INSECT FAUNA USED TO ESTIMATE THE POST-MORTEM INTERVAL OF DECEASED PERSONS

G.W. Levot

Elizabeth Macarthur Agricultural Institute, NSW Agriculture, PMB 8, Camden NSW 2570, Australia
Email: garry.levot@agric.nsw.gov.au

Summary

The insects collected by police at the crime scene or by pathologists at post-mortem from the bodies of 132 deceased persons and presented for comment are reported. The samples were submitted with the hope of obtaining an estimate of the most likely post-mortem interval (PMI) to assist police investigations. Calliphoridae, particularly *Calliphora augur*, *C. stygia*, *Chrysomya rufifacies* and *Ch. varipes*, Muscidae, particularly *Hydrotaea rostrata*, Sarcophagidae and Phoridae were the most represented Diptera. Beetles belonging to the Staphylinidae, Histeridae, Dermestidae, Silphidae and Cleridae were collected in a small proportion of cases. The absence of species succession during winter confounded estimates of PMI. Confidence in PMI estimates would increase with greater knowledge of the larval growth rates of common blowfly species, seasonal effects on growth rates and blowfly activity, differences between insects infesting bodies located inside verses outside buildings and significance of inner city sites compared to bushland locations. Further research to address deficiencies in knowledge of these subjects is needed.

Keywords: forensic entomology, post-mortem interval (PMI)

INTRODUCTION

Forensic entomology is the application of entomology to forensic science. It is not a new science. In the late 1800s the French biologist Megnin described the insects associated with corpses in an effort to provide post mortem interval (PMI) estimates (Catts and Haskell 1990). This remains the focus of the science. Over the past 10 years particularly, there have been numerous published reports of cases where entomology has provided evidence to incriminate violent crime suspects (see Erzinclioglu 2000). Public curiosity and professional interaction between entomologists working full-, or part-time in forensic science have created an interest in forensic entomology and several texts are now available. Forensic entomology has even found a place in popular works such as Thomas Harris' *Silence of the Lambs*, Kathy Reichs' *Death du Jour* and Patricia Cornwell's *The Body Farm.*

Although case histories make interesting reading selective reporting of investigations where entomological evidence is subsequently shown to be critical to the legal conclusion of a crime may create a false impression of the frequency with which this occurs. Of course, a lot of cases are not noteworthy because the circumstances surrounding a death are routine or perhaps because the entomology was inconsequential or unreliable. The utility of entomology to forensic investigations is determined by the reliability of the evidence, that is, by the predictable presence or absence of insect species at various times after death under particular conditions. The more times an event occurs, the more confidence one has in predicting that it may occur again under similar circumstances. Estimates of PMI are based on the faunal succession of invertebrates colonising, or associated with a corpse, and the rate of development of some, or all of these organisms. As in any ecology, species assemblages representing phases in decomposition come and go, attracted by particular conditions and repelled or leaving as conditions change. In this paper the insects recorded during 132 individual investigations of murder or suspicious death are presented with a view to identifying common species cohorts that may assist the entomologist determine the importance of insect groups or individual species to estimating the PMI. A secondary aim is to identify some of the knowledge gaps that have become evident during these investigations.

MATERIALS AND METHODS

Between spring 1984 and spring 2001 insect samples removed from the bodies of deceased persons either *in situ* by the police, or later by the pathologist at post-mortem, were presented to me for comment, or more particularly, to assist police estimate a likely PMI. In total 132 cases were investigated. All were from New South Wales and were being investigated by NSW Police. Usually, but not always, a short narrative describing some of the particulars of the case and the circumstances surrounding the discovery of the body was provided. Data for each case was entered into a spreadsheet (Microsoft Excel) and sorted to group cases with similar insect fauna. Information recorded included location (inside a dwelling, outside, in water, buried), insect species (or higher taxa) represented and season in which the body was found.

RESULTS

Locality

The situations in which bodies were discovered varied greatly. Thirty eight percent of cases (50 bodies) were found inside a house, garage or shed. Eight percent (11) of bodies were in cars, some of which were burnt out. Fifty one percent (67) of bodies were found outdoors. Five bodies were fully or partly submerged in water and six were buried. One body was in a locked valise and there was no information provided regarding the location of two of the bodies.

Diptera

Overwhelmingly blowflies (Calliphoridae) were the most common group of insects being represented in 86% of cases (113 cases). Species collected included primary wave colonisers like *Calliphora* spp. and secondary wave colonisers such as *Chrysomya* spp.. *Calliphora* spp. were represented in 66% of cases (87 cases), *Chrysomya* spp. in 44% of cases (57) and *Lucilia* spp. in 11.5 % of cases (15). The most commonly collected calliphorids were *Chrysomya rufifacies* (Macquart) (44), *Calliphora augur* (Fabricius) (42), *C. stygia* (Fabricius) (33), *Ch. varipes* (Macquart) (18), *Ch. nigripes* Aubertin (8), *Lucilia cuprina* (Weidemann) (8), *L. sericata* (Meigen) (7), *Ch. megacephala* (Fabricius) (7), *C. ochracea* Schiner (5) and *C. vicina* Robineau-Desvoidy (2) (Table 1). Of the 42 collections in which *C. augur* was represented it was the only species present in 18 cases. Similarly, *C. stygia* was the only species involved in 14 of the 33 cases in which it was recorded (Table 1). In 31 cases a *Calliphora* sp. occurred together with a *Chrysomya* sp., usually *Ch. rufifacies* (27 cases). On 16 occasions the pairing was *C. augur* with *Ch. rufifiacies* (Table 2). Only twice was *Ch. rufifacies* the only species represented in the samples submitted by the police (Table 1). As well as being commonly found together with *Calliphora spp.*, *Ch. rufifacies* often co-existed with other *Chrysomya* spp., Sarcophagidae, *Lucilia* spp. and on 13 occasions with Muscidae, usually *Hydrotaea rostrata* (Robineau-Desvoidy) (9 cases).

The Muscidae occurred in 27.5% of cases (36) with the black carrion fly, *H. rostrata* involved in 25 for these collections (Table 1). Sarcophagidae were present in the collections from only 16% of cases (21) often together with *Calliphora* spp. (14), *Chrysomya* spp. (12) or Muscidae (10) (Table 2). Other Diptera represented were Phoridae (12), Piophilidae (7), Sphaeroceridae (2) and Chironomidae (on a fully submerged corpse). Phoridae (*Megaselia* spp. etc.) were most often collected from bodies inside a house, garage or shed (7) (Table 3) but also occurred on a body in a locked car boot and from a buried corpse. In three cases they were the only insects collected but more frequently they co-existed with *Calliphora* spp. (5) and/or *Chrysomya* spp. (5) and/or *Lucilia* spp. (4) and/or Sarcophagidae (4) and/or Muscidae (3). Of the 11 cases in which Muscidae were collected from bodies located inside a house, garage or shed *H. rostrata* was present on only three occasions (Table 3).

In six of the seven cases in which *Piophila casei* (Linnaeus) (Piophilidae) was recorded, the body was located outdoors. Other insects co-existing with *P. casei* were *H. rostrata* (6), *Chrysomya* spp. (4), *Necrobia ruficollis* (Fabricius) (Coleoptera: Cleridae) (4) and Dermestidae (5). Sphaeroceridae were present on bodies found in two New South Wales State forests. The fauna co-existing with the Sphaeroceridae were vastly different in each case.

Coleoptera

Apart from the flies, beetles made up the next most frequently represented insect order. Families recorded were Silphidae, Dermestidae, Staphylinidae, Histeridae and Cleridae. Silphidae were recorded in 11 cases. Adults and larvae occurred together in three cases but it was more usual for either adults (4) or larvae (4) to occur alone. Silphidae often co-existed with *H. rostrata* (7) or other Muscidae (1), *Chrysomya* spp. (6), *Calliphora* spp. (6) and Staphylinidae (5). *Creophilus erythrocephalus* (Fabricius) (10) or other Staphylinidae (4) were recorded in 14 cases. They were commonly found with blowfly larvae and Histeridae. Dermestidae were present in collections from 14 cases. Adults and larvae were present in three cases, and larvae or adults only in six and five cases, respectively. Piophilidae co-existed with dermestids in five of the seven cases in which they were represented. *H. rostrata* was present in six cases, *Ch. varipes* and/or *Ch. rufifacies* in seven cases and *Calliphora* spp. in four cases in which dermestids were recorded.

Seasonal prevalence

Over the 16 years, 41 of the cases investigated concerned bodies found during summer, 33 in autumn, 16 in winter and 40 during spring. In some cases it was certain that a body had been *in situ* for longer than a single season. In other cases only empty blowfly puparia that were possibly years old were found with buried skeletal remains.

Table 1. Diptera represented in the insect collections from the bodies of deceased persons.

INSECT GROUP				No. cases (max. 132) in which represented (as only fly present)[1]
Diptera				
	Calliphoridae			113
		Calliphora	any *Calliphora* spp.	87
			C. augur	42 (18)
			C.stygia	33 (14)
			C. ochracea	5
			C. vicina	2
		Chrysomya	*Ch. rufifacies*	44 (2)
			Ch. varipes	18 (1)
			Ch. nigripes	8 (1)
			Ch. megacephala	7 (0)
		Lucilia	*L. cuprina*	8 (2)
			L. sericata	7 (1)
	Sarcophagidae		any sarcophagid spp.	21 (1)
	Muscidae		any muscid spp.	36 (4)
			Hydrotaea rostrata	25 (2)
	Piophilidae		*Piophila casei*	7 (0)
	Phoridae		any phorid spp.	12 (3)
	Sphaeroceridae		any sphaerocerid spp.	2 (0)
	Chironomidae		any chironomid spp.	1 (1)

1. No. cases in which the nominated species was the only fly species present.

Table 2. Frequency with which fly groups were collected together in insect samples taken from bodies of deceased persons.

INSECT GROUPINGS					No. of cases
any *Calliphora* + any *Chrysomya*					31
		any *Calliphora* + *Ch. rufifacies*			27
			C. augur + any *Chrysomya*		16
				C. augur + *Ch. rufifacies*	16
				C. stygia + *Ch. rufifacies*	5
	any *Calliphora* + any *Lucilia*				8
	any *Calliphora* + any sarcophagid				14
	any *Chrysomya* + any *Lucilia*				7
	any *Chrysomya* + any sarcophagid				12
	any *Chrysomya* + any muscid				18
		any *Chrysomya* + *H. rostrata*			14
		any *Chrysomya* + *P. casei*			4
	any *Chrysomya* + any phorid				5
	any *Calliphora* + any *Chrysomya* + any *Lucilia*				4
	any *Calliphora* + any *Chrysomya* + any sarcophagid				11
	any *Calliphora* + any *Chrysomya* + any muscid				12
	any *Calliphora* + any *Chrysomya* + *H. rostrata*				9

Table 3. Insects represented in collections from bodies located inside a building.

INSECT GROUP				No. cases (max. 48) in which represented
Diptera		any dipteran spp.		48
	Calliphoridae	any calliphorid spp.		44
		any *Calliphora* spp.		30
			C. augur	19
			C. stygia	5
			C. ochracea	1
			C. vicina	2
			C. sp.	3
		any *Chrysomya* spp.		23
			Ch. rufifacies	20
			Ch. varipes	6
			Ch. nigripes	2
			Ch. megacephala	4
			other *Ch.* sp.	1
		any *Lucilia* spp.		10
			L. cuprina	6
			L. sericata	4
	Sarcophagidae	any sarcophagid spp.		12
	Muscidae	any muscid spp.		11
			H. rostrata	3
	Piophilidae		*P. casei*	1
	Phoridae	any phorid spp.		7
Coleoptera				5
	Dermestidae			3
	Staphylinidae	*Creophilus erythrocephalus*		2
	Silphidae			1
	Cleridae	*Necrobia* spp.		1

In spring, 16 of the 40 cases involved a single *Calliphora* species only. In summer, autumn and winter the proportions were 9 of 41, 8 of 33 and 8 of 16, respectively. In many of the remaining cases the presence of a number of species provided an indication of faunal succession that was useful to the interpretation of the information. This too varied with the season. In spring 20% of cases (eight cases) involved a combination of a *Calliphora* sp. with a *Chrysomya* sp. and/or a *Lucilia* sp. or a sarcophagid. In summer and autumn the proportions were similar (9 of 41 and 6 of 33, respectively). These groups (*Calliphora* and Sarcophagidae) co-existed in only one case during winter when a muscid species was also present. In one other winter case *Calliphora vicina* was associated with a muscid. In spring muscids, usually *H. rostrata* occurred together with *Calliphora* spp. and *Chrysomya* spp. in two cases. In summer and autumn the three groups co-existed in four and two cases respectively. *Chrysomya* spp. were the only species collected in five summer cases, four autumn cases but no spring cases. If *Chrysomya* was the only calliphorid genus present muscid flies and dermestid or silphid beetles were sometimes found too.

DISCUSSION

The insect families represented in the collections are typical of those reported for other countries (Catts and Haskell 1990; Smith 1986). As well, the significance of the Calliphoridae is similar to elsewhere. The blowflies are the first, or primary wave of insects to arrive at a carcase after death. The species recorded here are analogous to those described by Fuller (1934) for her experiments with vertebrate carcases. *Calliphora* spp. were overwhelmingly the most significant primary insects. In spring and summer *C. augur* was the predominant species and in autumn and winter *C. stygia* was the most common species. *Calliphora ochracea* was only represented in five cases but none of these occurred in spring or summer. *Calliphora ochracea* was found once on a body inside a house but was usually collected from bodies found outside in shaded, cool, moist locations where silphid beetles were also sometimes found. Larvae of *C. ochracea* were usually found in association with those of *C. stygia* from which they are difficult to distinguish. In terms of estimating a PMI this is advantageous as apart from some old observations (Fuller 1931) little is known of its biology or larval growth rate. The rate of development of *C. ochracea* may be quite different to that of *C. stygia*. Failure to recognise *C. ochracea* could lead to miscalculation of the PMI.

In warm weather, if the only species present on a body was *Calliphora*, the estimate of PMI was usually only up to four days - any longer and it would be expected that eggs or larvae of the secondary wave *Chrysomya* blowflies would also be present. However, in winter fewer blowfly species were collected and, with one or two exceptions from temperate regions, there was no succession of blowfly species. Fuller (1934) described the same situation in Canberra. Clearly this is related to climate as O'Flynn (1983) reported on blowfly succession on carcases exposed in Queensland during winter. A consequence of the lack of succession in winter is that *C. stygia* or *C. ochracea* are not displaced by competing *Chrysomya* larvae and persist much longer than they would in warmer conditions. This confounds estimates of PMI, as larvae in specimen collections may not belong to the first wave, or even the first generation of *Calliphora* to develop on a corpse. During winter, failure of the crime scene officers to sieve the soil below a body for wandering third instar larvae, pupae or puparia can leave this point open to dispute in court.

During spring, summer and autumn, in cases in which more than one blowfly species was involved, it was common for *Chrysomya* larvae to be present with *Calliphora* larvae. *Ch. rufifacies* was the most often encountered species, but *Ch. varipes*, *Ch. nigripes* and *Ch. megacephala* were also recorded, often in concert with *Ch. rufifacies.* Although reported to sometimes act as primary blowflies in summer in Queensland (O'Flynn and Moorhouse 1979), it is much more usual for *Chrysomya* spp. to represent the most common secondary blowflies to infest carcases or human corpses. The species listed above are thought to perform similar roles in carrion ecology. Until the appearance of *Ch. rufifacies* larvae on a corpse the estimation of the PMI relies on an accurate estimate of the age of the *Calliphora* larvae. This is achieved by recognising the species, the instar of the largest (oldest) larvae and then by estimating the feeding period that has elapsed since the last moult. Once *Chrysomya* larvae are also present, however, the most likely PMI can be calculated by estimating the age of the oldest *Chrysomya* larvae and adding this to the length of the delay after death before *Chrysomya* females are likely to lay eggs. This is thought to coincide with the appearance of third-instar *Calliphora* maggots. These quick-growing larvae generate distinctive odours that attract *Chrysomya* and stimulate them to oviposit (Norris 1959). Typically, *Chrysomya* are present for a period from a few days after death until they have displaced the primary maggots (Fuller 1934) a couple of weeks later. By this time however, other species are also present including tertiary muscid flies like *H. rostrata* and various predatory beetles.

As suggested by Tillyard and Seddon (1933) *Lucilia* spp. and sarcophagid species have similar roles (primary and secondary wave species respectively) to *Calliphora* and *Chrysomya*. *Lucilia* spp. and sarcophagids were, however, much less frequently involved, and in the majority of cases were from bodies located inside a building. The situations in which bodies were found varied greatly and most likely influenced the insects that were able to locate and infest them. Goff (1991) reported differences in the insect fauna associated with bodies found inside dwellings, compared to those found outside. Generally, he found that bodies inside a dwelling had a greater variety of Diptera but less diversity of Coleoptera. Certainly, in the cases reported here, beetles were found less frequently on bodies inside dwellings. This may reflect their generally greater size and lesser flight ability relative to the Diptera. Silphid beetles occurred on bodies outside in 10 of the 11 cases in which they were represented but did occur once on a body inside a house. It was not true that the species were not capable of, or prepared to enter a dwelling, but their presence was less likely if a body was located inside a building. The same was true of some of the flies. For example, although phorids were more commonly found on bodies located inside a building they were not restricted to bodies located inside. Similarly, 21 (84%) of the 25 cases in which *H. rostrata* occurred concerned bodies located outside, whereas overall, 64% of cases concerned bodies located outside. Either *H. rostrata* was over-represented in these situations, was less likely to enter buildings or was delayed in entering as it was unable to detect olfactory or other cues as readily if the source was inside a building. It may be concluded that the absence of some elements of the insect fauna typically associated with a particular phase of decomposition from a body found inside a building may be an artefact of the location of the body and, unless delaying other species from infesting a body, may be inconsequential to the PMI.

In the cases reported here predatory beetles belonging to the Staphylinidae and Histeridae were most likely to be present while their prey, the primary and secondary calliphorid and sarcophagid larvae and tertiary fly larvae were actively feeding. Consequently, they represent extra elements of the fauna associated with these phases of decomposition rather than definitive examples. Moon and Kajii (1997) identified the insects invading rabbit carcases in Korea and found rapid colonisation by Calliphoridae, Sarcophagidae and Formicidae by day and by Silphidae and Carabidae at night. They found species richness was greatest while fly larvae and adult beetles co-existed and reported that *C. vicina, Lucilia illustris, L. sericata, Ch. megacephala* and *Muscina stabulans* had the highest forensic value.

After the blowflies, members of the Muscidae, particularly *H. rostrata* represent the next most important insect group involved in the decomposition of vertebrate carcases. Muscids are the main tertiary insect group overlapping with the secondary flies, particularly *Ch. rufifacies*. As such, their presence marks a vital stage in the estimate of PMIs that are of the order of about 12 or so days. Muscids were collected from bodies in 36 (27%) of the 132 cases investigated. On 25 (19%) occasions the species involved was *H. rostrata,* but of the 11 cases where muscids were collected from bodies located inside a building, *Muscina* spp. or other unidentified muscids were represented eight times. Dadour *et al.* (2001a) reported that *H. rostrata* occurred in approximately one third of all Western Australia homicide cases in which the body was exposed to insect attack.

Silphid beetles are another element of the tertiary phase insect fauna. Australia has only three species and each is associated with carrion (Lawrence and Britton 1991). *Ptomaphila lacrymosa* Schreib and *Diamesus osculans* Vigors were represented in collections submitted, however, for the purpose of this study the silphids were considered collectively, rather than as individual species. Although the sample size was only seven cases, silphid beetle larvae were only collected when *H. rostrata* larvae were also present. Associations like this are useful in defining the decomposition phase. Silphidae usually occurred on bodies in warm, moist, lush locations. Logically, adult Silphidae appeared earlier than their larvae and may have persisted throughout the tertiary phase. Although not studying the insect fauna associated with vertebrate carcases as a model for forensic investigations, Bornemissza (1957) distinguished between the intervals after death when silphid larvae and adults were present on vertebrate carcases. The importance of disparities like this cannot be overstated and further work is required to fine tune the differentials. The estimate of PMI provided by the author in one murder investigation was based on the occurrence of silphid larvae on the body and the absence of adult beetles. In this instance the suggested PMI was critical to the prosecution case.

The quaternary stage of decomposition is generally a drying stage when much of the flesh has been devoured and the skeleton is revealed (Fuller 1934), at least in places. Dermestid beetles were associated with this stage. As is the case with the Silphidae, the presence of adult beetles only, larval beetles only, or both offers the opportunity to fine tune the estimation of the PMI. Bornemissza (1957) observed that larval and adult dermestid beetles co-existed on carcases for a finite period but that only adult beetles were present prior to this time and only larval beetles after this interval. As with all decomposition phases however, the changeovers were gradual rather than sharply defined.

My experience has been that unless pivotal to the prosecution's case, there is little or no feedback from the police regarding the accuracy of a suggested PMI. Commonly, this indicates that the suggested PMI is undisputed, but also reflects the lack of any admissions of guilt by defendants. Consequently, this paper did not set out to demonstrate that the occurrence of particular insects on bodies is indicative of a specific PMI. Thorough experiments with pig carcasses should provide these data (Goff 2000). Instead the paper endeavours to record the insects likely to be encountered by entomologists working in forensic science in New South Wales, and provide an indication of how frequently the different insect types occurred in my experience. Other intentions are to give an insight into what are the most reliable indicator species and where further knowledge is needed to improve confidence in PMI estimates. In this regard *Calliphora* spp. and *Chrysomya* spp. are reliable indicators of the primary and secondary stages of decomposition, but the lack of succession in winter confounds estimations of PMI during this season. In outdoors situations *H. rostrata* and silphid beetles, if present, are useful and reliable species that identify the tertiary decomposition stage. Thereafter, Dermestidae are helpful but reliability declines, particularly in establishing an upper time limit for the PMI. Although the entomologist may consider a particular time of death most likely, often the undisputable upper limit for the PMI coincides with the last confirmed sighting of the deceased. This unsatisfactory situation may improve as knowledge of the habits of critical insect species is gained but it is possible that the problem may be resolved by a science other than entomology.

Areas of research needing further attention include replicated growth rate data for the main fly species. In particular, reliable data for *C. augur, C. stygia, C. ochracea, Ch. rufifacies* and *H. rostrata* under a variety of conditions and temperature regimens are essential. Information is needed on the delay between death and blowfly oviposition under a variety of situations such as season, bodies located indoors verses outdoors and bodies dumped at night. This last point has become more controversial as the accepted assumption that blowflies will not find and oviposit onto a body at night has been challenged (Greenberg 1990). As well, blowflies have been reported to delay oviposition by two to three days if a body is wrapped in blankets (Goff 1992). This needs to be confirmed and quantified for different seasons and situations. More replicated experiments on insect succession during different seasons under various circumstances such as inside inner city buildings verses outside in bushland areas would assist greatly. The Muscidae, particularly *H. rostrata*, have proved important to estimating likely PMI when decomposition has progressed to the tertiary phase. However, the significance of other muscid species, particularly if co-existing with Sarcophagidae or *Lucilia* spp. or in the absence of calliphorids or for bodies located inside buildings remains uncertain. Phorids were present on bodies that had been deceased for very different periods of time. This has also been reported elsewhere (Leclercq 1999; Smith 1986). It is tempting to consider the phorids as forensically insignificant insects, however, little is known of individual Australian species. Although collectively the Phoridae seem unhelpful, it is possible that once better known, one or more individual species may prove useful. Currently, the Sphaeroceridae are similarly unreliable. Piophilidae usually co-existed with dermestid beetles and other insects typical of the fourth wave fauna. However, it may be unwise to draw too many conclusions from the seven cases in which they were represented. Ideally, succession graphs, perhaps using data collected from pig carcases to simulate humans (Goff 2000), similar to those provided by Bornemissza (1957) for guinea pig carcases, are needed. It is hoped that research currently being undertaken in Western Australia (Dadour *et al.* 2001b) and at the University of Wollongong may provide this vital information.

REFERENCES

Bornemissza G.F. (1957). An analysis of arthropod succession in carrion and the effect of its decomposition on the soil fauna. *Australian Journal of Zoology* **5**: 1-12.

Catts, E.P. and Haskell, N.H. (1990). *Entomology & Death: a procedural guide.* Joyce's Print Shop Inc. Clemson, South Carolina.

Dadour, I.R., Cook, D.F. and Wirth, N. (2001a). Rate of development of *Hydrotaea rostrata* under summer and winter (cyclic and constant) temperature regimes. *Medical and Veterinary Entomology* **15**: 177-182.

Dadour, I.R., Cook, D.F., Fissioli, J.N. and Bailey, W.J. (2001b).

Forensic entomology: application, education and research in Western Australia. *Forensic Science International* **120**: 48-52.

Erzinclioglu, Z. (2000). *Maggots, murder and men. Memories and reflections of a forensic entomologist.* Harley Books, Essex, United Kingdom.

Fuller, M.E. (1931). The life history of *Calliphora ochracea* Schiner (Diptera, Calliphoridae). *Proceedings of the Linnean Society of New South Wales* **56**: 172-181.

Fuller, M.E. (1934). The insect inhabitants of carrion: a study in animal ecology. CSIR Bulletin No. 62

Goff, M.L. (1991). Comparison of insect species associated with decomposing remains recovered inside dwellings and outdoors on the Island of Oahu, Hawaii. *Journal of Forensic Sciences* **36**: 748-753.

Goff, M.L. (1992). Problems of estimation of post-mortem interval resulting from wrapping of the corpse: a case study from Hawaii. *Journal of Agricultural Entomology* **9**: 237-243.

Goff, M.L. (2000). A *fly for the prosecution. How insect evidence helps solve crimes.* Harvard University Press.

Greenberg, B. (1990). Blow fly nocturnal oviposition behaviour. *Journal of Medical Entomology* **27**: 807-810.

Lawrence, J.F. and Britton, E.B. (1991). Coleoptera. In: *The Insects of Australia. A textbook for students and research workers.* Volume 2. Division of Entomology CSIRO, Melbourne University Press.

Leclercq, M. (1999). Entomology and forensic medicine: importance of phorid flies on human corpses. *Annales de la Societe Entomologique de France* **35**: 566-568.

Moon T.Y. and Kajii, E. (1997). Forensic implication of predominant insects on rabbit carrions at the Islet Youngdo in Pusan. *Entomological Research Bulletin* **23**: 29-36.

Norris, K.R. (1959). The ecology of sheep blowflies in Australia. In: Keast, A.. Crocker, R.L. and Christian, C.S. (Eds.) *Biogeography and ecology in Australia. Monographie Biologicae* 8 Junk, The Hague, pp 514-544.

O'Flynn, M.A. (1983). The succession and rate of development of blowflies in carrion in southern Queensland and the application of these data to forensic entomology. *Journal of the Australian Entomological Society* **22**: 137-148.

O'Flynn, M.A. and Moorhouse, D.E. (1979). Species of *Chrysomya* as primary flies in carrion. *Journal of the Australian Entomological Society* **18**: 31-32.

Smith, K.G.V. (1986) *A manual of forensic entomology*. British Museum (Natural History) and Cornell University Press.

Tillyard, R.J. and Seddon, H.R. (1933). The sheep blowfly problem in Australia. Report No. 1 Joint Blowfly Committee CSIR Pamphlet No. 37; New South Wales Department of Agriculture Science Bulletin No. 40.

This page left blank intentionally.