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Forensic entomology of high-rise buildings in Malaysia: Three case reports

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Abstract. The distributions of flies are not only confined to ground level but can also be at higher altitudes. Here, we report three forensic cases involving dipterans in high-rise buildings in Kuala Lumpur, Malaysia. Case 1 involved a corpse of adult female found at the top floor of a fifteen-story apartment. Case 2 dealt with a body of a 75-year-old female discovered in a bedroom on the eleventh floor of an eighteen-story building, while Case 3 was a 52-year-old male found in his fifth floor shop house. Interestingly, entomological analysis revealed that all corpses were infested with similar Dipterans: *Megaselia scalaris* (Loew) (Diptera: Phoridae), *Synthesiomyia nudiseta* (Wulp) (Diptera: Muscidae) and sarcophagid (Diptera: Sarcophagidae). The first two species were commonly associated with corpses found indoors at ground level. We noted the additional occurrence of blowflies *Chrysomya megacephala* (Fabricius) (Diptera: *Calliphoridae*) and *Chrysomya rufifacies* Macquart (Diptera: Calliphoridae) larvae in Case 2 and Case 3, respectively. Findings from this study are significant as they demonstrate that certain groups of fly can locate dead bodies even in high-rise buildings. Forensic entomofauna research on corpses found at high elevation is scarce and our study has highlighted the peculiarity of the fly species involved in Malaysia.

INTRODUCTION

In Malaysia, forensic cases involving entomological specimens have been extensively reviewed over the recent years (Hamid *et al.*, 2003; Lee *et al.*, 2004; Ahmad *et al.*, 2007; Syamsa *et al.*, 2010; Kumara *et al.*, 2012; Kavitha *et al.*, 2013). However, there are only a few published data regarding the roles of flies in forensic cases involving high-rise buildings. Kumara *et al.* (2010) recorded the presence of flies of families Phoridae, Calliphoridae and Sarcophagidae on three forensic cases occurring on the 4th and 7th floor of residence buildings in Penang, Malaysia, while Syamsa *et al.* (2012) reported the occurrence of muscid fly, *Synthesiomyia nudiseta* (Wulp, 1883) (Diptera: Muscidae) on a corpse found at the 13th floor of a building in Kuala Lumpur, Malaysia.

Forensic entomology investigation is based on understanding of distribution and bionomic of sarcosaphrophagous insect community. In this article, we report three forensic cases occurred at high-rise buildings in Malaysia, and describe how forensic entomology plays important roles in

forensic investigation, particularly for minimum post-mortem interval (mPMI) estimation.

MATERIALS AND METHODS

Since the death scene was attended by the first author soon after the body discovery, the physical alteration of the death scene, if any, was minimal and has been noted via conversation with police officers and the deceased relatives or neighbours. Ambient temperature and relative humidity at the death scene were continuously recorded every 30 minutes by placing thermo-hygrometer EL-USB-2-Data Logger (LASCAR Electronics, UK) during the first visit at the death scene. The thermohygrometer was left for five to seven days to examine the fluctuations in temperature and relative humidity, and to obtain the average values of these parameters. All insect specimens were collected from decomposed corpses and surrounding areas during visits at the death scenes. Larvae and pupae were collected using blunt forceps based on prescribed method (Amendt *et al.*, 2007). The specimens were collected in two sets; 1) preserved in glass vials containing 70% ethanol, and 2) cultured on beef liver provided *ad libitum* in plastic containers measuring 5cm x 5cm x 4cm. Puparia were placed inside empty plastic containers. Ambient temperature and relative humidity during rearing process were recorded every 30 minutes by placing two units of thermohygrometers in rearing room, in which the resulting data were averaged with standard deviations presented. Newly emerged adult flies were pinned for identification using identification keys (Tumrasvin & Shinonaga, 1982; Disney, 1994; Kurahashi *et al.*, 1997). Preserved larval samples were prepared according to the method described by Omar *et al.* (1994b). The stage, size and species of the larvae were subsequently observed under light microscope for identification based on the keys of Omar (2002). Documentation of adult and maggot species was conducted by using Leica EZ4D digital microscope fitted with digital camera and Leica Application Suite (Leica, Switzerland).

CASE REPORTS

The three forensic cases below were part of forensic case studies sampled in 2012. All corpses were found in high-rise buildings located in urban areas in Kuala Lumpur, Malaysia. Autopsies were carried out at Forensic Unit, Department of Pathology, Universiti Kebangsaan Malaysia Medical Centre, Kuala Lumpur, Malaysia.

Case 1

A 36-year-old female was found dead in her bedroom on the top floor of a 15-story apartment on 3 January 2012. She was lying on the floor in her bedroom in prone position. The body was in advanced decomposition state with body fluid pooled beneath it. Oral contraceptive pills were found next to the body. All windows and doors were closed, apart from a window in the kitchen area. The average temperature of the room was 26.7°C. She was living alone and not in contact with her relatives for more than a month. The cause of death was unknown.

Third instar larvae of muscid fly *S. nudiseta* and sarcophagid were found crawling mainly on abdominal area and on the hairs. Numerous puparia of *Megaselia scalaris* (Loew, 1866) (Diptera: Phoridae) were found adhering to the hairs and also scattered on the floor (Figure 1).

All live specimens were reared until adult emergence in the laboratory with a temperature of 28.8 ± 0.4°C, RH 67.0 ± 4.5%, photoperiod (L:D)(h) 12:12. Adults of *M. scalaris*, *S. nudiseta* and sarcophagid fly emerged from the pupae on 7 January 2012, 13 January 2012 and 18 January 2012, respectively. PMI for this case was estimated based on the complete life cycle of *M. scalaris* puparia collected at the scene (Zuha *et al.*, 2012). Based on the date of adult emergence on 7 January 2012, egg deposition could have occurred on 26 December 2011. Therefore, the estimated PMI was 8 to 9 days from the date of body discovery, which

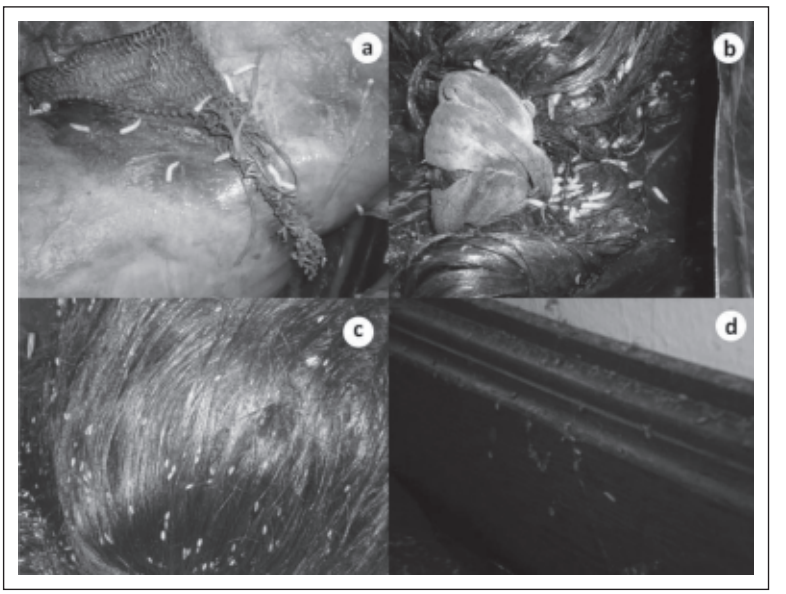

Figure 1. Case 1: a) Larvae of *S. nudiseta* crawling on abdomen. b) Larvae of *S. nudiseta* and sarcophagid on hairs. c) Puparia of *M. scalaris* adhering on hairs, and d) scattered on the floor.

correlated well with the estimation by the forensic pathologist based on pathologic features.

Case 2

On 8 February 2012, a decomposing body of 75-year-old female was found in her bedroom on the eleventh floor of an eighteen-story flat. She was lying laterally on the right side of her body with a pool of body fluid on the floor. She was fully clad with a night sweater, pants and woolen socks. She was last seen on 24 January 2012. The apartment unit was closed, apart from a window in the kitchen area. The average temperature of the death scene was 28.5°C. The cause of death was due to a coronary occlusion by atheroma.

The entomological evidence was collected on 9 February 2012, consisting puparia of *M. scalaris*, adhering to the clothes as well as on the nearby furniture where the body was lying. Third instar larvae of *S. nudiseta* were abundantly present and found on the body of the deceased. Several sarcophagids and *S. nudiseta* puparia were also present on the floor (Figure 2). We also noted the presence of medium-sized larvae, later identified to be of *Chrysomya megacephala* (Fabricius, 1794) (Diptera: Calliphoridae) third instar larvae.

In laboratory (28.2 ± 0.3°C, RH 69.9 ± 4.2%), *Ch. megacephala* and *M. scalaris* adults both emerged on 15 February 2012, while *S. nudiseta* and sarcophagid flies emerged on 18 and 21 February 2012, respectively. Unlike Case 1, PMI for this case was estimated based on life cycle of *S. nudiseta* by Rabinovich (1970). Based on the date of adult emergence on 18 February 2012, it was calculated that egg deposition could have occurred between 29 January 2012 and 2 February 2012. Considering that this species might be attracted to corpses that were already putrid (Omar *et al.*, 1994a), an additional four days of pre-oviposition period was added into calculation. Therefore, PMI was estimated to be 12 ± 2 days from the date of the body was found. The forensic pathologist pointed to a time of death one to two weeks before the body was found.

Case 3

The corpse of a 52-year-old male was found in his living room at the top floor of a 5-story shop house unit on 11 March 2012. The average temperature of the room was 27.3°C.

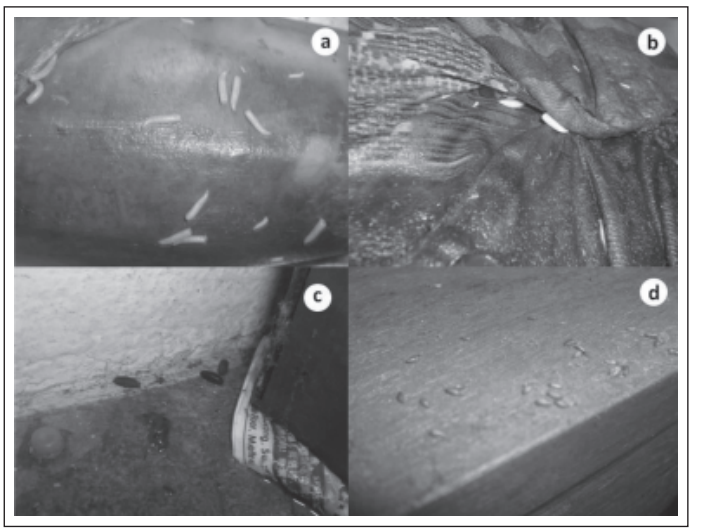

Figure 2. Case 2: a) *S. nudiseta* larvae on the body, and b) on the clothes. c) Puparia of sarcophagid on the floor. d) Puparia of *M. scalaris* scattered on the furniture.

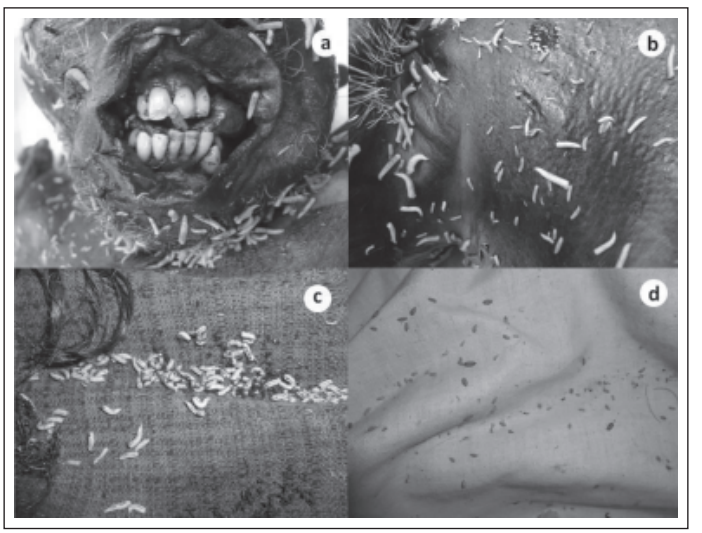

Figure 3. Case 3: a) Larvae of *S. nudiseta* and sarcophagid crawling on the neck and orifices. b) Various-sized larvae on the head. c) Larvae of *S. nudiseta* on the blanket. d) Puparia of *M. scalaris* scattered on the mattress cover.

He was fully clad and lying face down on the mattress. A pool of body fluid was presence as a result of decomposition process. Windows in the bedroom and kitchen area were found opened.

Entomological specimens at the death scene were collected on 12 March 2012. Various-sized larvae identified to be *S. nudiseta*, blowfly *Chrysomya rufifacies* (Macquart, 1842) (Diptera: Calliphoridae) and sarcophagid were found crawling mainly on the neck and upper half body part. They were also found in abundance beneath the blanket. Numerous puparia of *M. scalaris* were found scattered on dry areas of the mattress cover and on the floor (Figure 3).

With a rearing temperature of 27.2 ± 0.4ºC, RH 65.6 ± 3.1%, adults of *M. scalaris*, *Ch. rufifacies*, sarcophagid fly and *S. nudiseta* emerged from the pupae on 17, 20, 21 and 22 March 2012, respectively. The PMI was estimated according to known data of *S. nudiseta* life cycle (Rabinovich, 1970). Based on the date of adult emergence on 22 March 2012, it was calculated that egg deposition could have occurred between 2 to 6 March 2012. The PMI was estimated to be 11 ± 2 days prior to discovery after considering four days of pre-oviposition period of *S. nudiseta*. This time was also compatible with that estimated by the forensic pathologist.

DISCUSSION

The relationship between the decomposition stage and insect succession has been well documented (Goff, 1993). Despite the fact that the presence of certain carrion-frequenting fly species in high-rise buildings has been reported in Europe and North America (Anderson, 2001), the species composition in high-rise building in Malaysia remains unexplored. In this study, all cases described above were infested with similar Dipterans; *M. scalaris*, *S. nudiseta* and sarcophagids. We also observed additional occurrence of blowflies *Ch. megacephala* and *Ch. rufifacies* larvae in Case 2 and Case 3, respectively.

Synthesiomya nudiseta is known to be exclusively associated with corpses found indoors in Malaysia (Omar *et al*., 1994a; Hamid *et al*., 2003; Lee *et al*., 2004; Syamsa *et al*., 2012) and Thailand (Sukontason *et al*., 2007) due to its close association with human premises (Nazni *et al*., 2007). The presence of this species in all cases reported in the current study strengthened previous findings that this species is an indoor colonizer and prefers putrid meat which associated with decomposed body (Omar *et al*., 1994a; Syamsa *et al*., 2012).

Sarcophagid flies were reported to prefer shaded environments when colonizing corpses (Hamid *et al*., 2003; Lee *et al*., 2004; Ahmad *et al*., 2007; Sukontason *et al*., 2007; Pohjoismaki *et al*., 2010; Syamsa *et al*., 2010; Kumara *et al*., 2012). In this study, we noted the occurrences of sarcophagid larvae in all cases despite in small numbers. Similar findings were reported from a study on human remains (Kumara *et al*., 2012) as well as from carcasses (Dhang *et al*., 2008; Horenstein *et al*., 2010). Although the presence of sarcophagid is quite common in forensic cases in Malaysia, these flies are not presently be used in PMI estimation due to insufficient information about their biology and life cycle.

Buildings may act as a physical barrier to colonising insects and thus delay insect arrival and oviposition (Reibe & Madea, 2010). While this is probably true for certain relatively large dipterans such as sarcophagids and blowflies, the same cannot be applied for scuttle fly. It is known that this species has the ability to access concealed corpses such as in closed rooms (Kumara *et al*., 2010; Reibe & Madea, 2010) or buried coffin (Campobasso *et al*., 2004). Due to its small size, it has been reported that this species can even infiltrate into, or escape from apparently closed containers (Disney, 2008). Several studies showed that *M. scalaris* is a polyphagous species as they can consume a wide spectrum of food including decomposing organic matter and artificial media (Harrison & Cooper, 2003; Disney, 2008). The fact that the corpses were found inside highly occupied buildings may provide enough food sources (such as from garbage collecting room or domestic waste of other occupied units) for this species to stay around. Therefore, we hypothesize that the scuttle fly found in this current study probably originated from different units of the same building.

The presence of blowflies *Ch. megacephala* and *Ch. rufifacies* in Case 2 and Case 3, respectively, were also noted. Both species are PMI indicators and have been the primary species of fly found at death scenes in Malaysia (Hamid *et al*., 2003; Lee *et al*., 2004; Ahmad *et al*., 2007; Syamsa *et al*., 2010; Kumara *et al*., 2012; Kavitha *et al*., 2013) and Thailand (Sukontason *et al*., 2007). According to a case review by Lee *et al*. (2004), these were the two most predominant fly species, appearing in 48.0% and 29.5%, respectively, of all forensic cases in Malaysia

from 1972 to 2002. Recent study by Kumara *et al.* (2012) also indicated that these species were the most frequent colonizers of human remains in north Peninsular Malaysia. However, both species are not used as PMI indicators for the described cases as it was found that *Ch. megacephala* and *Ch. rufifacies* needed longer times to detect and to reach the corpses compared to *M. scalaris*, hence may affect the PMI estimation.

For Case 1, the PMI estimated from entomological evidence were calculated by taking into account the development of *M. scalaris* puparia collected at the death scenes. Several researchers have conducted developmental studies on this species using different methodology (Tumrasvin *et al.*, 1977; Trumble & Pienkowski, 1979; Amoudi *et al.*, 1989; Idris *et al.*, 2001). However, for this case, we used the data provided by Zuha *et al.* (2012) because of the following reasons: (1) the temperature regimes applied in his study were in line with our rearing temperatures, (2) the similarity of using beef liver as rearing medium, and (3) their research was conducted in the same region as ours, hence the possibilities of using different geographical strains could be ruled out.

Zuha *et al.* (2012) indicated that at 28.9 ± 1.4°C, RH 94.4 ± 7.1%, the duration of the immature stage (eggs to pupae) for *M. scalaris* reared in liver tissue was 95.0 ± 5.0 hours (3.95 ± 2.1 days while the pupation period (pupal stage until emergence) was 179.7 ± 6.9 hours (7.49 ± 0.29 days). Thus, the total time taken from eggs until adult emergence was 275.9 ± 0.0 hours (11.50 days). However, due to the slightly different temperatures at the death scenes and at rearing room, corrected calculation using accumulated degree hours (ADH) (Greenberg & Kunich, 2002) was utilized and showed that the life cycle took approximately 11.68 days.

Unlike Case 1, the PMI for Case 2 and 3 were estimated based on the data of complete life cycle of *S. nudiseta*. This species was used as PMI indicator because its life cycle period provides more reliable evidence for PMI estimation compared to other species found in Case 2 and 3. Previous researchers have carried out studies on the life cycle of *S. nudiseta* and came out with different developmental times ranging from 17.5 to 27.1 days at the temperatures of 25°C to 28°C (Kruger *et al.*, 2002; Rabinovich, 1970; Velasquez *et al.*, 2012). While in Malaysia, Kumara *et al.* (2009) reported shortest developmental time at 28.5 ± 1.5°C and 67 to 85% RH in which the species took 322 ± 19 hours (13.4 + 0.8 days) from eggs until adult emergence. However, it is unsuitable to use developmental data from Kumara *et al.* (2009) since our estimation based on their data contradict with the histories and investigation findings of both deceased. The contradiction between our findings and developmental duration of *S. nudiseta* by Kumara *et al.* (2009) probably due to several variations such as rearing methodology in the laboratory (Kaneshrajah & Turner, 2004; Ireland & Turner, 2006) and fluctuating environmental temperatures (Niederegger *et al.*, 2011).

Due to these circumstances, we estimate the PMI for these cases based on developmental data by Rabinovich (1970). These estimations fitted the histories of both deceased and were consistent with the conclusions drawn by the forensic pathologists. Furthermore, it has been used to estimate the PMI in our previous forensic case involving the same species (Syamsa *et al.*, 2012). Rabinovich (1970) reported that under the constant temperature of 28 ± 1°C, RH 90%, the eggs of *S. nudiseta* took 9.6 ± 1.6 days to become pupae and 8.2 ± 0.5 days to adult emergence, with the total development time (eggs to adult) of 17.8 ± 2.1 days. Corrected calculations due to developmental temperature variation indicated that the life cycles were completed in 17.58 days for Case 2 and 18.29 days for Case 3.

To determine the PMI for those cases, we considered the opinion of Omar *et al.* (1994a) who experimentally stated that the first oviposition of this species occurred four days after exposure. This was also in agreement with succession study done by Calderon-Arguedas *et al.* (2005) which showed that this species was commonly present during active decomposition phase. However, it is worth mentioning that the oviposition periods for those cases may not be exactly four days

considering that the oviposition process can be affected by many biotic (i.e.: inter- and intraspecies competition, sensorial behaviours) and abiotic factors (i.e.: weather condition, temperatures, condition of the dead bodies, accessibility of insects) which may ultimately change the ecology of carrion flies (Arnaldos *et al.*, 2005; George *et al.*, 2013; Tomberlin *et al.*, 2011). Therefore, estimation of minimum PMI must be based on previous scientific studies available and be dealt with greatest precaution due to a wide biological variability (Amendt *et al.*, 2011).

Referring to the above cases, it seems that the main forensic value of these species is the estimation of PMI when death occurs at high-rise buildings. They are useful especially when the common species of blowflies such as *Ch. megacephala* and *Ch. rufifacies* either do not have access to the body, or unable to give a reliable estimation.

This study describes the occurrences of forensically-important flies on corpses found in high-rise buildings in Malaysia and how the knowledge on insect biology could assist in forensic investigation. From this study, it seems that only certain species have the tendency to reach higher level of high-rise building. Given the scarcity of entomological studies at high-rise buildings, more experimental studies should be carried out and every single case should be reported to provide more information on this matters.

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