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Forensic Entomology
The Use of Insects in Death Investigations To Determine Elapsed Time Since Death In Interior and Northern British Columbia Regions

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EXECUTIVE SUMMARY

Research was conducted in Northern and Interior British Columbia in order to develop a British Columbia database of insect succession on carrion. This database will be used to determine the postmortem interval in homicide investigations. Decompositional experiments were conducted in both geographic locations during the spring and summer of 1995. Results of research not only proved that insects colonize in a predictable fashion thus the data can be used to determine time of death, but also illustrated distinct variations in insect succession pending on geographic, season and habitat variables. Despite these variables it was found that insect succession was predictable within each of these parameters. This work has been used in the investigation of two human death investigations and one poaching investigation. It will continue to be available for subsequent investigations in both these areas and areas of similar climatic conditions.

SOMMAIRE

On a effectue des recherches au nord et à l'intérieur de la Colombie-Britannique afin d'élaborer une base de donnees sur l'ordre d'apparition des insectes qui colonisent les carcasses d'animaux. Cette base de donnees servira à aider les enquêteurs à determiner le temps écoulé depuis le décès dans les cas de meurtre. On a fait des experiences de decomposition dans ces deux regions geographiques au printemps et à l'automne de 1995. Nos recherches ont non seulement prouvé que les insectes envahissent les carcasses d'une façon previsible et que les donnees ainsi recueillies permettent de determiner le moment du décès, mais elles ont aussi permis de distinguer les variations dans l'ordre d'apparition des insectes selon la geographie, les saisons et l'habitat. Malgré ces variables, on a decouvert que l'ordre successif des insectes est previsible en fonction de chacun de ces parametres. On a utilisé les résultats de ces recherches pour enquêter sur la mort de deux personnes et sur une affaire de braconnage. Ils serviront également à d'autres enquêtes dans ces mêmes regions et dans des endroits de conditions climatiques semblables.

FORENSIC ENTOMOLOGY -- THE USE OF INSECTS IN DEATH INVESTIGATIONS TO DETERMINE ELAPSED TIME SINCE DEATH IN INTERIOR AND NORTHERN BRITISH COLUMBIA REGIONS ANNUAL REPORT -- MARCH 1995 TO MARCH 1996

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ABSTRACT

Research was conducted in Northern and Interior British Columbia in order to develop a British Columbian database of insect succession on carrion. This database will be used to determine the postmortem interval in homicide investigations. Decompositional experiments were conducted in both geographic locations during the spring and summer of 1995. Results of research not only proved that insects colonize in a predictable fashion thus be used to determine time of death, but also illustrated distinct variations in insect succession pending on geographic, season and habitat variables. Despite these variables it was found that insect succession was predictable within each of these parameters. This work has been used in the investigation of two human death investigations and one poaching investigation to date. It will continue to be used in all subsequent investigations in both these areas and areas of similar climatic conditions.

ABSTRACT (non-technical)

Forensic entomology is the study of insects associated with carrion in order to determine elapsed time since death. There are two methods of establishing the postmortem interval. The first method involves measuring the rate of development of immature blowflies. The second method involves studying the predictable sequence of insects that are attracted to a corpse over time. Both methods vary according to habitat, season and geographic location. Research conducted in the spring, and summer 1995, established a database of

developmental rates and expected sequence of insects for Interior and Northern British Columbia. This was used in several death investigations in British Columbia in 1995 and 1996 to establish time of death.

OUTLINE OF PROJECT

Forensic entomology is the study of insects associated with carrion in order to determine elapsed time of death. Insects are attracted to carrion immediately following death and arrive over time in a predictable sequence. As a carcass decomposes, it changes from a fresh to skeletal state, going through a large range of biological, chemical and physical changes. Different stages of decomposition are attractive to different species of insects. When the sequence of insects colonizing carrion is known, an analysis of the insect fauna on the carcass can be used to determine the time of death. This procedure provides accurate and precise methods for determining elapsed time since death and has been admitted in court in homicide cases many times. Forensic entomology will be of equal use in poaching cases and can be used to determine whether an animal was killed in or out of season. This technology can also aid in the apprehension and successful conviction of a poacher, by focusing the investigation into the correct time interval. If this time interval is known, it may quickly eliminate several suspects, or corroborate other evidence which implicates a poacher. This may save law enforcement agencies both time and money.

Insect succession will vary according to geographic location due to biogeoclimatic differences. For this reason, a database of developmental rates and expected succession insects in various habitats and seasons must be compiled for each geographic location where this technique is used. Carrion communities have been studied in Europe, where insects have been used in death investigations since the 1850's but different geographical and meteorological conditions, coupled with geological distinctions make extrapolating these data to North American situations dangerous. Although forensic entomology research has been conducted in some States in America, including Hawaii, North Carolina and

Tennessee (Schoenly 1991; Greenberg 1990; Goff *et al.* 1986; Goddard and Lago 1985; Rodriguez 1983; Denno and Cothran 1976; Payne 1965; Reed 1958), very little research has been conducted in Canada. Publish data about insect succession in Canada includes Provinces of Quebec (Johnston and Villeneuve, 1897), and recently in British Columbia (Anderson and Vanlaerhoven, 1996; Dillon and Anderson 1995; Anderson, 1995), however no research until now has be conducted in Interior and Northern regions of British Columbia.

The goal of this research was to establish a badly needed baseline data for both Interior and Northern regions of British Columbia. Research was required in order to offer more reliable means of estimating the postmorten interval for these regions. Experiments focused on recording both developmental cycles of insect offspring as well as recognizing predictable patterns in insect succession for various seasons and habitats. This research expanded on previous research conducted in and case work from British Columbia. The developed database has provided vital information which in turn was directly applied to several human death cases and one wildlife death case. It is important to note that without this research, time of death in several cases in 1995 and 1996 could not have been established.

ORIGINAL OBJECTIVES OF PROJECT

During the spring, and summer of 1995, extensive research was performed on the use of insects as indicators of time of death in both Interior and Northern regions of British Columbia. The objectives of this research were to determine seasonal variations of insect succession as well as determine the rate of decomposition on domestic pigs *(Sus scrofa)* in two outdoor habitats; sunny and shady areas in order to develop data to determine elapsed time since death in homicide victims. This research provided a unique opportunity for interaction and co-operation between law enforcement officers, the B.C. coroners service, university researchers, local communities and school groups in order to develop the technology to determine time of death.

IMETHODS AND MATERIALS

Research Location

All research conducted for this project in 1995 was situated at the U.B. C. Alex Fraser Research Forests in the Cariboo Region of British Columbia (Figure 1). Field sites were generously donated for the duration of the experiments, free of charge by U.B.C. This forest is divided into two research blocks, each of which host different biogeoclimatic conditions. The first block, Knife Creek Block, approximately 3000 hectares in size, is located approximately 20 km east of Williams Lake and represents a dry Douglas-fir region (Figure 2). This region was the first site chosen for research plots as it represents typical climatic and geographical characteristics found in Interior British Columbia region. In contrast, the Gavin Lake Block, approximately 6000 hectares in size, is located approximately 80 km Northeast of Williams Lake and represents a moister, cooler, pine, Douglas-fir, and spruce region (Figure 3). This second region was also a designated site for research as it represents typical climatic and geographic features as Northern British Columbia. Both Interior and Northern British Columbia geographic locations were chosen for research as approximately 10 % of death investigations involving insects during 1988-1994 originated from these regions (Anderson, 1995). It is felt that this percentage is artificially low, as coroners, police officers, and conservation officers north of the Lower mainland were found to be unaware of forensic entomology as a method to determine time of death (Lazzarotto, pers comm; Slavens, pers comm; Tait, per comm). We suggested that extensive training about forensic entomological procedures be developed for all these law enforcement agencies.

Research sites in both blocks were carefully chosen with considerable help from the Alex Fraser Research Forest staff. As both research blocks have no restrictions on public access to the forest, sites deemed most isolated from the public were chosen. Limited public interference was important as it was considered desirable to avoid distressing the public with dead animals. As well, it was important to minimise any potential tampering with the experiments. As a precautionary measure, letters addressed to all residents located near the research blocks as well as letters addressed to ranchers using the forest as foraging grounds for their cattle were issued. These letters outlined the significance of the research as well as outline the potential hazards from large vertebrate scavengers such as black bears attracted to carcasses.

Safety Precautions

Due to the dangers of attracting large carnivores while conducting carrion-related work in the research forest, several precautionary measures were taken. Sites for carcass placement were located close to service roads to provide quick escape should danger arise. As well, a chemical repellent called "Bear Phaser", a loud sound device as well as a radio phone were available for use at all times during field work. During the research season, at the northern research plot, it became necessary to take further precautionary measures. Tremendous carnivore activity attracted to carrion in the forensic entomological burial project created dangerous working conditions in this area. Conservation officers, Roy Slavens and Ken Owen, credited the damage to either black bear or wolverine based on the extent of damage and scattering activity of the carcass (Owen, pers comm). This posed potential problems as carnivores will tend to protect an optimal feeding ground (Ministry of Forests, 1993). For safety precautions, research sites had to be moved for the next phase of experimentation to a further but safer location. All future field work conducted had to be accompanied by a volunteer from the local Rifle association (Figure 4). Forest staff insisted on being informed of each sampling day, and of my location in the forest. This was accomplished through scheduled phone checks while working in the field. As well, all local ranchers and residents in the area were issued a second letter notifying them of a new potential bear/wolverine problem.

Experimental Design

The experimental design implemented was based on a previous study conducted in the Lower Mainland of British Columbia (Dillon and Anderson, 1995). This study used a strong sample design in order to gather meaningful data about carcass decomposition and insect succession. As a result, all data could be applied extensively to current homicide cases for these geographic areas.

Decomposition experiments conducted both nationally and internationally have involved the use of a wide range of carcass types such as dogs (Reed, 1958), lizards (Cornaby, 1974) deer, calves (Pfuntner, 1977) and pigs (Anderson and VanLaerhoven, 1996; Dillon and Anderson, 1995; Hewadikaram and Goff, 1991; Shean et al, 1993; Tullis and Goff, 1987; Payne, 1965.). Domestic pig carcasses (*Sus Scofa*) were used in our experiments as they have been deemed the most acceptable animal model and have been widely used in many other decomposition studies (Goff, 1993). Pigs are omnivorous and possess a digestion system similar to that of humans. Gut fauna is important in the evaluation of the decompositional process of carcasses. As well, pigs are relatively hairless and have skin tissue so similar to that of humans that it has been used in human skin grafts. Pigs are available in large numbers in the same size, weight, sex and colour making replicating sampling possible. Only freshly killed pigs were used for experiments.

Approximately, twenty-three kilogram (50 lbs) pigs were used for all decompositional experiments conducted. This weight, is approximately the equivalent weight of an average adult male torso, which is the main site of decomposition and insect colonization (Catts & Goff, 1992). All pigs were shot and killed using a 15 cm pin gun (Figure 5) to the forehead of the pig. All carcasses were shot a second time with a .22” calibre, short, high velocity, bullet in the side. This second bullet wound was created for the sole purpose of inserting a temperature probe into control carcasses. At each site, four of the ten pigs were designated control carcasses and had temperature probes inserted into the bullet wound.

Internal carcass temperatures as well as ambient temperatures were recorded every 30 minutes. Freshly killed carcasses were immediately transported to research sites (Figure 6).

All pigs used in the spring experiment were clothed in underwear, socks, T-shirts and old R.C.M.P . uniforms obtained by the R.C.M.P. detachment in Burnaby, B.C. (Figure 7). As observed on two supplementary carcasses in the forensic entomology research project conducted in the Lower Mainland in 1994, clothing has absorbed bodily fluids and created shelter which seems to make the carcass more attractive to insect species (Dillon and Anderson, 1995). As well, clothing on the carcasses has greatly facilitated insect collection (Figure 8). Pig carcasses used during the summer experiment were similarly clothed.

Ten sites in each of the two research block were chosen for the spring experiment. Five of these sites were located in the shade habitat and five sites in a sun habitat. All sites were a minimum of 45m apart. Large steel barred protective cages that had been constructed for previous carrion studies were relocated (Figure 9), placed at each site and staked to the ground with four 45 cm steel spikes (Dillon and Anderson, 1995). These cages were designed to protect carcasses from large carnivore attack (such as that by black bears, *Ursus americanus)*, without impeding insect activity to and from the carcasses. Each cage measured 1.05 m long, 0.75 m wide, and .45 m high and was constructed with $1cm^2$ steel bars, evenly spaced 4 cm apart. Three chain-linked rings acted as hinges so that the cages opened upwards. Cages were bolted closed using 3 cm bolts. Preliminary testing proved that the cages were able to withstand approximately 650 lbs of direct weight. (This testing leads us to believe that the cages would be able to withstand bear tampering). Each cage housed one pig carcass. Pig carcasses were placed in the middle of the cages so that no parts of the carcass was close to the edge of the cage.

Pitfall traps, a sampling method designed to trap crawling insects, were used to collect both insects associated with the carcass as well as insects not associated with the carcass. Control pitfalls were placed approximately 15-20 meters away from the related pig site to determine naturally occurring fauna. Each pitfall consisted of a 250mL jar buried so that the lip of the jar was flush with the surface of the ground. Soapy water was placed into the bottom of the jar. The contents of each pitfall jar was filtered through a labelled piece of muslin cloth weekly. Insects collected on the muslin cloth were identified, recorded and preserved.Photographs of each pig carcass were taken, on each sampling day. Photographs were taken to provide a means of recording the decomposition progress as well as a means of comparing pig carcasses from different sites and different seasons.

In total, four experiments (two in the Interior British Columbia region and two in the Northern B.C. region) were designed for 1995. Each experiment took place during either the spring or summer season. All experiments were aimed at examining insect succession on pig carcasses in two different habitats, a sunlight habitat and a shaded habitat.

Experimental Carcasses

Three carcasses in each experiment were designated as experimental carcasses. The carcasses were examined approximately every three to four days throughout the experiment. At each sampling session, carcasses were weighed, visually examined, insect samples collected and photographed. Clothing associated with the carcasses were also scrutinized. Carcasses were placed on a large mesh platform, which could be raised by a pulley system. This allowed for weight measurements to be taken and also facilitated insect sampling beneath the carcass. The mesh platform also allowed the carcass to maintain contact with the ground. This design was chosen as previous preliminary experiments in British Columbia confirmed that thin, large spaced mesh did not impede insect activity nor affect the rate of decomposition (Anderson and VanLaerhoven, 1996). Biomass removal over time was recorded and insects directly associated with experimental carcasses were collected on every sampling day during experimentation. All insects collected were examined, identified and catalogued. These insects were also used to create a large reference collection for future use in homicide investigations.

Such regular collection no doubt resulted in the majority of insects on the remains being recorded. However, many carrion insects are nocturnal or crepuscular, and would, therefore, be missed by hand collection. Therefore, pitfall trapping was carried out at each carcass. Previous experimentation discovered that a pitfall trap placed anywhere within -20 cm of the carcass would catch a representative sample of insects attracted to and leaving the carcass (Dillon and Anderson, 1995).

Also, although baseline data for naturally occurring fauna was established prior to carcass placement, seasonal changes could be expected, so a control pitfall trap was placed ~ 20 m away from each carcass, and collected every second day, as with carcass-related pitfall traps, to determine which insects were carcass-associated and which were merely naturally occurring in the area for that time of year.

Control Carcasses

Control carcasses were used in order to determine whether or not the sampling method employed in the experimental carcasses for the specific geographic region, disturbed the rate of decomposition and insect fauna associated with the carcasses. Therefore, control pig carcasses were not disturbed. Only temperature measurements and visual observations were made. Ambient and internal carcass temperatures were recorded at each control pig. Internal carcass temperatures were obtained by means of inserting a permanent temperature probe approximately 8-10 cm into a small entrance wound on the carcass immediately after death (Figure 10). The entrance wound was created by shooting the carcass with a .22" calibre short, high velocity bullet, as previously mentioned. This probe was connected to a datalogger (SmartReader 1, Young Environmental Systems, Richmond, B.C.) which recorded temperature every half hour. All temperature data recorded was later downloaded into a PC laptop computer for analysis. Maggot masses are capable of raising the temperature of the carcass which in turn can affect the developmental rate of blow flies (Goff, 1993) (Figure 11). Temperature measurements were taken in order to compare ambient with internal carcass temperature between carcasses in the same habitat, different habitats and different seasons. Such comparisons were important in determining insect developmental rates at these carcasses. No insects were collected directly from the control carcasses, however extensive visual analysis was made for comparison with experimental carcass fauna. As well, pitfall traps were placed near each carcass, together with control pitfalls 20 m away. Pitfall traps were not considered to effect the actual insect succession on the carcass or the rate of decomposition, but allowed for a direct comparison with experimental carcasses, and served as a back-up to visual insect identification on control carcasses. Pitfalls were the only means of collecting insects on control carcasses.

RESULTS

Spring season results regarding the rate of decomposition, rate of blowfly development and insect succession in various habitats (sun and shade) is presented. Only observations for the summer season will be offered as this data is currently still under analysis.

Control *Versus* Experimental Carcasses Observations

Regardless of season and geographic location, no significant differences were found between control and experimental pig carcasses located in the same habitat. Colonization times for many successional insects such as Dermestidae, Silphidae, Staphylinidae, Histeridae and Piophilidae occurred within l-2 days of each other. This observation is important as it means that the methodology utilized for experimental carcasses did not disturb both insect succession as well as the rate of decomposition to any significant degree despite extensive sampling of experimental carcasses. Based on these findings all data obtained the same experimental set was complied together.

Habitat Differences (Sun Versus Shade)

1. General Observations

Interior Region

Carcasses located in the sun habitat tended to decompose slightly faster than those located in the shade habitat regardless of season. While differences in larval development and rate of decomposition were noted, no significant differences were found in insect succession during the spring. Based on preliminary observations, it is suspected that these trends continue in the summer season. Summer data is still under analysis.

Northern Region

In general, decomposition, blow fly development and insect succession occurred at a faster rate than in the exposed sun sites compared to the shade sites during the spring season.

2. Rate Of Blow Fly Development

Blow fly development can be linked to the recording of internal carcass temperatures. These temperatures become elevated with maggot activity. All temperatures used in the results reflect average temperatures recorded.

Interior Region

Graphs 1-4 depict average ambient or external temperatures (shown as black solid line) and internal carcass temperatures (shown as the dotted line) recorded during decomposition for both sun (Graphs 1,3) and shade (Graphs 2,4) sites during the spring and summer season.

During the spring, ambient temperatures for sunny sites tended to be approximately 5 C higher than experienced in shade sites. Despite this difference, both sites were able to attain internal carcass temperatures of approximately 30-35 C (Graphs 1-2). Highest internal temperatures were reached 8-15 days since death in the sun habitat and 20-28 days since death in the shade habitat. However, both sites had an extended period of elevated temperatures above ambient, from 8-29 days in the sun and from 8-30+ days in the shade habitat.

No ambient temperature differences were observed for the summer season. Both sun and shade sites had peak internal carcass temperatures of close to 40 C (Graphs 3-4) at 8 and 9 days since death respectively. Internal temperatures in the shade habitat were elevated to higher temperatures overall in comparison to internal temperatures achieved in the sun habitat.

Northern Region

Similarly, Graphs 5-8 represent ambient and internal carcass temperatures recorded during decomposition for both sun (Graphs 5,7) and shade (Graphs 6, 8) sites.

Surprisingly, higher ambient temperatures of approximately 5 C were experienced in shade sites compared to sun sites during the spring (Graphs 5-6). It is felt that extreme temperatures recorded in the sun habitat were a contributing factor. However, internal carcass temperatures seemed independent of ambient temperatures. Internal temperatures though not as great, peaked earlier in sun sites compared to shade sites.

Unlike temperature recordings for the spring season, sun ambient temperatures were approximately 5 C warmed than that recorded in the shade habitats. During the summer, internal carcass temperatures, which indicate third instar dipteran larvae activity peaked an entire 10 days earlier in the sun carcasses than in shade carcasses. The length of elevated internal temperatures also varied; in the sun, such temperatures remained elevated for only 5 days whereas in the shade, temperatures were elevated for 14 days.

3. Rate Of Decomposition

During experimentation, weight measurements were taken in order to record the reduction in biomass as a result of maggots feeding upon the carrion. However many difficulties in obtaining representative measurements were experienced. These difficulties are discussed in further detail later in this report.

4. Insect Succession

Interior Region

Tables 1 and 2 represent the presence and absence of several key successional insects over time on pig carcasses, located in both habitats for the spring experiment. These tables depict slight variations observed in the timing of successional insects. Arrival and duration times of insects such as Piophilidae larvae, Histeridae, Silphidae, Staphylinidae and Cleridae are recorded. One key successional insect species, Fanniidae, was never found on either sun or shade carcasses during the spring season.

Although successional data from summer experiments are currently being processed, trends indicate definite habitat variation.

Northern Region

Insect successional trends for the northern region is illustrated in Tables 3 and 4. Once again, the presence or absence of successional insects and their duration times associated with the carcass are presented. It is interesting to note that Fanniidae sp., never found on interior region carcasses, were found on all northern carcasses. Despite problems with scavenging experienced in the shade habitats (Figure 12), the presence of several key successional species was still identified.

DISCUSSION

Habitat Differences

1. Rate Of Larval Development

While many scientists offer extensive recorded details about larval developmental rates generated in a controlled laboratory setting (Greenber, 1991; Kamal, 1958), nature does not exist in a controlled manner. Temperature, humidity, and other environmental factors fluctuate unpredictably and hence, possible taphonomic processes on a cadaver are many. For this reason, it is vital to analyze the fauna of a cadaver under natural conditions. This allows for a more accurate representation of real case scenarios and is more defensible in court.

In all spring experiments, blowflies were not found to immediately invade carcasses. Immediately following death, both experimental plots experienced average daily temperatures of approximately 13-15 °C. While these temperatures are reported to be within normal blowfly flight activity (Mann et al, 1990), extreme minimum temperatures of below 0°C seemed to delay oviposition. Due to the lack of rainfall, rainfall was excluded as a possible factor delaying oviposition.

In all carcasses, egglaying was found to occur predominately around facial areas, wound sites and ground body interfaces. This findings correspond with other carrion studies (Anderson and VanLaerhoven, 1996; Rodriguez and Bass, 1983). However, experience with multiple carcasses indicated that blowflies may also oviposit between body-body interfaces (Figure 13). We feel this has tremedous implications towards human death scenarioes involving multiple bodies.

Blowflies attracted immediately following death tend to colonize a carcass, creating large maggot masses within approximately 5-10 days in the interior region and 6-17 days in the northern region. Heat is produced within a maggot mass as a result of mechanical, and metabolic maggot activity as well as a result of the putrefaction processes (Goff 1993). This heat is measured in experiments as the internal carcass temperatures. It is important to record increases in internal temperatures as insect development is temperature dependent. This means that the normal metabolic rate is increased with increased temperature, which results in a faster rate of development, so that the duration of development decreases in a linear manner with increasing temperature (Chapman 1955). For this reason, both internal and ambient temperature must be determined. Temperatures were measured by utilizing dataloggers which were calibrated to record internal and external temperatures every half hour. Only average daily and internal temperatures were considered for analysis. As reported in Anderson and VanLaerhoven, 1996, most carrion studies only seem to consider single internal temperatures usually taken during the day. However, internal temperatures of carcasses have been found to greatly fluctuate throughout daily recordings. We have found that average internal temperatures more accurately reflect actual living conditions of maggots in comparison to single temperature recordings.

The lag time prior to heat being produced has been found to be related to the lack of an organized maggot mass during early instars (Goff, 1993). In general, lag times were greater during colder seasons, shade habitats, and northern geographic areas. A greater lag time of approximately 7 days during the spring season and 3 days during the summer season was found to be always associated with shade carcasses, regardless of geographic location. The end of lag time (hence beginning of organized maggot masses generating heat) was considered to occur when internal carcass temperatures were 3°C or more above ambient temperatures. Temperatures above 3 °C were considered to be primarily due to maggot activity. As well, both sun and shade carcasses located in the northern region had a greater lag time (approximately 2-6 days depending on season) than carcasses in the interior region. Longer lag times can be attributed to lower ambient temperatures during the spring, in the shade and in the northern region. More research analyzing the length of lag times is suggested, as it may be possible to gain an immediate rough in field estimation of elapsed time since death for carcasses lacking organized maggot masses. However, it is important to add that any correlation's discovered with lag time would not be useful in situations where no organized maggot masses were generated. Lack of organized maggot masses may occur under situations of cold weather (fall/winter seasons), extreme scavenging, and any other disturbances to the cadaver.

In general, it was found that internal carcasses temperatures were greatly elevated above ambient temperatures during the period of decay. This corresponds to the findings in other field projects (Dillon and Anderson, 1995; Catts & Haskell 1990). While these elevated temperatures were found to occur in all habitats and geographic locations, the degree and time of temperature variation differed between all experimental sites. Elevated and peak internal carcass temperatures were a direct result of intense maggot activity within the carcass. For all carcasses studied in 1995, peak temperatures occurred earlier at the exposed carcasses than was experienced at shade carcasses (please refer to Graphs 1-8). However, these earlier peaking times in the sun sites varied from 1 to 9 days before those experienced in shade sites. It is interesting to note that these peaks also coincided with larval migration. This infers that the growth and development of maggots in the sun habitat occurred at a more accelerated rate than in the shade habitat.

Although temperature was seen to be a major difference between the sun and the shade habitats, there are many other environmental differences. These include depth of shade, sun exposure (none, partial etc.) type of canopy (Figure 14), amount of shelter for insects, small rodents etc., effect of rainfall (may be ameliorated somewhat in shade, but moisture may remain for longer), light intensity, wind levels, to list just a few. Such parameters may effect the number and presence of insects and other fauna in the habitat prior to and during carcass placement.

2. Rate Of Decomposition

The rate of decomposition was measured by recording weight reduction of carcasses over time. This would enable us to record changes in carcass weight as a direct result of decomposition and maggot feeding activity upon each carcass. This means of determining the rate of decomposition was found to be less successful as previous experiments using unclothed carcasses (Anderson and Vanlaerhoven, 1996; Dillon and Anderson, 1995; Shean, 1993). Weight measurements did not reflect the true biomass loss. Clothing on carcasses tended to absorb bodily fluids as well as moisture from any rainfall. Any weight gain could be attributed to this. As well, prepupal maggots tended to pupate within clothing rather than the soil, (Figure 15) as it provided adequate shelter required for the pupation stage. This meant that weight reduction due to maggots leaving the carcass was not able to be recorded.

During the spring, vertebrate scavengers in the northern region acted to remove both tissue and associated clothing. This also created abnormal weight measurements being recorded.

Rainy weather conditions created many problems in obtaining accurate weight measurements of carcasses. Due to the weight and size of the tripod apparatus, this equipment had to be transported into the field sites in a truck. Public access roads utilized were hilly and impossible to traverse when wet. Therefore, on some occasions, equipment could not be moved to field sites.

Clothing associated with carcasses was also found to hamper identification of deompositional stages. Decompositional stages are recognized as a useful and convenient means of labelling the decompositional process (Schoenly, 1983). Identifying features of these stages such as odour, discolouration, and extent of bloat was hampered by clothing. Attempts to search for these discrete stages were hindered as disturbances to the carcasses had to be minimized. Experiments conducted by Shean et al, 1993 suggest the use of girth measurements to gain information regarding bloat stages. However, despite difficulties in observing the rate of decomposition in clothed carcasses, it was still very valuable in providing an accurate assessment of insect succession.

3. Insect Succession

Insects visiting carcasses over time in both habitats were carefully recorded in order to establish a predictable sequence of insect succession (Tables 1-4). In these tables, the presence or absence of several key successional species during the spring season was recorded. Little variation of insect colonization times between the habitats was noted. For example insects such as Piophilidae larvae, Cleridae adult beetles, various Staphilinidae beetle larvae, and emerging blowflies were all first observed regardless of habitat, within one day of each other.

Clothing was found not only to attract insect successional species for long periods of time but to greatly enhance collection of insects. Many insects including nocturnal species were found to use the clothing as shelter. Most carrion studies have researched colonization times of successional insects utilzing unclothed animal models (Anderson and VanLaerhoven, 1996; Shean, 1993; Hewadikaram and Goff, 1991; Rodriguez and Bass, 1983). In fact, in one decompostional study, cadavers were first completely unclothed prior to commencing insect related research (Rodriguez and Bass, 1983). However, most death investigation, humans are either partially or fully clothed (personal observations, LCD and GSA). Through our research, we advocate the use of clothed animal models as these models would more accurately represent real case scenarios.

While many trends in insect succession were found during the extensive research conducted in the Interior and Northern regions of B.C., only two major groups of insects are highlighted in this discussion. Successional insect data from the 40 carcasses used are still under investigation. All successional data will be used to create a British Columbian database. This database will be based on a BASIC algorithm created by Shoenly et al., 1992.

As was previously noted in Canadian carrion studies, Piophilidae larvae occurred considerably earlier than in carrion experiments conducted in different geographic locations (Anderson and VanLaerhoven, 1996; Dillon and Anderson, 1995). For example, Piophilidae larvae were first observed approximately 21-26 days since death regardless of experimental site. In comparison, experiments conducted south of Canada and in Europe reported Piophilidae larvae colonizing carcasses after approximately 3-6 months since death (Smith 1986).

Another feature important to note is the absence of any Fanniidae species found during the spring, in the interior region. This was not the case for the northern region, nor for any sites in the summer season. The summer season was plagued with rain, and it is felt that more optimal conditions for Fanniidae species were created.

Seasonal Differences

Experiments took place during both spring and summer seasons. This enabled comparisons to be made outlining any seasonal variation. As was expected, season of death had a major effect on the development of blowflies, as well as successional insect species. This data is still under analysis.

It is suggested that the size of the fly may be indicative of season. During the summer, both experimental sites experienced ambient temperatures above 25 C This heat was a catalyst, creating fierce competition between larval stages for food resources. High intraspecific competition lead to the inability for dipterian larvae to obtain adequate food resources. In fact, as with Kamals findings, in lab conditions, such competition lead to the production of undersized blowfly adults (Kamal, 1958). These findings were restricted to carcasses located in the sun habitats, during the summer season. We believe that undersized blowflies may be indicative of not only hot seasons, but also of exposed habitats. This may have important implications towards actual human death cases.

CONCLUSIONS

This investigation showed that insects do colonize carcasses in a predictable sequence and that this insect colonization sequence can be used to determine elapsed time since death. The sequence of colonization varies depending on geographic location but not habitat location. We know from this work that variations also occur depending on season of death. The data generated from this investigation is now available for use in death cases in which the victim was killed in spring, and summer in Northern and Interior Regions of British Columbia and is applicable to both shaded and sunny crime sites. These data have already been applied to several human death investigations in B.C. in 1995 and 1996 and will continue to be used in future cases. Combined with research conducted in 1994 in the Lower and Coastal Mainland, data collection for the B.C. database has been obtained (Dillon and Anderson, 1995).

Clothing was found to not only to impede measurement of the rate of decomposition, but also hindered the identification of distinct decompositional stages. . Decompostional stages however, were much more similar to those of actual homicide victims than wee naked carcasses (personal observations, LCD and GSA). Despite these difficulties, clothing prolonged insect colonization, making the carcass more attractive to carrion feeding insects for longer periods of time. Clothing provided many diural and nocturnal insects with shelter. Clothed animal models was found to provide much more realistic homicide scenarios. It is recommended that future studies consider this all factors related to clothing carcasses.

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Figures 1-7

Figures 8-15

Graphs and Charts