Forensic entomology in British Columbia: A brief history

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Forensic, or medicolegal, entomology is the study of the insects associated with a dead body, primarily to determine time of death. In its broadest sense, forensic entomology actually refers to any legal activity that involves insects or other arthropods. This includes urban entomology, involving insects which affect the human environment, such as structural damage by termites or carpenter ants and even spider bites (Haskell *et al.* 1997) and stored products entomology, involving the insects and insect residue in stored products such as grain and flour. However, it is the medicolegal or medicocriminal aspects that are most commonly referred to by the general term 'forensic entomology'.

Determining time of death is paramount in a death investigation. Knowing time of death focuses the police investigation into the correct time frame, can support or refute a suspect's alibi, helps in the identification of an unknown victim, improves efficacy of the police investigation and most importantly, is vital in determining time line prior to death, victim's whereabouts, associates seen with victim, *etc.* Determining time of death is, therefore, vital. Pathologists can estimate time of death based on several medical parameters (Henssge *et al.* 1995) but these are only valid for the first few hours after death, becoming less valuable as time passes and can usually not be used beyond about 72 h. However, homicide victims are frequently not discovered for days, weeks or months. Forensic entomology is the most accurate, and frequently the only method of determining time of death when more than a day or two have elapsed (Kashyap and Pillai 1989). It continues to be valuable up to a year or more after death. Forensic entomology also can be used to determine whether the body has been moved from one site to another, whether the body has been disturbed after death, the position and presence of wounds, *etc.*, but its primary use is to determine time of death.

A dead body, whether animal or human, is a rich but temporary and ephemeral resource, exploited by many organisms, primarily insects. Within minutes of death, assuming conditions are suitable, insects, primarily the Calliphoridae and Sarcophagidae, colonize a body, developing at predictable rates, based on environmental and meteorological conditions (Anderson and Cervenka 2001; Anderson and VanLaerhoven 1996). As the body decomposes it goes through rapid biological, chemical and physical changes, attracting a sequence of colonizing insects until nothing of nutritional value is left. This sequence of colonization depends on biogeoclimatic zone, habitat, season, microclimate *etc.* but is predictable within those parameters (Anderson 2000a). This predictable and sequential colonization of a body allows an entomologist to determine the tenure of the insects on the body, and therefore the minimum time since death.

The use of insects in death investigations dates back to 13th Century China (McKnight 1981) and came into some use from the mid 19th Century in Europe (Smith 1986; Yovanovitch 1888). This early interest led to a study on insect succession on human corpses in Quebec, Canada, in 1897 (Johnston and Villeneuve 1897). However, little forensic entomology was used in Canada after this time until the 1970s, when police interest in forensic entomology began to grow in North America, with interest developing in three major centres in North America: one of those was Vancouver, British Columbia.

In the 1960s and 1970s Peter Zuk, Vancouver Research Station, Agriculture and Agri-Foods Canada (then Agriculture Canada) was involved in several cases for the police, including the infamous Clifford Olsen cases. He was probably the first to present forensic entomological evidence in court in Canada, and certainly in British Columbia. In the early 1970s, police came to Dr. John Borden at Simon Fraser University wondering whether an insect found on a dead railway worker might be implicated in his death. John identified the insect as *Monochamus* species (Coleoptera : Cerambycidae), and stated that it could only be the cause of death if the decedent suffered from an extreme case of entomophobia! Forensic entomology at Simon Fraser University was born!

During the 1970s and early 1980s, Professor Thelma Finlayson, of the Centre for Pest Management at Simon Fraser University, received preserved specimens from several cases and was able to provide identifications and expertise. Cases were handled when a police officer had a specific question about insects involved in an investigation, but only on a sporadic basis, with Professor Finlayson, Dr. Borden and members of his lab providing the expertise. Other entomologists were also sometimes called in on a case by case basis. In the early 1980s, the BC Coroners Service approached John Borden about providing forensic entomology expertise on a more regular basis. John enlisted the aid of Akbar Syed, the head of the Simon Fraser University Insectary, and Akbar was involved in about a dozen cases until 1987. He attended crime scenes and autopsies and testified in court as an expert witness in forensic entomology (Skinner *et al.* 1988).

By 1987, police interest in the field was increasing, and case work and the need for court appearances was growing. I was just starting my Ph.D. in medical and veterinary entomology, with Dr. Peter Belton and Dr. John Borden at Simon Fraser University in the Centre for Pest Management. In late 1987, John Borden approached me and asked if I would like to take over the forensic entomology, as case work was increasing and Akbar Syed no longer wished to continue taking cases. Intrigued by the idea, I agreed. Although I immediately delved into the literature, nothing happened until August when I was thrown into the deep end with two cases arriving on the same weekend! One was a young man and another a single human thigh. I attended my first two autopsies on the same day! I determined the young man had been dead for a little over 3 weeks, based on the presence of Calliphoridae puparia and pupae, and the thigh had been colonized 3-4 days prior to discovery, based on Calliphoridae larval development. Both cases remain unsolved at time of writing. Although already an entomologist and continuing in my entomology training under John and Peter's guidance, I had no knowledge of forensic science, crime scene analyses, autopsies, court procedure *etc.* However I was fortunate to be kindly guided in this by then Corporal Bob Stair, (now Staff Sergeant, Retired) Royal Canadian Mounted Police (RCMP), Regional Forensic Identification Support Section (RFISS), Coroners Bart Bastien and Chico Newell of the BC Coroners Service Forensic Unit, and pathologists Dr. Sheila Carlyle, Dr. Laurel Grey and Dr. Rex Ferris. Everyone in the forensic field was extremely supportive and enthusiastic and I was hooked!

Case work was increasing every year and by late 1991 I was about to complete my graduate work. Therefore John Borden met with the Coroners office and the University and raised the money between the two to establish a position in forensic entomology at Simon Fraser University for me, which began in 1992. The Information and Identification Services Directorate and the Training Directorate, Royal Canadian Mounted Police (RCMP) later also supported this position.

It had become apparent to me during my case work that there was a desperate need for more research in this field: there had been no research in Canada since 1897 (Johnston and Villeneuve 1897), and none in BC. As a newly minted Ph.D. and professor I could now devote my research to forensic entomology. Analysis of maggot development, used in the early days and weeks after death, is based primarily on temperature, humidity and species so literature reports, although at the time few in number, could be applied. Insect succession over time, however, is much more dependent on local conditions and so literature reports from other areas, seasons, habitats *etc.* are not applicable. Therefore, the first research project in forensic entomology this century in Canada, and ever in BC was begun in 1992, funded by a small start up grant from SFU. I hired a keen young second-year year undergraduate student, Sherah VanLaerhoven and our first pig project began!

This first study looked at insect succession on carrion beginning in one season, summer, one scenario, direct sunlight, and was conducted in the Lower Mainland of BC, the Coastal Western Hemlock zone, using freshly killed pig carcasses. Pigs have long been accepted as the best model for human decomposition studies (Catts and Goff 1992) due to their similarity in skin type, gut bacteria, size, and relative lack of hair. Insect colonization on the carcasses was studied over a 10-month period. Results were dramatic. In previous studies in other temperate countries, with very similar climates to the Lower Mainland of BC, such as Britain, publications had suggested that key colonizing groups, such as Dermestidae (Coleoptera) and Piophilidae (Diptera) arrived months after death. Dermestidae were generally considered to be the last group to feed on the remains worldwide in temperate zones, with the majority of adults and larvae being collected in the final stages of decomposition when only skin and bones remain (Early and Goff 1986; Smith 1986; Rodriguez and Bass 1983; Payne and King 1970; Easton 1966; Reed 1958; Fuller 1934), although the actual post mortem interval varied with geographic region. Early colonization was only reported from much more tropical regions, such as Hawaii (Hewadikaram and Goff 1991; Early and Goff 1986). The only other report of insect succession on carrion in Canada states that Dermestidae, including *Dermestes frischii* Kugelman, were not collected on human remains until 3-6 months after death, despite compelling evidence of a case in which *Dermestes* sp. were found less than 5 weeks after death (Johnston and Villeneuve 1897). However, in the Lower Mainland of BC, Dermestidae larvae were first collected 21 days after death, and were commonly collected after 43 days post mortem (Anderson and VanLaerhoven 1996).

Piophilidae or skipper flies were similarly collected earlier than previously reported, with larvae being present 29 days after death. This confirmed case work in which I had collected Piophilidae from human remains 26 days after death (Anderson 1995). This initial study (Anderson and VanLaerhoven 1996) highlighted the need to conduct research in all biogeoclimatic zones, seasons and habitats in which forensic entomology is used. Such data are not necessarily transposable to other regions.

When large numbers of maggots congregate on a body, they form masses which generate high temperatures, affecting development rates. It had been previously assumed that although diurnal temperatures obviously fluctuated, internal carcass temperature fluctuated less, remaining at a higher, more constant temperature than ambient (Deonier 1940). Previous studies had measured maggot mass temperature daily but only at a single time each day (Shean *et al.* 1993; Early and Goff 1986; Payne 1965). In our experiments, we placed datalogger probes inside the carcasses, continuously recording internal carcass temperature, and found that although internal carcass temperature does increase considerably during active decay, there is greater fluctuation in internal than ambient temperature, with diel differences of more than 35°C (Anderson and VanLaerhoven 1996).

This study became the foundation for our future work. Research was needed in different geographical areas and situations as I was training police officers, in BC and across North America (Anderson *et al.* 1996; Anderson 1993a, b, 1991), so case work was increasing rapidly (Anderson 1995). I was also testifying in court as an expert witness, or my report was admitted as evidence in more and more cases.

Funding from the Canadian Police Research Centre (CPRC) allowed me to take on my first M.Sc. student, Leigh Dillon, and to expand the research into three biogeoclimatic zones, the Coastal Western Hemlock zone, the Sub-boreal Spruce Zone and the Interior Douglas Fir Zone. Although BC is divided into 14 biogeoclimatic zones, these three zones include the most populous areas, such as the majority of the Lower Mainland, Vancouver

Training police officers to collect insect evidence in a mock homicide scene.

Island, Prince George Region and the Okanagan, so consequently are the areas from which most forensic cases originate. This work again used pig carcasses as human models and insect succession was studied in the three zones, in spring, summer, and fall, in sun and shade.

Colonization times varied with season, habitat and biogeoclimatic zone, and occurred in a predictable sequence with similar species colonizing in each area, although colonization times varied (Dillon 1997; Dillon and Anderson 1996a, 1995). Some species were found in all areas, but in some areas certain species predominated. A distinct difference was noted between pigs in sun and shade, in species composition and abundance, as well as seasonal differences in both. Level of shade impacted decomposition rates, actual species attracted and arrival times. Pigs in shade were also scavenged more heavily by vertebrates, which impacted insect colonization (Dillon 1997; Dillon and Anderson 1996a, 1995).

This work generated excellent databases of insect succession on carrion for these biogeoclimatic zones and also confirmed our previous observations of earlier colonization times for many species in BC in comparison with some other regions, and the diurnal temperature fluctuations within the maggot mass. However, this work also showed that in some cases, primarily those in shade, or cooler seasons, the oldest maggots would enter the prepupal stage and leave the body before the high temperatures were generated by the maggot mass (Dillon 1997; Dillon and Anderson 1996b). This obviously has a major impact on determining time of death using maggot development. Maggot mass temperature is usually taken into account when determining age of the oldest maggots, but this work indicates that in some cases, the oldest maggots may not be impacted by the maggot mass.

However, early on in the research, although the pigs in spring and fall, and those in the shade in summer decomposed in a manner similar to the human cases I was analyzing at the time, we noticed that Leigh's summer, sun pigs decomposed much faster than a human body, with the skin and extremities actually mummifying (Dillon 1997; Dillon and Anderson 1995). We realized that, while the pigs that Leigh was working with were naked, the majority of the human cases I was involved with were clothed. We also noticed that the majority of my previous cases involved either clothed, partially clothed or wrapped bodies.

We postulated, therefore, that clothing might be having an effect on pig decomposition and insect colonization, as clothing absorbs body fluids, and provides habitats for insects. I sent a simple little electronic message to my departmental colleagues requesting donations of used clothing. The message somehow reached the media; to Associated Press and then went international! I received large quantities of used clothing from all over and we were able to clad our pigs! For years, I continued to receive disreputable packages of old clothing! However, some good did come of all this as although my work had received a tremendous amount of media attention prior to this, which continues to this day, it was this particular attention that was noticed by an entomology student in Ontario, Niki Hobischak, who became my third graduate student.

In 1995, a wildlife enforcement officer noticed this work and contacted me, asking whether forensic entomology could be applied to poaching cases. Bear poaching is a major crime in BC with animals being taken illegally as trophies and for body parts, primarily for the Traditional Chinese Medicine market. Most carrion insects are ubiquitous and do not discriminate between carrion species, except in the case of particularly small carcasses (Denno and Cothran 1975), and most species are more likely to colonize animal carcasses than human bodies, simply due to availability. However, although pigs are accepted as good models for human decomposition, it was not known whether they would be valid as models for bear decomposition. Therefore, supported by various wildlife organizations, including World Wildlife Fund and the Vancouver Foundation, we added several bear carcasses to Leigh's project. These were bears that had been killed as nuisance bears, which are normally incinerated. In 1995, they were donated to forensic entomology research! Obviously we could not get enough bears at the same time for a full experiment, but Leigh was able to compare bear decomposition and insect colonization with her extensive pig experiments (Dillon 1997; Dillon and Anderson 1997, 1996b). Leigh Dillon graduated in 1997 and is presently a coroner with the BC Coroners service.

In 1995, I was called into my first bear poaching case, in which two cubs had been killed for their gall bladders. The case involved first instar Calliphoridae eclosion rates and I testified in the court case in 1996 (Anderson 1999). The insect evidence indicated a time of death that successfully linked two suspects to the scene. Both defendants were found guilty of two counts of poaching under the Provincial Wildlife Act of Manitoba. They were sentenced to 3 months in jail per count. This was the first time in Canada where a jail term was secured for the actual poachers of the animals in question and has set a precedent.

By this time, the compilation of an extensive database was under way in BC for bodies found above ground, but many bodies are buried and there was little research worldwide on buried carrion, and no research for BC. This point was brought home when the body of a child was found in a shallow grave nearly two months after the child was last seen alive. I collected the insects from the grave and autopsy but had no direct database with which to compare. Sherah VanLaerhoven, my first forensic entomology research assistant, was completing her undergraduate degree with a small research project in my lab (VanLaerhoven and Anderson 2001) and decided that she would like to do her Master of Pest Management on insect colonization of buried bodies. Again funded by the CPRC, and with support from the RCMP, large numbers of clothed pig carcasses were buried in shallow graves in two biogeoclimatic zones, with above ground carcasses as controls. Three pigs were exhumed each time and their fauna analyzed at 2 and 6 weeks, 3, 6, 12 and 16 months. This work showed that burial encouraged some species and discouraged others. In particular, species in the family Calliphoridae, although present, were much rarer on buried bodies (VanLaerhoven and Anderson 1999; VanLaerhoven 1997; VanLaerhoven and Anderson 1996), than on above ground carcasses (Dillon 1997) and Muscidae were much more common, possibly due to the lack of competition with Calliphoridae. In some cases, the same species were present above and below ground, but at very different times. For instance, *Fannia* species (Diptera: Fanniidae) were found 6 weeks or more after death in above ground bodies (Dillon 1997), but were found within 2 weeks of death on buried bodies (VanLaerhoven and Anderson 1999; VanLaerhoven 1997; VanLaerhoven and Anderson 1996). Decomposition was also greatly slowed by even such shallow burial. As Calliphoridae were low in numbers, no maggot masses formed so carcass temperature remained very close to soil temperatures (VanLaerhoven and Anderson 1999; VanLaerhoven 1997; VanLaerhoven and Anderson 1996). This is quite different from data from Tennessee in human bodies (Rodriguez and Bass 1985), and also from our preliminary research in Alberta in which maggot masses did form, indicating major geographic differences. This work indicated that it is difficult if not impossible to extrapolate data from above ground research to buried victims. I used these data when I testified in both the preliminary and supreme court trials associated with the death that had prompted this research in the first place. Sherah went on to complete a Ph.D. in entomology at the University of Arkansas and has now returned to BC as an NSERC postdoctoral fellow at Agriculture and Agri-foods Research Station, Agassiz and Simon Fraser University with Dr. Dave Gillespie and Dr. Bernie Roitberg. This is coming full circle, as Sherah first became intrigued with entomology in Dave's lab as a volunteer at the research station when she was just 17!

We had developed databases for terrestrial environments, both above ground and buried. However, whenever I gave seminars to police officers, one of the first questions asked always concerned what happens to a body in water? So, in January 1996, Niki Hobischak began an MPM degree on the effects of freshwater submergence on a body, funded by CPRC. Pig carcasses were again used to model human decomposition and were compared with human deaths in similar habitats. Niki looked at decomposition and faunal colonization on carcasses in freshwater streams and ponds and found that variation in aquatic organisms occurred over time, based primarily on season but also on decompositional stage, with Trichoptera being the major scavengers. Calliphoridae also colonized when parts of the body were exposed, but were rarely successful (Hobischak and Anderson 2002; Hobischak 1997; MacDonell and Anderson 1997). The pig carcass research compared well with human death cases with known elapsed time since death in the same time period (Hobischak and Anderson 1999). Niki was a Coroner after completing her MPM in 1997, and is now the Research Coordinator for the Forensic Entomology Lab at Simon Fraser University.

In 1997, I moved to the School of Criminology at Simon Fraser University, and in 1999 received funding from the Ministry of the Attorney General of British Columbia, Proceeds of Crime Fund and the University, to build the first laboratory in Canada dedicated to forensic entomology. Through the lab, I am now coordinating research across Canada to develop databases of insect succession on carrion in several biogeoclimatic zones. This work involves extensive collaboration with entomologists, forensic scientists and students in several provinces.

Although by then data existed for the effects of freshwater decomposition on a body, no data were available for bodies in the marine environment. In talking with Cpl. Bob Teather, RCMP (retired) a distinguished police diver, I mentioned my desire to look at the effects of marine submergence on faunal colonization and decomposition rates of a body. However, this project was limited by a lack of resources such as boats, divers *etc.* Bob said "well, we have divers, we have boats!". So the marine project was born. Funding was provided again by the CPRC, but massive in kind support, including divers, boats, hovercrafts, field research facilities, safety equipment *etc.* was provided by the RCMP, Canadian Coast Guard, Canadian Amphibious Search Team and the Vancouver Aquarium Marine Sciences Centre. Pig carcasses were submerged in the waters off Vancouver shortly after death in both early summer and fall, and divers observed, photographed and sampled the carcasses every few days. In general Niki and I found that decomposition was much slower than in terrestrial environments, although the carcasses went through much the same stages. The tissue itself remained intact for much longer than on land, and decomposition was affected by whether the body was in contact with the sediment because the diversity of animals were limited when the body floated. A sequence of marine fauna colonized the remains, focusing at first on wounds but very shortly after, on non-wound areas, unlike terrestrial colonization where wounds and orifices are the focus (Dillon 1997; Anderson and VanLaerhoven 1996; Dillon and Anderson 1996a, 1995). Fauna included crustacea, mollusks, annelids and echinoderms (Anderson and Hobischak 2001). This work is ongoing.

Forensic entomology is now an established part of death investigations in Canada, as well as providing greatly needed knowledge on carrion ecosystems, an area which has often been sadly neglected in the past. It has extended into studying ancient human remains and a future collaboration will involve looking at Calliphoridae myiasis in live people for maggot debridement therapy for wounds. Present research includes extending our aquatic work into large bodies of freshwater and white water, the effects of commonly used human drugs, illicit and therapeutic, on insect development and the effects of several microclimatic features on insect development. Of course, the lab continues to receive many cases every year from BC and across Canada as well as from other countries. Each case is unique and often provokes more questions which will be addressed through the Forensic Entomology Lab at Simon Fraser University.

One of the most satisfying things about doing research in forensic entomology, for myself and my students is the knowledge that the data we generate can and will be used in a death investigation and a court of law, often very soon after it has been generated. In a case in Manitoba, I was testifying in the second degree murder trial of a man accused of murdering a teenage girl. Empty pupal cases of *Phormia regina* (Meigen) (Diptera : Calliphoridae) indicated that the insects had completed an entire life cycle on the body and I based my determination of a minimum elapsed time since death of 30 days (or 480.5 accumulated degree-days) on my lab generated data for this species (Anderson and Cervenka 2001; Anderson 2000b). During the preliminary trial, defense counsel argued that the data were lab generated and therefore could not be applied to a field situation. Although it was true that the data were lab generated, Calliphoridae larval development is primarily temperature driven, so lab conditions can simulate the main parameters involved. However, it was true that I did not have field data to back up my lab data. Just weeks before the supreme court trial, by sheer coincidence, Leigh Dillon's field work had been conducted in almost the exact same weather conditions as those in the case. She noted that it took the first specimens of *Phormia regina* exactly 30 days to complete development under those temperature conditions (Dillon 1997; Dillon and Anderson 1996a), confirming the lab data exactly. The defendant was convicted.

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