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Problems Facing Application of Forensic Entomology

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Abstract

Several methodological difficulties and inherent variation in the relevant entomological phenomenon, however, are still likely to confront a forensic entomologist and should be considered when using insects to estimate the postmortem interval (PMI) (1) Animals as models for human corpses, (2) Replicated carcasses, (3) Manner of death (4) Nocturnal oviposition of flies (5) Species identifications (6) Age determination of maggots and (7) Foreign chemicals as a source of error.

The solution of such problems needs innovation experimental designs and careful investigations in future forensic entomology research. This article reviews these important and common problems along with some approaches to their solution.

Introduction

Medicolegal forensic entomology is the study of the insects associated with a human corpse, primarily to estimate time since death or postmortem interval (PMI), although other inferences may be made (Catts and Goff, 1992). PMI is the period of time between death and corpse discovery (Catts and Haskell, 1990). The discipline is now widely recognized and practiced in the courts of most First World countries. Such information is of crucial importance in any homicide because it helps to identify both the criminal and the victim by eliminating suspects and connecting the deceased with someone reported missing for the same amount of time (Catts, 1990).

Postmortem changes in a body depend upon many factors and the PMI can be a remarkably difficult thing to determine (Micozzi, 1991). In the first few hours, a forensic pathologist can provide a reasonable estimate of PMI from the physical and histochemical consequences of death (Henssge *et al.*, 1995). However, these methods become less precise with time and after 72 hr., entomological evidence usually is the most accurate and frequently the only method of determining PMI (Kashyap and Pillai, 1989). Carrion, a patchy and ephemeral resource (Hanski, 1987), attracts a variety of organisms ranging from microbes to vertebrate scavengers (Putman, 1983), and the products of decay produce changes in the underlying soil fauna and flora (Bornemissza, 1957). Arthropods usually constitute the major element of carrion fauna, and insects predominate as the most constant, diverse and conspicuous group present in both terrestrial and freshwater situations. Concerning terrestrial habitats, among 522 species of animals in 3 phyla recovered from decomposing fetal pig carcasses in South Carolina, 84 percent were insects (Payne, 1965). A total of 227 arthropod species were recorded utilizing impala ram carrion in South Africa where 98.7 percent of the species were insects (Braack, 1986). Approximately 100 arthropod species were collected on rabbit carcasses in Alexandria, Egypt, 86 percent of these were insects (El-Kady *et al.*, 1994). For freshwater habitats, Payne and King (1972), in an artificial environment conducted in South Carolina, collected 102 insect species

inhabiting submerged fetal pig carrion. In marine environments, Crustacea replace insects for carrier exploitation (Dahl, 1979).

Terrestrial vertebrate cadavers are often fiercely contested by great numbers of insect species. The overwhelming majority are *Diptera* and *Coleoptera*, with some families being especially characteristic: Calliphoridae, Sarcophagidae, Muscidae, Sepsidae, Sphaeroceridae, Piophilidae, and Phoridae (Dipter); and Histeridae, Staphylinidae, Silphidae, Scarabaeidae, Cleridae and Dermestidae (Coleoptera) (Reed, 1958; Payne and Crossley, 1966; Goff *et al.*, 1986).

Adult sarcosaprophagous flies are highly vagile insects with extremely efficient sense organs for detecting corpses (Hall, 1948; Elton, 1966). In warm weather, blow flies (Calliphoridae) can arrive within a few minutes (Payne, 1965; Tullis and Goff, 1987) or few seconds (Mann *et al.*, 1990) following carrion exposure. These flies have a strong physiological drive to go to their food resource of oviposition site (Norris, 1959; Braack and Retief, 1986). If given access, females will oviposit on carrion within the first few hours after death (Hall, 1948; Catts, 1992). This action starts a biological clock whereby subsequent determination of the age of the developing fly progeny is the basis for estimating the PMI (Greenberg, 1991). Because most bodies are discovered in the first few weeks, blow flies are encountered more frequently and can reveal PMI more accurately than other carrion insects (Nuorteva, 1977; Lord, 1990; Greenberg, 1991).

There are two ways of using insects to determine the PMI (Catts, 1990; Anderson, 1995). During the earlier progress of decomposition, the age of specimens collected from a victim may be estimated to provide a minimum PMI. Most developmental data have been obtained for blow flies because they are ubiquitous and typically the first to find a body, often before the police do (Greenberg, 1991). Depending on detailed knowledge of the fly species used and temperature at the crime scene, the degree of development can indicate a PMI from less than one day to more than one month, i.e. a period which covers the first life cycle (Smith, 1986). However, this method is relatively

conservative if one assumes no knowledge of the interval between human death and oviposition or larviposition (Wells and LaMotte, 1995), especially in conditions where fly invasion of the corpse is delayed (Erzincliglu, 1985a; Goff, 1992).

The second method to determining the PMI relates to those corpses in advanced stages of decomposition. It is based on the fact that carrion, during its decomposition and aging passes through characteristic physical and chemical changes and in the absence of vertebrate scavengers, a temporal heterotrophic succession of arthropod species occurs in relatively predictable patterns (Schoenly and Reid, 1987; Anderson and van Laerhoven, 1996; Tantawi *et al.*, 1996). In contrast to the first method, a succession model includes information about the time elapsed between death and the appearance of a particular arthropod species and stage, and can therefore be used to estimate both the minimum and maximum PMI (Schoenly *et al.*, 1992).

Succession data have been used to very accurately calculate a PMI as large as 52 days (Schoenly *et al.*, 1996). However, investigators who use succession (as opposed to development) data must deal with a larger number of complicating factors (Wells and Greenberg 1994 a and b; Tantawi *et al.*, 1996).

Substantial scientific progress has been made by forensic entomologists in recent years. Carrion succession is a classical subject in ecology (Fuller, 1934; Reed, 1958; Payne, 1965) and recent studies have stressed observations applicable to criminal investigations (O'Flynn, 1983; Early and Goff, 1986). Developmental data have also been gathered for a large number of carrion fly species (Nishida, 1984; Reiter, 1984; Nishida *et al.*, 1986; Introna *et al.*, 1989; Goodbrod and Goff, 1990; Greenberg, 1991; Davies and Ratcliffe, 1994; Wells and Kurahashi, 1994; Wells and LaMotte, 1995). Both methods have been used frequently in death investigations worldwide (Smith, 1986; Catts and Haskell, 1990).

Several methodological difficulties and inherent variation in the relevant entomological phenomena, however, are still likely to confront a forensic entomologist and should be considered when using insects to estimate the PMI. The solution of such problems needs innovative experimental designs and careful investigations in future forensic entomology research. This article reviews a number of most important and common problems and discusses the implications of their effects on PMI estimates.

Animals as models for human corpses

One area of frequent concern regarding the validity of baseline data obtained from decomposition studies is the kind of nonhuman model used. A wide array of different animals have been used in decomposition studies including sheep (Fuller, 1934; Braack, 1981; Morris, 1988), rabbits (Chapman and Snakey, 1955; Denno and Cothran, 1976; McKinnerney, 1978; Tantawi *et al.*, 1996), guinea pigs (Bornemissza, 1957), dogs (Reed, 1958; Jiron and Cartin,

1981), pigs (Payne, 1965; Tullis and Goff, 1987), foxes (Easton, 1966; Smith, 1975), birds (Wasti, 1972; Lord and Burger, 1984a; Hall and Doisy, 1993), lizards and toads (Cornaby, 1974), elephants (Coe, 1978), mice (Putman, 1978), turtle (Abell *et al.*, 1982), seals (Lord and Burger, 1984b), cats (Early and Goff, 1986) and monkeys (Omar *et al.*, 1994). The validity of extrapolating from these studies to human corpses has been questioned in court trial cases (Catts and Goff, 1992).

Carcass type and size can have an effect on decomposition rate (Denno and Cothran, 1975; Hewadikaram and Goff, 1991), species composition (Schoenly and Reid, 1983; Hanski, 1987), and insect succession (Wells and Greenberg, 1994a). Also, carrion fly species that coexist within a regional and a local scale have different oviposition preferences to certain kinds of carcasses as means of resource partitioning (Denno and Cothran, 1975; Kneidel, 1984; Davies, 1990; Wells and Greenberg, 1994b). Therefore, care must be taken when applying data from one carcass type (e.g., non human) to estimating the PMI of another type (e.g., human).

The opportunity to use human corpses for experimental field studies are rare (Rodriguez and Bass, 1983 and 1985) due to ethical and religious reasons. In Tennessee, U.S.A., Rodriguez and Bass (1983) described patterns of corpse decomposition as related to insect activities. Although, this research was done under atypical conditions (Corpses enclosed in a wire cloth coffin were suspended above a concrete slab substrate), the insect activity patterns do agree very closely with those from nonhuman carrion (Payne, 1965).

Recently, domestic pigs (*Sus scrofa* L.) weighing approximately 23 Kg have been recommended as suitable animal models for insect succession in humans (Catts and Goff, 1992) and their suitability has been confirmed by side-by-side comparisons with human remains (K. Schoenly, personal communication to J.D. Wells). Pigs closely approximate the pattern of human decomposition. They are omnivorous, so have similar gut fauna are relatively hairless and have skin that is very similar to that of humans, and a size of ~ 23 kg is approximately equivalent to that of an adult human male torso (Anderson and van Laerhoven, 1996). Validation of the pig model creates tremendous opportunities for new experiments because of the restrictions on using human corpses.

Replicated carcasses

It had recently been suggested (Wells and Greenberg, 1994a) that baseline observations of succession be made in an identical manner on replicated bodies. This would allow one to measure any natural variations in the arthropod assemblage found in a body as a function of the PMI.

Some ecological studies of carrion involved a large number of carcasses, but the authors did not describe either their methods or results in enough detail to know what conditions might have been replicated (Fuller, 1934;

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Johnson, 1975; Abell *et al.*, 1982). Other experiments included replication of carcasses, but the authors did not sample fly larvae (Payne, 1965; Kentner and Strait, 1990). Some authors who used more than one carcass under the same conditions and sampled in the manner presented their results as a composite "typical" succession pattern with no information about differences among carcasses (Bornemissza, 1957; Reed, 1958; Cornaby, 1974; Nabaglo, 1973; Hall and Doisy, 1993). Also, Reed (1958) excluded some carcasses from analysis because they were "atypical", while, Nabaglo (1973) mentioned that some carcasses decomposed more slowly than the reported succession model if they were invaded by fungi, or more quickly if they were monopolized by silphid beetles. Other authors (Early and Goff, 1986; Braack, 1987) used more than one carcass at a site with the clear purpose of comparing their rates of decomposition. They indicated that succession patterns did not appear to vary among bodies. The most ambitious study so far was that of Anderson and van Laerhoven (1996), who simultaneously exposed 7 pig carcasses. Arthropods were collected from three of these pigs. They stated that there was no recognizable differences among pigs in the daily changes in gross morphology, and that the timing of colonization by individual arthropod species varied by no more than one day.

Tantawi *et al.* (1998) simultaneously exposed 4 rabbit carcasses. They observed two distinct patterns in the species and instars of carrion fly larvae present as a function of time since death. Larvae were found for a period of 23 days in two rabbits (A & B) while in the other two rabbits (C & D) larval activity persisted for 91 days. The two sets of carcasses also differed slightly in the fly species that were observed. Using these data as a reference, a crime-scene sample containing only post feeding *Ophyra ignava* would lead one to estimate a PMI range of 13-23 days if carcass A were the chosen model, whereas carcass C would suggest a PMI range of 24-91 days. They, however, suggested several hypotheses to explain why carcasses A and B were so different from C and D. These are:

1. Differences in larval succession might have resulted at least in part from differences in oviposition activity. Carcasses that appear to be identical to the investigator can attract different number of flies.
2. Presumably, the number of gravid flies attracted to a carcass reflects the amount of volatile chemicals (sulphur and ammonia containing compounds) that it emits, and this could vary between carcasses that appeared to be the same.
3. Females are stimulated to oviposit by the oviposition activity of other females (Cragg, 1956). Small initial differences in arthropod populations could become greater as time elapses.
4. Weather: Heavy rains has been known to revive insect activity by rehydrating dried tissue (Fuller, 1934).

Whatever produced the variation in succession pattern observed by Tantawi *et al.* (1998), their results illustrate the potential danger of relying on a succession mode developed from a single body for estimating the PMI and highlights the importance of including replication where conducting experimental studies of carrion succession and of specifying the precision of a PMI estimate.

Manner of death

The manner of death can affect the rate of decomposition and faunal succession. Consequently, these changes may interrupt the accurate determination of the PMI (Smith, 1986).

Utsumi *et al.* (1958) found that poisons prolonged the rate of decomposition and affect the growth rates of beetles and flies feeding on rat carrions. Nuorteva *et al.* (1967) found a few numbers of *Calliphora vicina* R.D. and *Fannia canicularis* L. larvae on a badly burnt body, whereas, in Britain Smith (1986) have noticed a few larvae of *Calliphora vomitoria* L. and *Lucilia caesar* L. on burnt bodies and *Ophyra ignava* and *Fannia canicularis* on a burnt foetus remain.

El-Kady *et al.* (1994) stated that the manner of death has induced several noticeable differences either in the succession pattern of the calliphorids and sarcophagids in the rate of the development of their immature stages. Generally, there is little information on the effect of the manner of death on the developing maggots and the succession patterns. However, this area of research needs more investigations and a careful consideration estimating the PMI.

Nocturnal Oviposition of flies

It is generally acknowledged by fly biologists that blow flies are not active and do not oviposit at night (Greenberg, 1985). Cessation of oviposition at night is of forensic importance because it could change an estimate of PMI by as much as 12h. Nuorteva (1977) sums up current belief follows;

"Forensically it is important to note that sarcosaprophagous calliphorids fly only during daytime. Thus, if eggs are detected in a corpse during night or early morning, the conclusion can be reached that death occurred during the previous day or earlier".

Recently, Greenberg (1990), found that three common forensic flies namely, *Calliphora vicina* (R.D.), *Phoenicia sericata* (Meigen) and *Phormia regina* (Meigen) oviposited during the dark of the night, under dim light provided by an alley light, and in the deep shade of a bush during the summers of 1988 and 1989. He also stated that the forensic entomologist must reckon with the possibilities of nocturnal oviposition in his calculations of the PMI. Because determination of the PMI is based on the older specimens and these could be from a nocturnal ovipositor. On the contrary, Tessmer *et al.* (1995) found that calliphorid flies oviposited on poultry carcasses, during the

afternoon diurnal hours and during the morning diurnal period of the following day, during July and August, 1994. However, egg deposition did not occur on any poultry carcass during the nocturnal period, regardless of the presence or absence of artificial or natural (i.e. full moon) lighting.

The data of Tessmer *et al.* (1995) are the first documented effort to support the assumption that necrophilous flies do not oviposit at night when subjected to new moon or fully moon phases couples with the presence or absence of artificial lighting. Certainly, a subsequent research effort is needed in the form of replicated field experiments to define whether a threshold of light or other factors are required to stimulate a gravid fly female to search for a compatible carrion source for oviposition or larviposition.

Species Identifications

One problem facing the entomologist is the accurate identification of the maggots collected from a corpse. Frequently, only dead specimens, often poorly preserved, are submitted for identification. Even when the local fauna is well known, identification can be difficult, particularly of the early instar maggots. The work by Erzincliglu (1985b) in England, by Liu and Greenberg (1989) in the U.S.A. and by Tantawi and El-Kady (1997) in Egypt, have resulted in identification keys to either eggs or larvae of some forensically important species. However, even a careful scanning electron microscope study can fail to separate some species (Liu and Greenberg, 1989). Zumpt (1965) considered the larvae of the two calliphorid flies; *Chrysomya albiceps* and *C. rufifacies* indistinguishable, but Erzincliglu (1987) separated third instars of *C. rufifacies* by the presence of short spines on the shaft of dorsal process 1 and their absence in *C. albiceps*. Tantawi and Greenberg (1993a) revealed another diagnostic character. The outermost ventral process of *C. albiceps* is less cylindrical and more triangular in view and is crowned with numerous, smaller spines than the same process of *C. rufifacies*. They also found that 5 specimens of third instar larvae of *C. albiceps* possess spines on the shaft of dorsal process 1. These observations appear to refute Erzincliglu (1987). However the data of Tantawi and Greenberg (1993a) call attention to the necessity for extensive examination of larvae of both species from different regions to determine the taxonomic reliability of the aforementioned characters.

A variety of biochemical techniques have been used to identify insect species. Allozymes are widely used as diagnostic markers for species and races, but these markers are often expressed only in particular life stages and are easily degraded in material that is not live or deep-frozen. Immunological techniques such as ELISA have the disadvantage of being relatively insensitive to differences between closely related species (Sperling *et al.*, 1994). In contrast, DNA-based identification of organisms is possible, using any life stage, and can greatly reduce the time

necessary to obtain identification. Mitochondrial DNA (mt DNA) is particularly well studied by Johnson and Cockburn (1992) and Sperling *et al.* (1994), as a marker for such identification, since it is a small molecule that is relatively resistant to degradation, hundreds of copies are generally present in each cell, and its mutation rate is high enough to provide numerous sequence differences between closely related species.

Nonetheless, until population data is established for DNA-based identification, forensic entomologists are advised to use this method as a complement to, rather than a substitute for, standard taxonomic methods to identify species.

Age determination of Maggots

Because sarcosaprophagous fly larvae (maggots) are the initial and the most common entomologic inhabitants of human corpses, they are frequently encountered by the forensic investigator (Nuorteva, 1977; Smith, 1986). In forensic practice, the age of the largest (oldest) actively feeding maggots recovered on a body can usually provide the most precise estimate of PMI, especially within the first life cycle, once their thermal history and species is determined (Greenberg, 1991). The age of the maggots is expressed by their length or weight (Wells and Kurahashi, 1994). Another way to estimate the age of fly larvae is to rear them into the adult stage and calculate the PMI on the basis of the total development time (Nuorteva, 1977).

In post feeding maggots growth stops and may actually regress, and the size is no longer a useful criterion of age. Greenberg (1991) has shown, in the two calliphorids, *Calliphora vicina* and *Lucilia sericata* that the size of the crop can serve as a good age indicator for this stage. The age of development stages of the fly inside the puparium is more difficult to determine. Greenberg (1991), however, has initiated chronological studies to detect post-pupariation age markers.

The methods used for maggot age determination generally involve a comparison of sample maggots to maggots of known ages which were reared under constant conditions (Lord *et al.*, 1986 a and b and 1992; Goff *et al.* 1988; Goff, 1992). However, under field conditions temperatures are rarely constant and it has been shown that fluctuating temperatures differently affect the development of larvae (Erzincliglu, 1986). In addition, laboratory rearings under constant temperatures may not give an actual picture of the developmental time and strategy of flies in nature (Greenberg and Tantawi, 1993). Development data obtained from laboratory rearings can be applied directly to indoor situations where environmental conditions are relatively constant (Catts, 1992) or to field cases in which the temperature fluctuated little.

Ratte (1984) stated that developmental rates are the same for natural fluctuating and constant temperatures, provided the temperature range is favorable and the temperature sum is the same.

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Greenberg (1991) has shown that although the development of 4 blow fly species was faster at a constant temperature than at alternating temperatures, the differences were statistically significant only for *L. sericata*. He suggested that the accuracy of a PMI estimate may be increased when the possible retardation of development due to natural swings in diurnal temperature is considered.

Davies and Ratcliffe (1994) recorded a significant acceleration of larval development of the calliphorids, *Calliphora vomitoria* (L.), *Protophormia terrabenova* (R.D.) and *L. sericata* and a retardation of that of *C. vicina*, at alternating temperatures relative to the constant regime of equivalent thermal sum.

Byrd and Butler (1996) emphasized that when constructing the PMI estimation, it is essential that laboratory studies of insect development use temperatures with mean values comparable to those for the death scene and the corpse.

Introna *et al.* (1989) programmed the hourly fluctuations in temperature, humidity and light recorded in the field into laboratory rearings of *L. sericata*. Their results showed that, statistically, there is no difference between developmental rates of flies reared in the field and those reared in the laboratory under artificial field-like conditions.

Therefore, the uncertainties of extrapolation from the laboratory to the field can be avoided by consulting appropriate field experiments or a careful tabulation of actual cases from a given area.

An accurate record of ambient conditions during the postmortem interval is a key element in determining the age of associated maggots. The mean temperatures obtained from meteorological stations are useful, but it is noted that these records do not reflect the microclimatological conditions existing at the place where a corpse has been found. Microclimatological variation with an area (e.g. sun vs. shade) may, indeed, greatly affect the duration of fly development (Greenberg, 1991; Catts, 1992). Catts and Haskell (1990) recommended the recording of ambient conditions at the death scene for 3-5 days following removal of the corpse to give a basis for some interpolation of consistent weather differences with those of the more distant recording station.

It has been shown that under apparently identical laboratory conditions, fly larvae of the same species and age may normally grow at quite different rates (Davies and Ratcliffe, 1994; Wells and Kurahashi, 1994; Wells and LaMotte, 1995). Wells and LaMotte (1995) constructed a 95 percent confidence interval about an estimate of larval age. Variation in growth rates may also occur among geographical races of the same fly species (Cyr, 1993). Therefore, regional studies may be desirable to increase the precision of PMI estimates in local medicolegal investigations.

An important consideration related to maggot development rate is the amount of metabolic heat generated by the maggots massed in the corpse (Early and Goff, 1986; Tullis and Goff, 1987; Cianci and Sheldon, 1990;

Catts, 1992; Turner and Howard, 1992). Catts (1992) during his studies in fall in Washington, U.S.A., found that maggot mass temperatures exceeded subfreezing ambient low temperatures by as much as 35°C, even though carcass temperatures were only 8°C above the low. He also mentioned that regardless of season (Summer or fall) maggot-mass temperatures ranged as much as 35-45°C higher than ambient low temperature and about 20°C about ambient high temperatures.

A large maggot-mass results from an abundance of the following oviposition frenzy by aggregated gravid female blow flies (Catts, 1992). Carrion in nature tends to be overloaded with a far greater number of eggs than there is food for larval development (Norris, 1965). However, larva maggot masses occur in large carcasses but not in small ones (Smit, 1931; Greenberg and Tantawi, 1993).

Maggot-mass elevated temperatures in carcasses may have several evolutionary advantages to blow fly larvae. These include increased efficiency of food processing, gaining a competitive advantage over potential rivals and a reduction in the predation level by accelerating development (Cianci and Sheldon, 1990), and mitigating the effect of climatic conditions (Deonier, 1940; Greenberg and Tantawi, 1993).

The lower threshold of maggot density needed to generate heat sufficient to override ambient fluctuations is not known, and probably differs among species and perhaps among geographic races within the same species (Catts, 1992). Laboratory studies by Goodbrod and Goff (1990) demonstrated that massed maggots heated their substrate population densities as low as 4 larvae/1 gm. of medium. Marchenko (1988) determined a lower density threshold for maggot-generated heat to be a 1:1 ratio of maggots to grams of medium but that at a 2:1 ratio considerable accelerated development occurred.

Greenberg (1991) has demonstrated the thermal contribution of each larval instar in a maggot mass. Female instars have little measurable effect, but second instars began to produce excess heat which peaked at 18°C above ambient, slightly before third instars reached maximum size. The temperature falls rapidly when post-feeding larvae disaggregate. Therefore, in a heavy infestation, the developmental rate of second instars and actively feeding third instars should be calculated at a higher temperature than ambient. This could reduce the PMI estimate by more than a day, depending on the ambient temperature. Deonier (1940) observed active maggot masses in sheep and goat carcasses when the ambient was -4°C. So, the cooler the ambient, the greater the potential error.

An important consequence of maggot-mass heat is that maggot development may not be arrested when a corpse is held in a refrigerator before autopsy (Catts, 1992). Thus the collection of maggot specimens for preservation at the death scene is preferred if an accurate estimate of PMI is to be made.

In nature, the maggot mass in decomposition remains is

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complex of species in mixed age classes. The interaction of the species involved may influence their developmental rates (Wells and Greenberg, 1992) and the level of generated heat can selectively affect the species present in the mass (Waterhouse, 1947; Williams and Richardson, 1984).

It has been shown that individual maggots can control their own environmental temperatures by moving in and out of the mass (Cianci and Sheldon, 1990; Catts, 1992). Byrd and Butler (1996) stated that known developmental rates of blowflies at their preferred temperature can be used to calculate accelerated larval development and the subsequently altered PMI caused by maggot mass formation.

The probable impact of the maggot-mass heat generation phenomenon on developmental rates, and ultimately on determination of the PMI, demands much more study (Catts, 1992).

Forensic entomologists often rely on specimens of maggots collected and preserved using a variety of techniques by police or medical examiners. Tantawi and Greenberg (1993b) found that the kind of solution in which maggots are killed or preserved has a significant effect on their length and therefore their estimated age, and hence can lead to a miscalculation of the PMI. This underscores a need for standardization in the techniques used for collecting and preserving maggots at the crime scene and at autopsy.

Foreign chemicals as a source of error

The effect of substances ingested, imbibed or otherwise taken internally prior to death was identified by Smith (1986) as an area needing research in forensic entomology. Little attention has been given to the effect of these substances or their metabolites, on the developing maggots. Nuorteva and Nuorteva (1982) observed a certain degree of development inhibition of blowfly larvae, when they consumed seal liver baui; polluted by methyl mercury. Goff *et al.* (1989) noticed two patterns of development of the sarcophagid, *Boettcherisca peregrina* (R.D.), when reared on liver containing cocaine. The control and sublethal dosage colonies developed at approximately the same rate, whereas the lethal and twice lethal dosage colonies developed more rapidly. Similar increased in the rate of development of sarcophagid maggots, induced by heroin and methamphetamine were also noticed by Goff *et al.* (1991 and 1992). These may yield a significant error in the calculation of the PMI of up to 29 hr, if based on the larval stage and 18-38 hr, if based on the duration of the puparial stage.

In contrast, recent studies concerning the effects of the tricyclic antidepressant amitriptyline on the developmental patterns of *Parasarcophaga ruficornis* by Goff *et al.* (1993), no significant differences were observed.

Although data currently available concerning the effects of drugs and toxins on the developmental rates of dipterous larvae are limited in scope, it is essential that forensic

entomologist be made aware of any data indicating the presence of these substances in the remains. This will allow for need corrections to life cycle data, based on the substances involved, and result in more accurate estimation of the PMI.

Conclusion

Forensic entomology is still a young science and precisely for this reason, it must maintain rigorous standards among its researchers and practitioners, if it is to gain widespread acceptance. There is no substitute for good data nor for well-trained entomologists to interpret and apply them.

In general, our knowledge of the biology and ecology of fauna associated with the decomposing corpse must be refined. The problems discussed in this article relate to estimating the PMI; a key element in any death investigation. They are all areas in need of immediate research efforts both in the laboratory and the field.

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