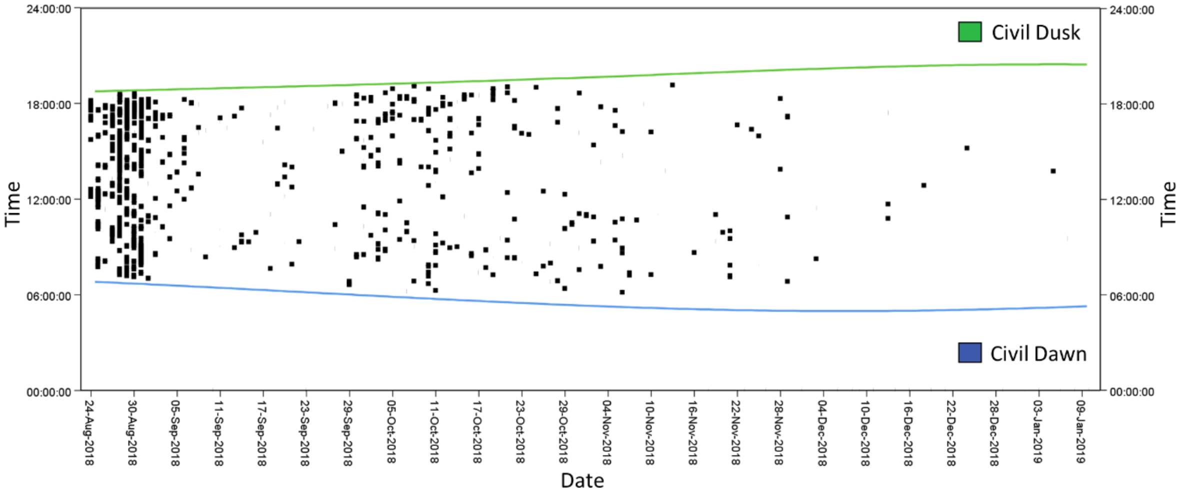


Figure G.5: Mongoose visit duration for Clothed 2 Winter 2018 (C2-W18) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

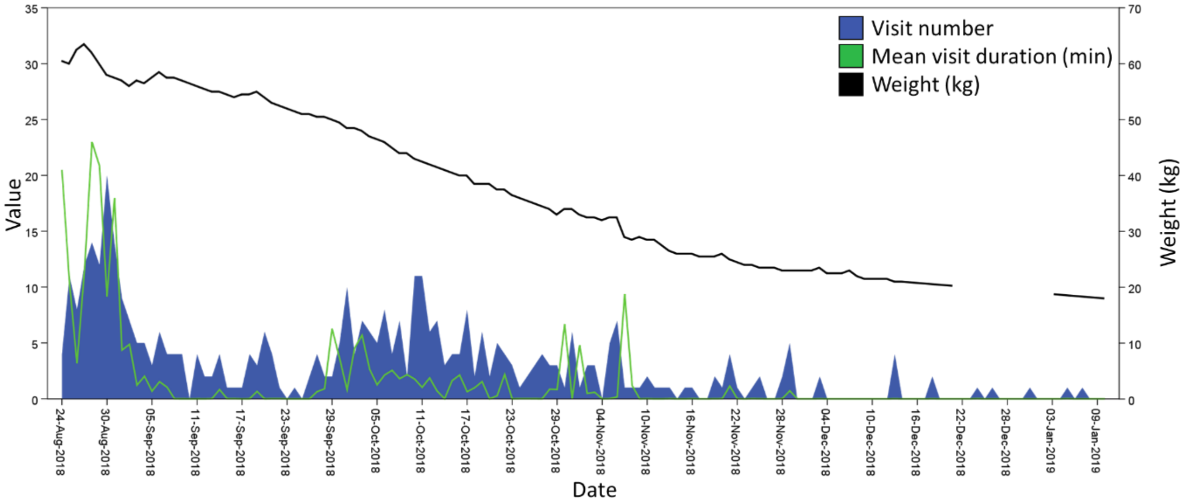


Figure G.6: Mongoose visit number and mean duration for Clothed 2 Winter 2018 (C2-W18) plotted against date overlaid with carcass mass loss.

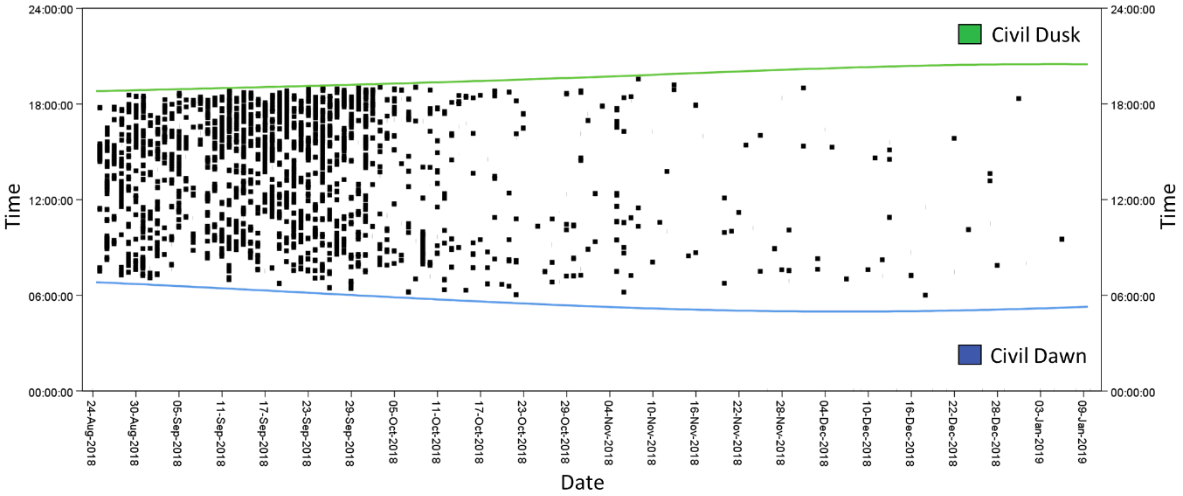


Figure G.7: Mongoose visit duration for Unclothed 2 Winter 2018 (UC2-W18) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

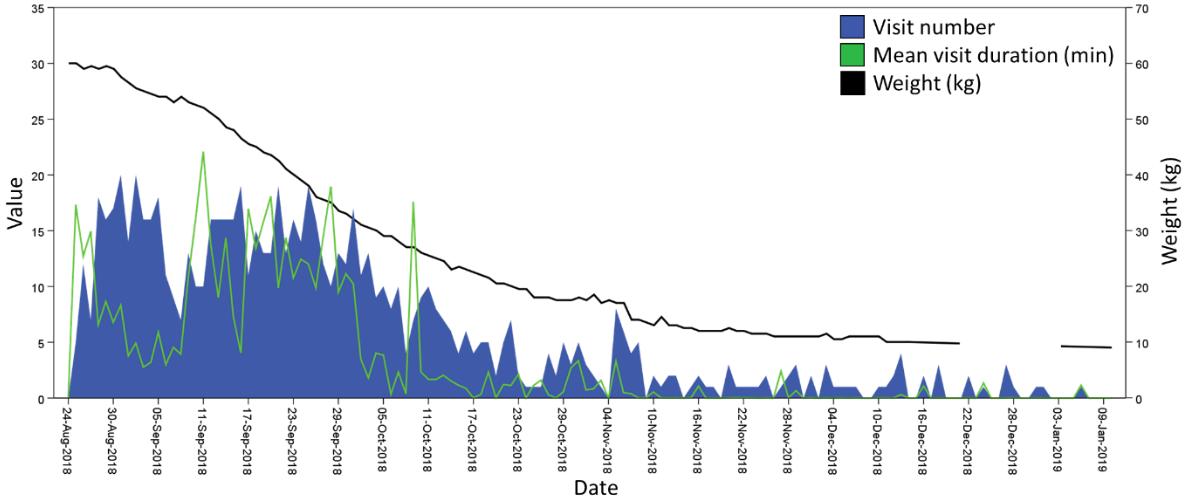


Figure G.8: Mongoose visit number and mean duration for Unclothed 2 Winter 2018 (UC2-W18) plotted against date overlaid with carcass mass loss.

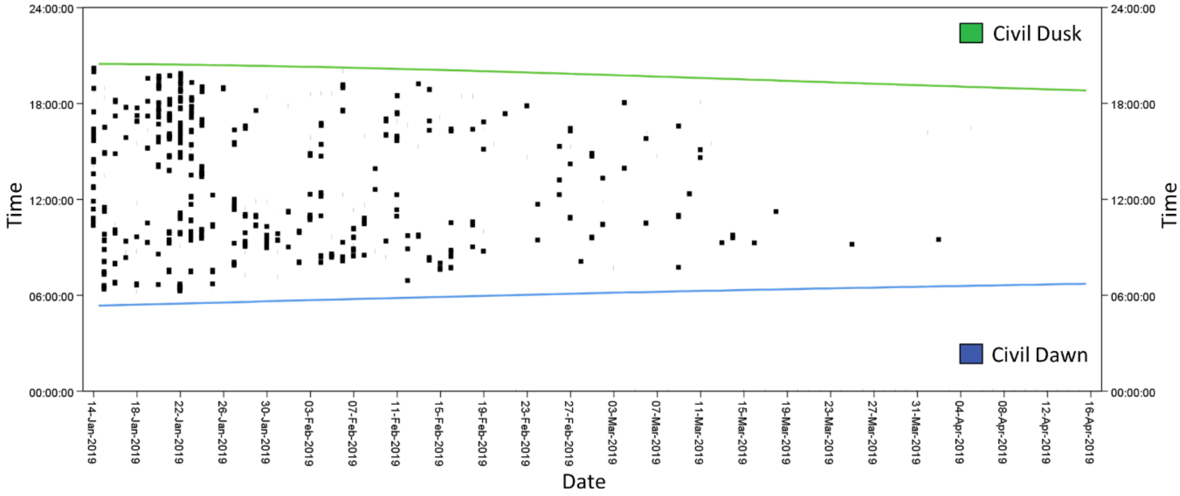


Figure G.9: Mongoose visit duration for Clothed 1 Summer 2019 (C1-S19) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

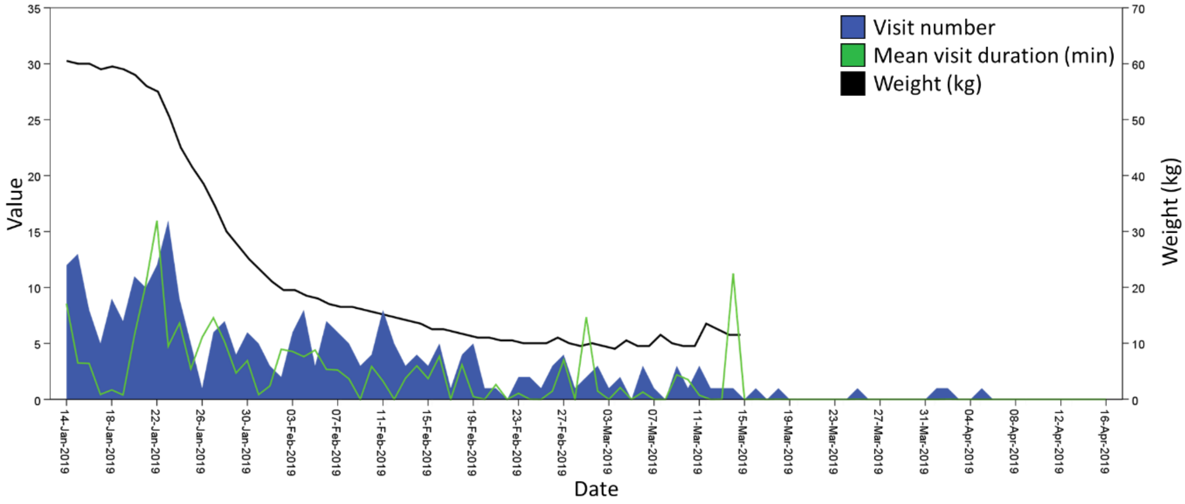


Figure G.10: Mongoose visit number and mean duration for Clothed 1 Summer 2019 (C1-S19) plotted against date overlaid with carcass mass loss.

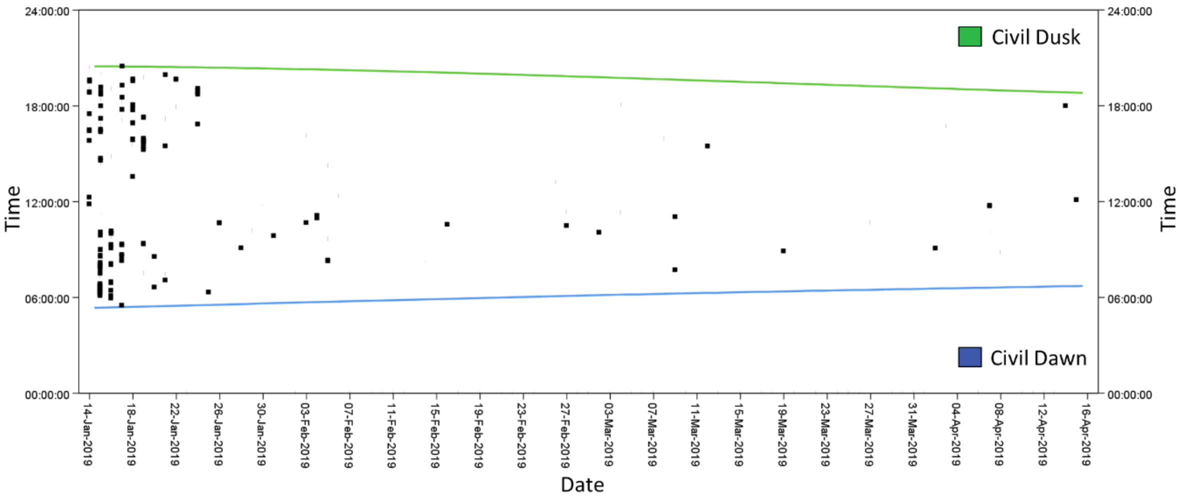


Figure G.11: Mongoose visit duration for Unclothed 1 Summer 2019 (UC1-S19) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

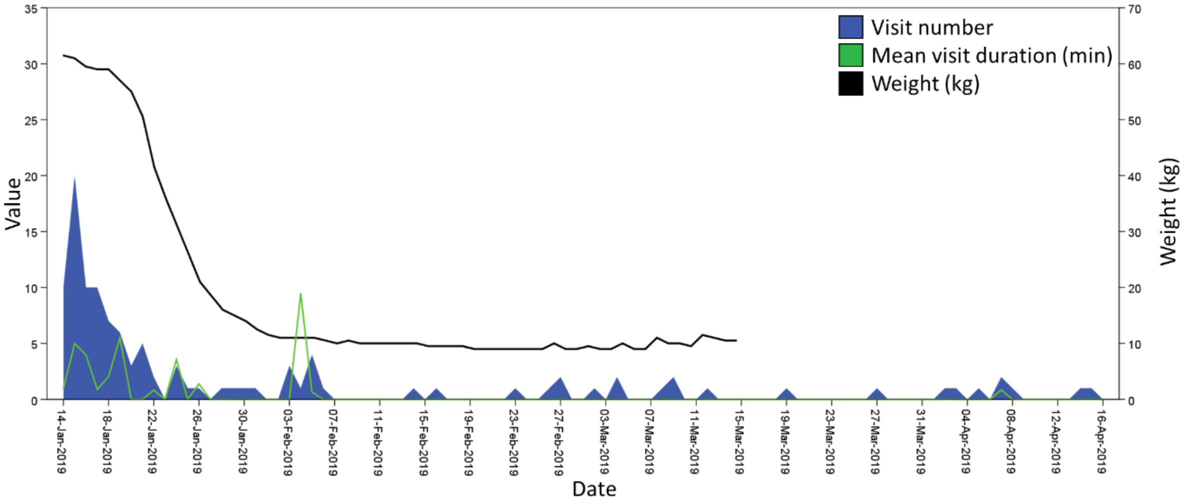


Figure G.12: Mongoose visit number and mean duration for Unclothed 1 Summer 2019 (UC1-S19) plotted against date overlaid with carcass mass loss.

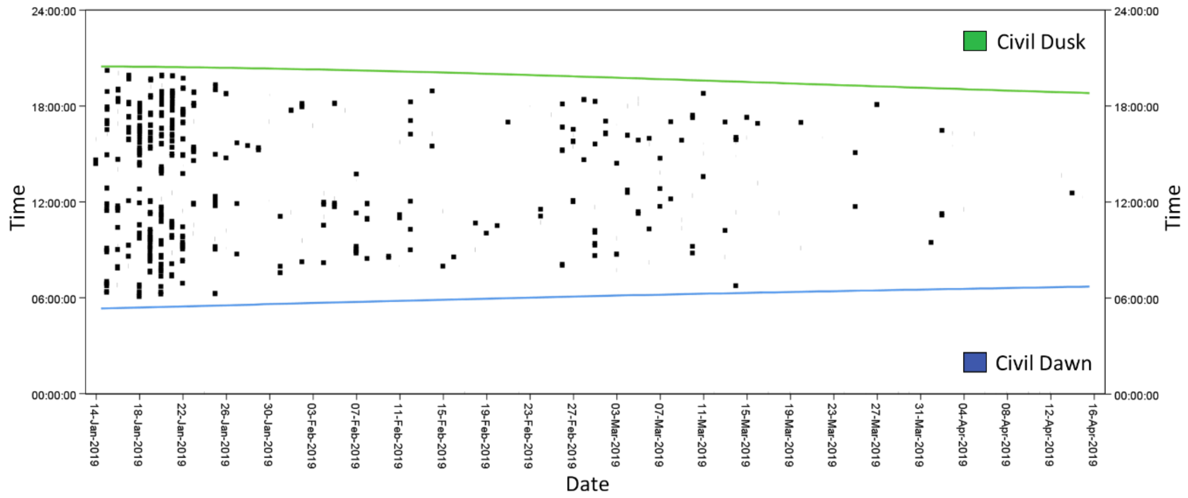


Figure G.13: Mongoose visit duration for Clothed 2 Summer 2019 (C2-S19) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

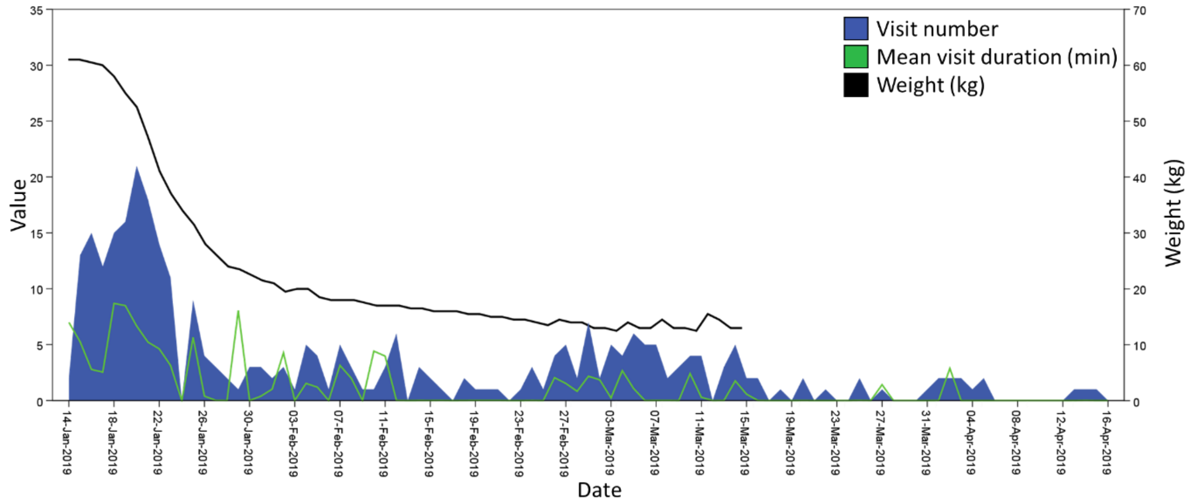


Figure G.14: Mongoose visit number and mean duration for Clothed 2 Summer 2019 (C2-S19) plotted against date overlaid with carcass mass loss.

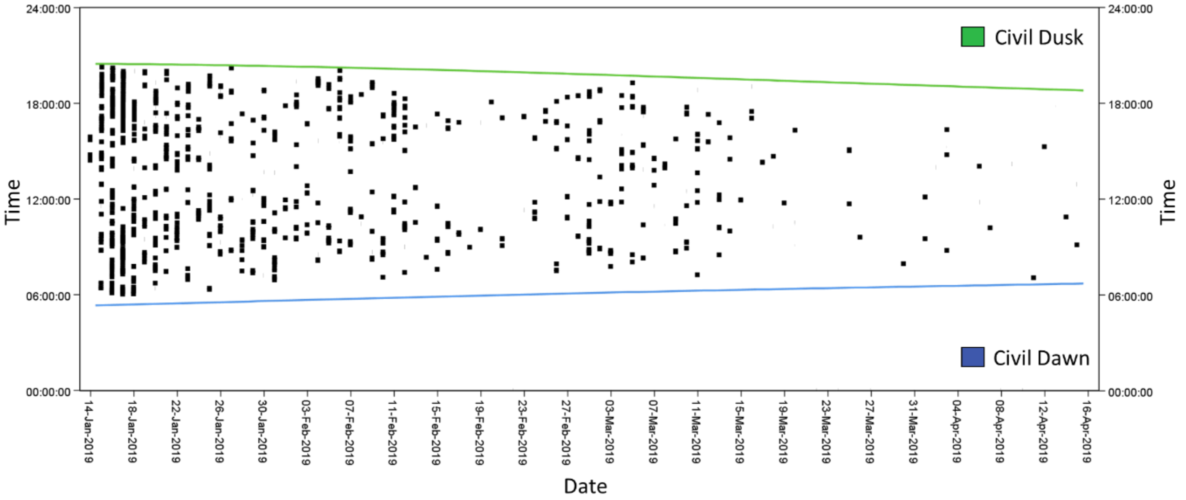


Figure G.15: Mongoose visit duration for Unclothed 2 Summer 2019 (UC2-S19) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

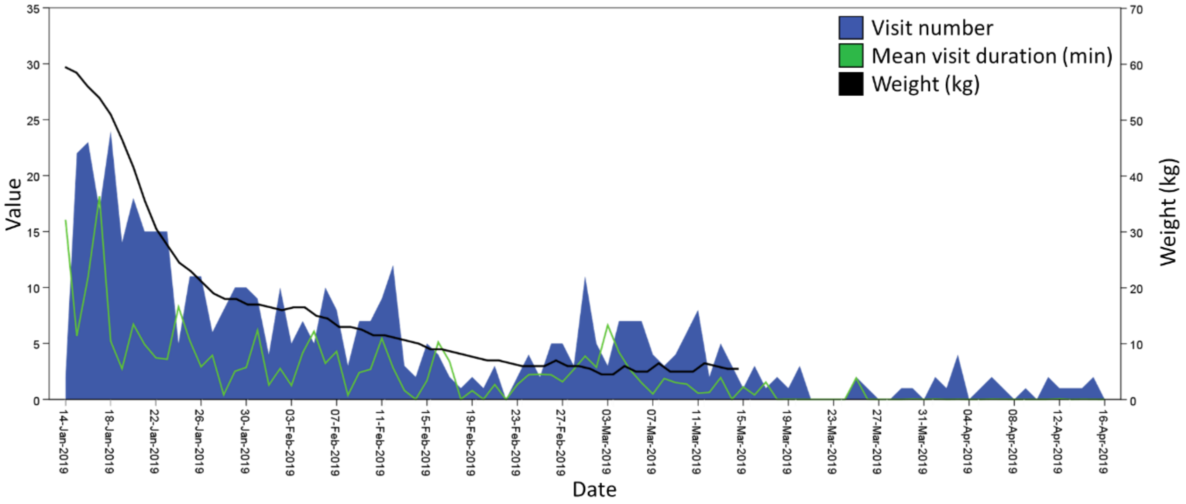


Figure G.16: Mongoose visit number and mean duration for Unclothed 2 Summer 2019 (UC2-S19) plotted against date overlaid with carcass mass loss.

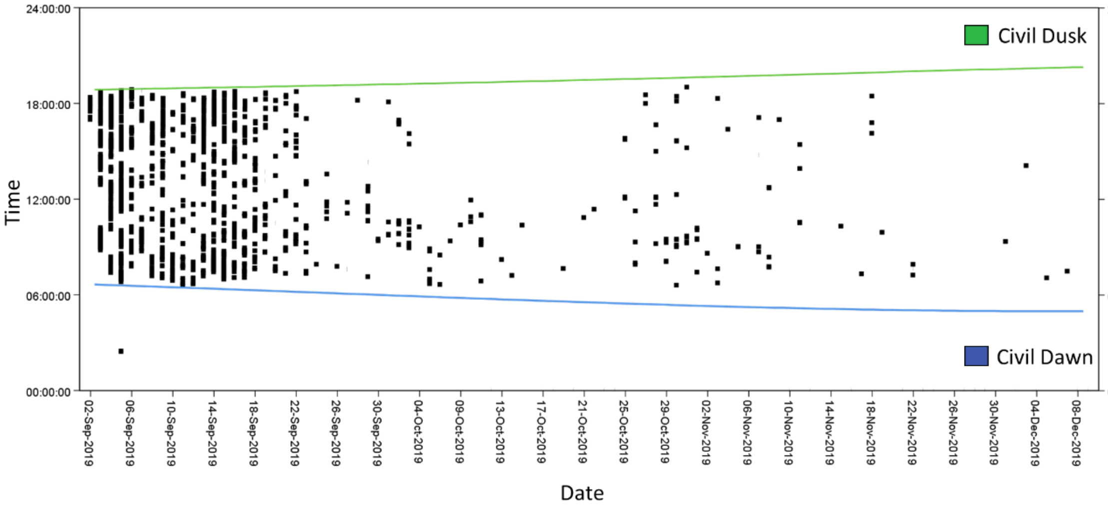


Figure G.17: Mongoose visit duration for Clothed 1 Winter 2019 (C1-W19) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

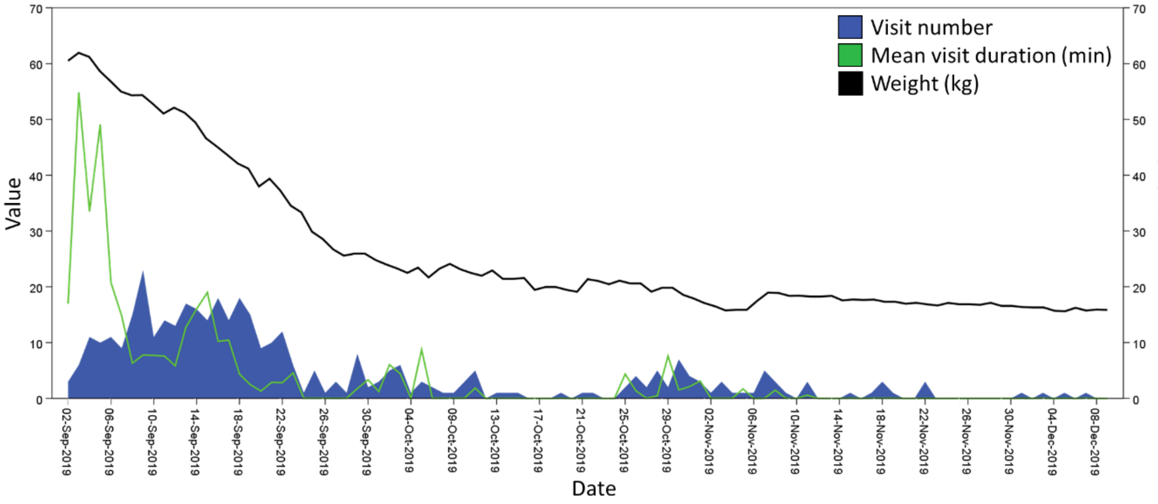


Figure G.18: Mongoose visit number and mean duration for Clothed 1 Winter 2019 (C1-W19) plotted against date overlaid with carcass mass loss.

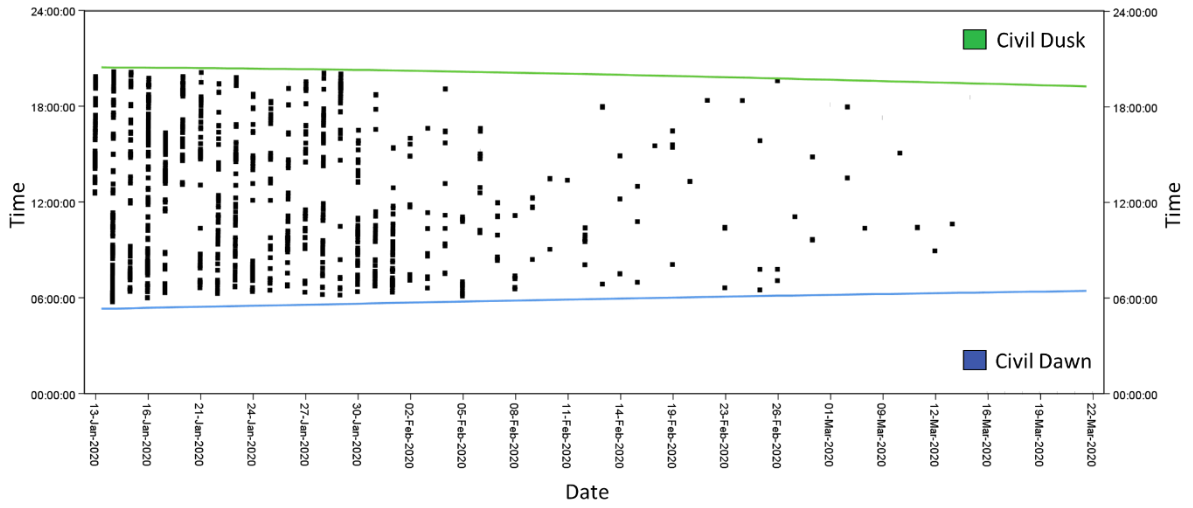


Figure G.19: Mongoose visit duration for Clothed 1 Summer 2020 (C1-S20) plotted against date between civil dawn and dusk with the longest visits occurring early in the cycle.

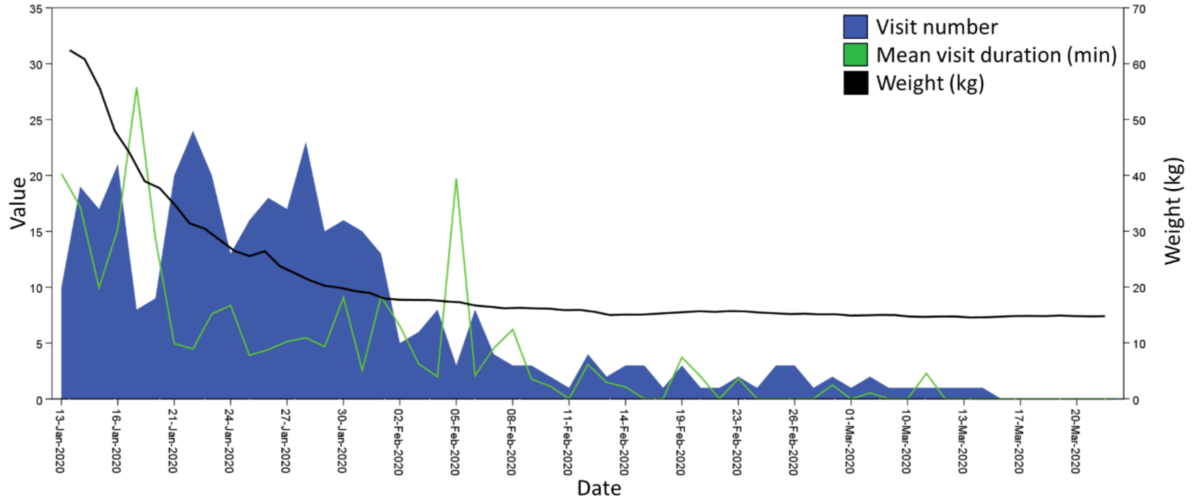


Figure G.20: Mongoose visit number and mean duration for Clothed 1 Summer 2020 (C1-S20) plotted against date overlaid with carcass mass loss.